Emergency Medicine:

Problems, Patterns and Probability

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Innehåll

PREFACE

”Many years ago, before attending medical school, I was a fighter pilot flying F-86 Sabrejets in the Air Force. I and most of my flying colleagues always used checklists that were strapped to our thighs while we were sitting in the cockpit. Every one of the myriad switches, gauges, dials, handles, and circuit breakers had to be properly set or checked. Procedures had to be followed assiduously, especially during an emergency. Checklists helped us do that. Each of us knew that a careless mistake could lead to our death. By contrast, if physicians or nurses make a careless mistake, someone else suffers or dies. Many of us evince too cavalier an attitude in working with patients. If all of us in medicine thought our own lives were at risk, you can bet a lot fewer mistakes would be made. Requiring the use of checklists is an excellent way to reduce errors and keep our patients safer.” David Levin [1]

This textbook-in-progress is built around two central concepts:
- the checklist
- point-of-care information

A **checklist** may be defined as a list of concrete assessments or measures (the "list" part) that is meant to be carried out systematically (the "check" part). Checklists have been used for decades in the flight and construction industries to improve performance and safety, and are increasingly used in medicine [2].

Emergency Medicine consists of processes. The posit behind this textbook is that each process can be described using a checklist. Each checklist can be regarded as Standard Operating Procedure (SOP), a step-by-step description of how specific tasks are carried out. SOPs are used in various industries to increased efficiency and quality by minimizing performance variability and miscommunication. The advantages of SOPs are that they provide a concrete description of the process that can be taught and used to evaluate performance; the output of a process that is carried out according to a well-defined standard can be measured and the effect of modifications in the SOP can be evaluated.

The checklist allows for a reversal of the traditional medical textbook format. The usual textbook consists of lots of explanatory text (answering "why" questions) followed, sometimes, by concrete advice regarding investigations and treatments (answering "what should I do" questions). The core sections of this textbook place concrete advice about investigations and treatment upfront and justifications/explanations on the second tier. Such a format allows the textbook to be used in clinical practice, when action is paramount, as well as outside of clinical practice, when deepening understanding is the goal. The checklist format allows the user to find information by providing a common structure for various sections in the textbook. For example, the structure of the sections in Chapter 08 focussing on problems roughly parallels the structure of the sections in Chapter 09 focussing on diagnoses.

Point-of-care information is defined here as clinical information that can be rapidly obtained at the patient's bedside. Sources of point-of-care information are the history and physical examination, as well as point-of-care testing which include the electrocardiogram, blood tests that can be rapidly obtained using instruments in the Emergency Department, point-of-care ultrasound (PoCUS), urine dipstick and point-of-care pregancy test. Conceptually, there is a threshold for performing every investigation or treatment. Once the threshold is reached or crossed, performing the investigation or treatment can be justified and the aquisition of additional information is not necessarily in the patient's interest. Being able to reach decision-

thresholds using point-of-care information allows for efficient care in Emergency Medicine, where time is of the essence. This textbook therefore focuses on these sources of information, in order to help the emergency physician milk as much information as possible from the initial clinical assessment.

This textbook is incomplete and unproofed, but it may hopefully be of benefit in its current form to medical students, residents and specialists working in the Emergency Department.

Lund, February 2018

ABBREVIATIONS

The following abbreviations are used throughout the manual. While 'A' may stand for 'Airway', 'Autoimmune / Allergic' or 'Allergies,' the context within which the abbreviation is used is hopefully sufficient to avoid misinterpretation.

DOSES & TIME

bpm	beats per minute
g	grams
Hg	Mercury (as in a systolic blood pressure of 150 mm Hg)
hr	hours
kg	kilograms
L	liter
min	minutes
mg	milligrams
mm	millimeters
msec	milliseconds
sec	seconds
U	units (as in 10 U insulin)
µg	micrograms

RESUSCITATION

A	Airway (upper) and cervical spine
B	Breathing
C	Circulation
D	Disability
E	Exposure

DIFFERENTIAL DIAGNOSIS

V	Vascular	Cardiac
I	Infectious	Infiltrative
N	Neoplastic	Neurological
D	Degenerative	Deficiency
I	Intoxication	Abstinence
C	Congenital	Collagen vascular
A	Autoimmune	Allergic
T	Trauma	Mechanical
E	Electrolytes	Endocrinological

EPIDEMIOLOGY

Age	Age
Gen	Gender
Her	Heredity
Inci	Incidence
Men	Men
Prev	Prevalence
Wom	Women

BACKGROUND

M	Medications, including over-the-counter medications, hormonal preparations, illicits drugs
A	Allergies
P	Past medicatl history
L	Life circumstances, including occupation, marital status, support network, ADLs
E	Ethanol
S	Smoking

HISTORY

O	Onset: time of onset and how rapid the onset was (seconds, minutes, hours)
P	Position: location on the body, size, radiation, migration
Q	Quality
R	Relieving and aggravating factors, e.g. with deep inspiration, movement, exercise
S	Severity, both subjective according to the visual analog score (VAS) and objective
T	Temporal factors: course, prior episodes
+	Associated manifestations

PHYSICAL EXAMINATION

Abdo	Abdominal examination: inspection, auscultation, palpation
BBT	Bedside Blood Tests, e.g. pH, pCO_2, HCO_3, Na, K, Cl, lactate, Hb, Creatinine
BP	Blood Pressure (mm Hg)
CV	Cardiovascular examination: auscultation of the heart, jugular venous pressure, peripheral pulses
CVP	Central Venous Pressure
CW	Chest wall
DBP	Diastolic Blood Pressure
Ear	Ear examination
Eye	Eye examination
GA	General appearance
GU	Genitourinary
H&N	Head & neck examination
HR	Heart Rate (beats/min)
Insp	Inspection
JVP	Jugular Venous Pressure
Lung	Pulmonary examination: lung auscultation, percussion, tactile fremitus
MAP	Mean Arterial Pressure
Msk	Musculoskeletal examination
mm Hg	Millimeters of mercury
Neuro	Examination of the nervous system
O2%	Oxygen saturation
Palp	Palpation
Perc	Percussion
PR	Per Rectum
RR	Respiratory Rate
SBP	Systolic blood pressure
Temp	Temperature
VS	Vital signs: respiratory rate, oxygen saturation, heart rate, blood pressure, temperature
◘	Heart
☽ ☾	Lung

⬣ Abdomen
≋ Nervous system

BEDSIDE TESTS

BBT	Bedside Blood Tests
EKG	Electrocardiogram
US	Ultrasound
UT	Urine tests

TESTS

AXR	Abdominal X-ray (flat plate)
BBT	Bedside blood tests (that can be obtained
BE	Base Excess
BNP	Brain Natriuretic Peptide
BTs	Blood Tests
CK	Creatine Kinase
Cl	Chloride
CT	Computer tomography
Crea	Creatinine
CRP	C Reactive Protein
CXR	Chest X-ray
d-d	d-dimer
EEG	Electroencephalogram
EKG	Electrocardiogram
FiO2	Fractional concentration of inspired oxygen (Check)
Glu	Glucose
Hb	Hemoglobin
INR	International Normalized Ratio
K	Potassium
kPa	kilopascal
LFT	Liver function tests: ASAT, ALAT, GT, ALP, bilirubin, albumin
MR	Magnetic resonance imaging
Na	Sodium
PaO2	Partial arterial pressure of oxygen (Check) (kPa)
PaCO2	Partial arterial pressure of carbon dioxide (Check) (kPa)
PCR	Polymerase Chain Reaction
TEE	Transesophageal ultrasound
TnI	Troponin I
TnT	Troponin T
TTE	Transthoracid ultrasound
Udip	Urinary dipstick
US	Ultrasound
UT	Urinary tests
WBC	White Blood Cell count (x 10^9/L)

ULTRASOUND

IVC	Inferior Vena Cava
LV	Left ventricle
RV	Right ventricle

TEST CHARACTERISTICS

HR	Hazard ratio
LR	Likelihood ratio
LR+	Positive likelihood ratio
LR-	Negative likelihood ratio
NPV	Negative predictive value
NS	Non significant
OR	Odds ratio
PPV	Positive predictive value
RR	Relative risk or risk ratio
SN	Sensitivity
SP	Specificity
(..-..)	95% confidence interval. When intervals are provided (e.g. OR 2.5 - 12), it is due to the fact that heterogeneity between the studies does not allow for the calculation of a summary value.

TREATMENT ROUTES

IM	Intramuscular
IV	Intravenous
Neb	Nebulized
PO	Per os
PR	Per rectum
SC	Subcutaneous

1. Measure/Assessment	Refers to measures to be carried out or considered, or assessements to be performed, for which a specific order is recommended
☐ Measure/Assessment	Refers to measures to be carried out or considered, or assessements to be performed, for which the order is not important
• Finding/Fact	Refers to findings on assessment results or information.
Drug X mg (Y mg/kg)	X refers to the dose for adults Y (between parentheses) refers to the dose for children

CHAPTER 01–FUNDAMENTAL CONCEPTS

"Emergency medicine is the specialty that takes care of your mitochondria." Lance Becker, EuSEM Congress 2014, Amsterdam

Emergency physicians assess patients who present with a broad range of subjective, objective and potential problems caused by approximately 10,000 diagnoses [1]. Emergency physicians are also faced with organisational challenges that have to do with prioritizing between health-care needs and delegating health-care tasks, such as leading a multidisciplinary team taking care of a critical patient or organizing the initial management of major incidents. While many of these tasks are rote, physicians are sometimes faced with situations they have not faced before. To some degree, all patients and all organisational challenges are unique and there are few 'one size fits all' solutions. Emergency physicians may therefore benefit from explicit concepts that can help guide and justify decision-making. This chapter presents several key concepts that underlie the practice of Emergency Medicine (EM).

Time is Blood & Fly Ahead of the Plane

Efficiency is paramount in Emergency Medicine. Anticipation promotes efficiency.

"Anticipation is key for goal-oriented behaviour. Consider the requirements of a case in advance, think of what could be difficult and plan ahead for each possible difficulty. Also expect the unexpected! Be prepared. Mentally stay ahead of the game. Good pilots say "Always fly ahead of your plane!"" Marcus Rall and Peter Dieckman [2]

A minority of patients who are managed within the realm of EM suffer from conditions where prompt treatment, in the order of seconds to minutes, impacts on outcome. For example, mortality from a severe anaphylactic reaction increases when adrenalin administration is delayed [3]. For such patients, efficient management is paramount. Anticipating and mentally planing for potential developments, e.g. ventricular fibrillation in a patient with an ST-elevation myocardial infarction or the simultaneous arrival of three critical patients in the ED, may allow for shortened response times. Emergency physicians should heed the pilot's dictum to "always fly ahead of the plane" [2]. Informing colleagues ahead of time that they are likely to take over a critical patient allows them to "fly ahead" as well, prepare for patient care and minimize time to key treatments.

It may even be argued that *all* patients should be managed efficiently. Crowding in the ED is associated with increased morbidity and mortality [4-6]. Prolonging the ED stay of one patient through unnecessary investigations may threaten the outcome of another patient whose management is delayed and who is suffering from conditions (e.g. severe sepsis) where timely treatment, on the order of hours, impacts on outcome. In summary, efficient management is paramount in EM. Efficiency may be promoted by standardizing the manner processes are carried out (see Checklists below).

Collective Intelligence & SBAR

Teamwork is required for efficient patient management. Patients benefit from an environment where health-care personnel are encouraged to contribute with their heads as well as their hands. SBAR is a communication template that allows patients to benefit from the team's collective intelligence.

"our capacity to think well—our intelligence—resides not just in our heads but is distributed throughout the physical, social, and symbolic environment. . . . You function more intelligently with physical (paper and pencil, books), social (thinking with others), and symbolic (verbal advice to yourself, for instance) support systems than you do without." David Perkins [7]

The outcome of critically ill patients is often contingent upon the urgent performance of several investigations and treatments. For example, a patient with cardiac arrest requires chest compression, ventilation, rhythm analysis and urgent investigations to identify reversible causes of the cardiac arrest. One health-care personnel cannot carry out these measures simultaneously; rather, a team of health-care personnel working together in a coordinated fashion is required. For non-critical patients, health-care personnel may deliver health-care sequentially instead of simultaneously. Nevertheless, effective teamwork is also crucial to prevent unnecessary delays in patient management. In other words, teamwork is necessary for efficient care in EM.

To err is human. High reliability organisations such as air traffic control centers have attained high degrees of safety by recognizing that individuals make mistakes. Safety is achieved by improving the work-environment to minimize the risk of mistakes and allow mistakes to be identified before they cause harm [8]. The flight industry has recognized the importance of promoting a working atmosphere in which all teammembers are encouraged to voice concerns and volunteer suggestions. Flight crews worldwide participate in 'Crew Resource Management' (CRM) training that emphasizes the importance of healthy team dynamics in error prevention [9]. The CRM concept has been promoted in other working environments such as anaesthesia. CRM has been defined as "a flexible, systemic method for optimizing human performance in general, and increasing safety in particular, by (1) recognizing the inherent human factors that cause errors and the reluctance to report them, (2) recognizing that in complex, high risk endeavors, teams rather than individuals are the most effective fundamental operating units and (3) cultivating and instilling customized, sustainable and team-based tools and practices that effectively use all available resources to reduce the adverse impacts of those human factors." (David A Marshall, in Crew Resource Management: From Patient Safety to High Reliability 2009)

The term 'Collective Intelligence' refers broadly to the intelligence of a group of individuals who communicate and collaborate to reach consensual decisions (Wikipedia Collective Intelligence) (Fig 1-1). There are many examples where collective intelligence outperforms individuals, e.g. predicting elections [10, 11]. Teammembers need to communicate and collaborate effectively with each other to allow their patients to benefit from their collective intelligence. There is some evidence that promoting communication and collaboration among health-care teams improves patient safety. The success of the WHO Surgical Safety Checklist [12] has been attributed in part to the Time-Out's ability to promote teamwork and communication [13]. The implementation of a handoff bundle, which included a formalization of oral and written communication during handoffs of patient care from one

resident to another, has been associated with a reduction in the rate of preventable adverse events [14].

SBAR is a communication format according to which information is provided in a standardized order [15]:

- S (Situation) consists of a brief introduction to the clinical context and the main problem
- B (Background) consists of a presentation of pertinent information
- A (Assessment) consists of an interpretation of the cause of the problem
- R (Recommendation) consists of a proposal for further management and an invitation for questions and alternative proposals.

SBAR may be used within a number of different contexts, e.g. when admitting a patient to ward, patient handoff at the end of a shift, or reviewing a patient with a senior colleague. In particular, SBAR may be used to brief and prepare a multidisciplinary team prior to the management of a critically ill patient (Fig 1-2 & Chapter 02). Communication according to SBAR creates a working environment that promotes a shared sense of accountability for patient outcome. SBAR encourages all team members to contribute with their heads as well as their hands. Patients may thereby benefit from the team's collective intelligence.

Fig 1-1: Collective Intelligence

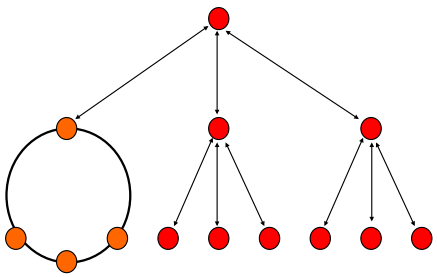


Fig 1-2: SBAR

Setting:	Awaiting the arrival of a trauma patient
Situation	• Team introduction: names + competences • Patient introduction: age + main problem
Background	• Relevant past medical history, medications etc. • Current: mechanism of injury, vital signs etc.
Assessment	• Possible conditions, e.g. hemorrhagic chock • Possible measures, e.g. O negative blood
Recommendation	• Role assignment • Suggestions / concerns from teammembers

When the SBAR is used to request a consult or to request that another physician takes over responsibility for patient care, the purpose of the communication includes justifying involvement of another party and conveying the urgency of the request. In this setting, the S ought to be a "catchy headline. " For example, communication with a cardiologist may begin with "This is Dr. ____ calling from the ED, I have a 47-year-old man with a STEMI and cardiogenic shock who needs an urgent PCI." A call to the ICU physician may begin with "This is Dr. ___ calling from the ED, I have a 55-year-old woman with severe sepsis and a lactate of 5.7." Irrelevant information should be left out of the initial SBAR to not cloud the message. When it comes to the SBAR, less is often more.

Delegation Pyramids & Closed-Loop Communication

When a large number of health-care personnel are working together, a pyramidal organisation allows for effective task delegation and communication. Closed-Loop communication is a form of communication that promotes reliable information transfer.

"Delegating work works, provided the one delegating works, too." Robert Half

Health-care has to do with the identification of health-care needs and the optimal allocation of health-care resources (personnel and equipment). For teamwork to be effective, organisation is required to prevent task duplication, unassigned tasks, overload versus underutilization of personnel and suboptimal task delegation. The ability to organize is especially important in EM given the plethora of situations—most previously experienced, some new—that health-care personnel are exposed to. In particular, EM personnel need to be able to adapt their organization to fluctuations of health-care needs and health-care resources. A pyramidal organisation (Fig 1-3) 'divides and conquers' the organisational challenges and provides a structure for effective communication. It allows each health-care personnel to

- be assigned a task from a health-care personnel 'above'
- divide this task and delegate the subtasks to health-care personnel 'below'
- receive information from health-care personnel 'below'
- report information back to health-care personnel 'above'
- share accountability for the health-care measures taken on both adjacent levels (see White Paper The Value of Standard Operating Procedures: "At each level, good leaders will think 'two levels up' and provide oversight 'one level down'.")

Such a pyramid may need to restructure itself as the nature and number of needs and resources changes. Pyramids may grow 'downwards' as more health-care resources become available or 'upwards' as the need to orchestrate health-care measures on a larger scale becomes apparent or possible. Two pyramids may merge into a larger pyramid when coordination of health-care measures is required on a larger scale, such as during major incidents.

Communication within a health-care team is crucial to allow team members to coordinate their activities and allow the team as a whole to adapt to the evolving situation. When small groups of health-care personnel carry out limited health-care tasks, coordination and communication are usually not problematic but they may rapidly become so when large groups of personnel are involved in complex tasks. This phenomenon is due to the fact that the number of one-to-one communications within a group grows rapidly as the group expands. The number of possible one-to-one communications in a group of four is 3+2+1 = 6; in a group of five 4+3+2+1 = 10; and in a group of six 5+4+3+2+1 = 15. As the number of health-care personnel involved in a common task expands, so does the risk for inefficient communication and suboptimal resource allocation.

Organizing the flow of communication according to the delegation pyramid model may prevent communication chaos when multiple health-care personnel are involved. Information needs to flow up and down the pyramid in a reliable way in order to adapt the allocation of

resources to the evolving health-care needs. 'Closed-loop,' 'read-back' or 'repeat-back' communication is a communication format whereby the receiver of the information repeats the information in order to confirm that the information has been received undistorted (Fig 1-4) [16]. The information might be an assignment ("John, please take an EKG") or a value ("Marie, the patient's systolic blood pressure is 120"). Repeating the information ("I'll take an EKG" or "blood pressure 120", respectively) provides the sender with a confirmation that the information was received unadulterated. The purpose of closed-loop communication is to convey information with high fidelity up and down the delegation pyramid.

Fig 1-3: The Delegation Pyramid

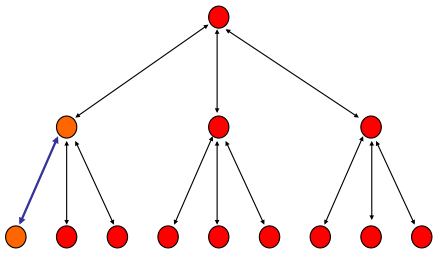


Fig 1-4: Closed-loop communication

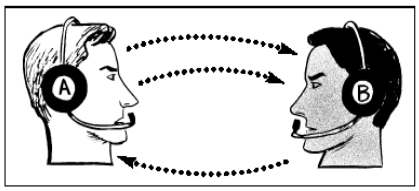


Figure 2.2: An example of closed loop communication

A: "B, take a BP please"
B: "Blood pressure"
A: "Thanks"

A: "Resp rate is 24"
B: "Resp rate 24"
A: "Correct."

Problems & The Buddha's Poisoned Arrows

Patient management in EM originates from the patient's problem or problems, not from a suspected diagnosis. The management of critical patients begins with a search for problems that can be treated initially in an appropriate manner regardless of their cause.

"Suppose Malunkyaputta, a man is wounded by a poisoned arrow, and his friends and relatives bring him to a surgeon. Suppose the man should then say: "I will not let this arrow be taken out until I know who shot me; whether he is a Ksatriya (of the warrior caste) or a Brahmana (of the priestly caste) or a Vaisya (of the trading and agricultural caste) or a Sudra (of the low caste); what his name and family may be; whether he is tall, short, or of medium stature; whether his complexion is black, brown, or golden . . . ." Malunkyaputta, that man would die without knowing any of these things." Walpola Rahula [17]

Patients enter the realm of EM because of problems that are

- Subjective, e.g. chest pain
- Objective, e.g. decreased level of consciousness, fever, an abnormal blood test result
- Potential, e.g. suspected poisoning, suspected allergic reaction, potential post-traumatic fracture or bleeding

For some of these patients, a putative diagnosis has already by posited by other health-care personnel or by the patient him- or herself. While these diagnoses may be correct, the emergency physician should also consider alternative diagnoses where targeted treatment impacts on morbidity and mortality. 'Premature closure,' whereby a physician settles for a diagnostic hypothesis without adequately considering alternative diagnoses, is a common cognitive cause of diagnostic error [18]. In other words, the starting point of patient management in the realm of EM should be the patient's problem or problems.

Certain patients suffer from conditions where urgent, appropriate treatment decreases morbidity and mortality. The diagnostic process in medicine is not instantaneous. Information is required to reach a diagnosis, or at least to recognize a syndrome, a pathophysiological condition where targeted treatment can be motivated despite not knowing the root cause. Information acquisition takes time, yet information acquisition per se does not help critical patients—appropriate treatment is what counts.

The solution to this apparent catch-22 is that certain problems can be treated appropriately prior to the identification of the underlying cause of the problem. For example, all patients with hypoglycemia should receive treatment to raise the blood sugar, regardless of the cause of the hypoglycemia. Certain constellations of problems may strongly suggest an acute condition where acute therapy can be justified without further information. For example, the combination of unilaterally decreased breath sounds and chest movement, hypotension and tachycardia in a trauma setting suggests tension pneumothorax and motivates acute chest decompression. These constellations are referred to hereafter as 'resuscitation syndromes' and covered in Chapter 07. Problems and syndromes that motivate acute treatment may be described as 'poisoned arrows.' In situations where patients appear critically ill, the emergency physician should prioritize looking for poisoned arrows and removing them when present. The poisoned arrow concept underlies the raison d'être of the ABCDE algorithm presented in Chapter 03. The process of looking for poisoned arrows allows the physician to simultaneously acquire diagnostic information that guides further management.

System-1 & System-2

Pattern recognition (System-1 thinking) is crucial for identifying syndromes requiring immediate management and for generating diagnostic hypotheses. Analytical (System-2) thinking is required to prevent premature closure.

[Jumping to conclusions is] "an apt description of how System 1 functions. Jumping to conclusions is efficient if the conclusions are likely to be correct and the costs of an occasional mistake acceptable, and if the jump saves much time and effort. Jumping to conclusions is risky when the situation is unfamiliar, the stakes are high, and there is no time to collect more information. These are the circumstances in which intuitive errors are probable, which may be prevented by a deliberate intervention of System 2." Daniel Kahneman [19]

Research into diagnostic reasoning suggests that there are two fundamental modes of thinking [19, 20]:

- System-1 thinking recognizes patterns; the thought process is intuitive, unconscious, rapid, effortless, influenced by emotion and error-prone
- System-2 thinking is an analytical thought process that is conscious, rule-based, less error-prone than System-1 thinking but slower and more energy-intensive.

In EM, System-1 thinking is valuable for identifying syndromes, constellations of data that suggest a certain pathophysiological condition (Fig 1-5). The conjunction of stridor and an urticarial rash suggests anaphylaxis. The presence of crushing, non-pleuritic chest pain radiating to the left shoulder in the presence of focal ST-segment elevation suggests an acute coronary syndrome. For certain syndromes, a specific treatment (e.g. adrenalin in the case of anaphylaxis) is urgently indicated. Other syndromes are best thought of as diagnostic hypotheses. Pattern recognition, however, may contribute to the diagnostic pitfall known as 'premature closure,' whereby a physician settles for a diagnostic hypothesis that explains the problem-pattern at hand without considering alternative diagnoses [18, 21]. For example, a physician may misdiagnose a patient presenting with pleuritic chest pain, fever, cough, elevated white blood cell count and a peripheral infiltrate on the chest X-ray with pneumonia without considering pulmonary embolism (Fig 1-6). System-2 thinking is activated when physicians consciously consider the likelihoods of competing diagnoses, work through the differential diagnosis of abnormal findings, or interpret a diagnostic test according to a preestablished sequence. System-2 thinking is less error prone but more time consuming and laborious.

In summary, System-1 thinking allows emergency physicians to recognize syndromes where urgent tailored therapy is beneficial and generate diagnostic hypotheses. System-1 is honed through clinical experience, reading case reports, and scenario training. System-1, essential as it is to EM, works by jumping to conclusions; some degree of analytical, System-2 thinking is required to prevent diagnostic errors due to premature closure. A proposal for how System-2 may be used in EM is presented in the rest of this chapter.

Fig 1-5: Hypothesis Formulation

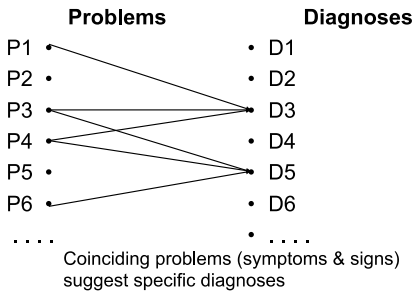


Fig 1-6: The Pittfall of System-1 Thinking

Don't Miss Diagnoses & Decision Thresholds

The goal of information acquisition in EM is to reach test and treatment thresholds for conditions where timely management decreases morbidity and mortality.

"Absolute certainty in diagnosis is unattainable, no matter how much information we gather, how many observations we make, or how many tests we perform. . . . Our task is not to attain certainty, but rather to reduce the level of diagnostic uncertainty enough to make optimal therapeutic decisions." Jerome Kassirer [22]

The main goals of patient management within the realm of EM are to:

- assess the likelihood of conditions where timely management, within minutes to days, decreases morbidity and mortality
- initiate appropriate investigations and treatments when these conditions cannot be ruled-out.

Sepsis, acute coronary syndrome, scaphoid fracture, diabetic ketoacidosis are examples of such conditions, which are hereafter referred to as 'don't miss' diagnoses. On the other hand, lung cancer is not such a diagnosis. The prognosis of patients with lung cancer does not hinge upon appropriate initiation of therapy within minutes to days. If all potential don't miss diagnoses can be ruled out, patient care can be pursued outside the realm of EM.

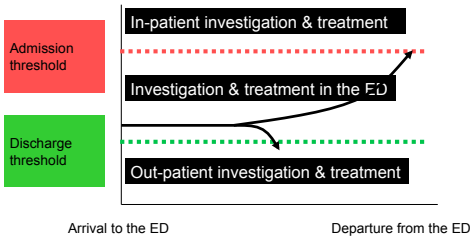
Emergency physicians need to make numerous decisions regarding investigations and treatments. Conceptually, thresholds may be invoked when making these decisions (Fig 1-7) [23]. The 'test threshold' is the probability of the disease where testing for the disease is just as likely to benefit the patient as not testing for the disease. Let us consider the threhold for performing a CT angiography in a patient with potential pulmonary embolism. Complications of CT angiography occur seldom but include anaphylactoid reactions, severe pulmonary edema requiring intubation, renal failure requiring hemodialysis, tissue necrosis and an increased risk of malignancy. The CT is not 100% sensitive nor 100% specific for pulmonary embolism. Treatment of pulmonary embolism with warfarin is not 100% effective in preventing death from or recurrence of pulmonary embolism, and it confers a risk of major hemorrhage. Based on available data, Kline et al. calculated that the test threshold for pulmonary embolism is 1.8% [24]. In practical terms, if the patient's probability of pulmonary embolism is less than 2%, it is not in the patient's interest to investigate for pulmonary embolism. The 'treatment threshold' is the probability of the disease where testing for the disease (to confirm the diagnosis) is just as likely to benefit the patient as assuming that the disease is present and treating it without further testing.

In order to make sound decisions, information is necessary. Incomplete information acquisition can lead to misdiagnosis [18] because of failure to detect a ‘red flag,' a clinical finding that significantly alters the likelihood that the patient is suffering from a 'don't miss' diagnosis. On the other hand, information acquisition has costs. Time spent investigating one patient is time not spent assessing the patients who are waiting and potentially deteriorating. Some radiological examinations are costly, increase the risk of cancer [25] and management time in the ED thereby contributing to crowding, and impact on the availability of radiology for other patients. In order to work efficiently while minimizing the risk of misdiagnosis, information acquisition in EM should be goal-directed, or more precisely threshold-directed. The primary goal of information acquisition in EM is to determine the likelihood of 'don't miss' diagnoses in relationship to the test threshold and the treatment threshold. Acquiring information that does not alter the likelihood of 'don't miss' diagnoses and change management decisions wastes time and resources and is potentially harmful to other patients

in the ED. Thresholds can also be invoked when deciding whether to admit the patient for in-hospital care or discharge from the ED (Fig 1-8).

Fig 1-7: Test and Treat Thresholds

Fig 1-8: Admission and Discharge Thresholds



Bayes' Theorem

Probability (A given B) = Probability (A) x Probability (B given A) / Probability (B)

Anonymous Internal Medicine Dogma: "When you hear hoofbeats, think horses, not zebras."
Kline's Dogma Collar: "If you don't know what a zebra looks like, good luck putting a saddle on that 'horse.'" Gregory Kline [26]

Bayes' Theorem
Bayes' theorem (Fig 1-9) provides a framework for understanding how information alters the likelihood of diagnoses. The easiest way to understand Bayes' theorem is to begin with an example. A young woman has been referred to the ED to rule out a pulmonary embolism (PE). An intern has ordered a d-dimer that turns out to be negative. The intern asks the attending physician whether PE is now effectively ruled out.

- Let P(A) be the probability that the patient has a PE.
- Let P(B) be the probability that the d-dimer is negative
- Let P(A given B) be the probability that the patient has a PE given that the d-dimer is negative.
- Let P(B given A) be the probability that the d-dimer is negative given that the patient has a PE.

The intern is in fact asking the attending physician whether P(A given B) is lower that the test threshold for PE. The test threhold for PE around 2% [27]. The attending responds that a negative d-dimer can effectively rule out PE if the patient's risk of suffering from a PE—prior to the test being taken—is low. In other words, the posttest probability P(A given B) depends in part on the pretest probability P(A). The attending reviews the patient with the junior resident and they estimate the patient's pretest probability of suffering from a PE by using the Canadian (Wells) Prediction Score for Pulmonary Embolism [28]. The patient gets 1.5 points because she has a heart rate of 105/min. According to the Christopher study, PE can be effectively ruled out in patients with a score ≤ 4 points if a d-dimer is negative with a false negative rate of less than 2% [29]. The physicians conclude that PE can indeed be considered ruled out. If the patient had had a high PE pretest probability (e.g. because of active pancreatic cancer), a negative d-dimer would not have been sufficient to rule-out PE.

P(B given A) : P(B), the other factor involved in the calculation of posttest probability, has to do with the d-dimer's test characteristics and its ability to discriminate between patients with PE and those without. It consists of the frequency that the d-dimer is falsely negative P(B given A) divided by the frequency that d-dimer is negative P(B).

Pretest Probability and MAPLES
The threshold for admitting patients with chest pain for observation is lower for patients who have suffered prior myocardial infarctions than for young healthy patients, even when the history, physical examination, blood tests and EKG are identical, because the pretest probabilities for acute coronary syndrome are different. The threshold for aggressively investigating the cause of back pain is lower for the woman who has had prior breast cancer than for the one who has not, given that history of malignancy increases the risk for cancer in the spine [30]. In addition to the patient's age and gender, some information is, as a rule, relevant when estimating the pretest probability of all 'don't miss' diagnoses.

The patient's **past medical history** plays an important role in estimating the pretest probability of conditions potentially causing the patient's current problem. Depending on the problem, the physician should specifically enquire about certain previous conditions; for example:

- patients with back pain should be asked about prior cancer; even remote cancer that is apparently cured may metastasize.
- patients with abdominal pain should be asked about prior abdominal surgery, which increases the risk of bowel obstruction caused by adhesions.

If the patient is a small child, the relevant questions include events during pregnancy, delivery, birth weight, development, immunizations.

The **medications** that the patient is taking:

- influence the probability of certain conditions; e.g. patients taking NSAIDs have an increased risk of gastric ulcers, patients taking Warfarin have an increased risk of bleeding.
- may indicate which chronic conditions the patient is suffering from even if the patient cannot provide a past medical history, or reveal inconsistencies (prior myocardial infarction but not taking acetylsalicylic acid) that are worth clarifying.
- may influence how physical findings are interpreted; e.g. a patient taking a beta-blocker may have a low heart rate despite hypovolemic chock; a patient taking corticosteroids may lack peritonitis despite having a perforated ulcer.
- should be taken into account when initiating additional pharmacotherapy in order to avoid drug interactions.

Depending on the problem or diagnostic hypothesis, the patient should be asked about specific exposures, e.g.

- oral contraceptives and hormonal medications if the patient has chest pain or dyspnea, since many patients do not consider oral contraceptives to be medications
- NSAIDs if the patient has abdominal pain, since they are easily available, over-the-counter medications
- alternative medicines such as herbs and dietary supplements if the patient has abnormal liver function tests
- antibiotic use during the past several weeks if the patient has diarrhea
- intravenous drug abuse if endocarditis or a spinal infection are suspected

Life circumstances, e.g. occupational exposures, recent travel history and exposure to animals, may affect the likelihood of certain diagnoses and provide diagnostic clues. In addition, marital status, functional status (activities of daily living) and the degree of available support at home may impact on whether a patient requires hospital admission or whether further care can safely be carried out on an out-patient basis. Of note, the presence of children (< 18 years old) in the family may impact on management:

- Physical abuse and substance abuse among parents or guardians raise concerns about children's physical and pyschological well-being and, in Sweden, should lead to contact with social services according to Socialtjänstlagen 14 kap., 1§, (SFS 2001:453).
- Special consideration should be given to providing information and support to children of parents with severe somatic and psychiatric conditions.
- If the patient is a child, relevant questions include living situation, siblings, childcare.

Alcohol is a risk factor for several conditions, e.g. pancreatitis, alcohol withdrawal, Wernicke's encephalopathy. Patients may underreport alcohol consumption [31, 32], and when the suspicion of alcohol abuse is high, repeated questioning may be of value. Under

certain circumstances, e.g. when the patient is very young or demented, asking about alcohol consumption is not revelant. The following table presents information on what is considered to be 'risk drinking' [33].

Standard Drink = 14 g of ethanol	Risk drinking in men	Risk drinking in women and people > 65 years
• 350 ml of beer • 150 ml of wine • 45 ml of 80-proof liquor	• ≥ 15 drinks per week on average • ≥ 5 drinks on an occasion	• ≥ 8 drinks per week on average • ≥ 4 or more on an occasion

Smoking is a risk factor for several conditions, e.g. abdominal aortic aneurysm. Smokers may be asked how many cigarettes they smoke daily, and for how long they have been smoking. Patients who report not smoking should be asked whether they have smoked previously, since some patients may have recently quit smoking. Under certain circumstances, e.g. when assessing the victim of a traffic accident, asking about smoking is not relevant.

In addition, all patients should be routinely asked about **allergic reactions** to medications and contrast agents, what symptoms they developed and when following exposure:

- Isolated abdominal pain or loose bowel movements do not suggest an allergic reaction.
- A mild allergic reaction consisting of a maculopapular or morbilliform rash without pruritus is unlikely to be IgE-mediated and is not a contraindication to continued or repeated treatment with the same antibiotic [34].
- Pruritus, urticaria, angioedema and anaphylaxis suggest an IgE-mediated allergic reaction, which usually develop within one hour of exposure and rarely after 72 hours [34].
- Severe skin reactions such as toxic epidermal necrolysis and erythma multiforme are not IgE-mediated; these reactions are contraindications to treatment with the same category of antibiotics, e.g. to all betalactams if the reaction was due to penicillin.

Suspected or documented IgE-mediated allergy to penicillin is not a contraindication to treatment with a third- or fourth-generation cephalosporin. A review of 23 studies including 2400 patients allergic to penicillin and 39000 patients without allergy to pencillin reported no increased frequency of allergic reaction to second- and third-generation cephalosporins [35]. A litterature review from 1950 to 2010 reported no cross-allergy when patients allergic to penicillin were exposed to third- or fourth-generation cephalosporins [36].

In summary, a case can be made for routinely acquiring information pertaining current medications (M), allergies (A), past medical history (P), life circumstances (L), ethanol consumption (E) and smoking (S) in most patients in order to determine the pretest probabilities of 'don't miss' diagnoses. The mnemonic **MAPLES** summarizes this background information. Under certain circumstances, life-circumstances, ethanol consumption and smoking history are irrelevant and the background information may be restricted to **MAP**. This background information may be obtained from the patient, the patient's chart or from the patient's family and friends.

Problem-Driven & Hypothesis-Driven Information-Acquisition

Once a test result is obtained, the patient's probability of suffering from a specific diagnosis is altered depending on the test's performance characteristics. The resulting posttest probability can now be considered a pretest probability for the next test. Asking a patient whether the abdominal pain has migrated from the umbilicus to the right lower quadrant (yes/no) can be

considered a diagnostic test. If the patient answers "yes" to the question, the odds that the patient has an acute appendicitis have increased by a factor of 2-3; if the answer to the question is "no," the odds that the patient has an acute appendicitis have been reduced by half [37, 38].

The ideal investigational modalities in EM are those that provide reliable information fast and safely. The main sources of information in EM are the history and physical examination, augmented by point-of-care data from bedside blood and urine tests, the electrocardiogram and ultrasound. A growing body of litterature has investigated the value of the history, physical examination and point-of-care data in regards to the likelihood of don't miss diagnoses (e.g. The Rational Clinical Examination Series[39]). Given the patient's problem, there is usually a short list of 'don't miss' diagnoses that should be considered. For example, acute coronary syndrome, pulmonary embolism and aortic dissection should be considered in patients presenting with chest pain. Some information is, as a rule, relevant to assessing the probability of all problem-specific 'don't miss' diagnoses. For example, rapidity of pain onset, pain location and radiation, relief or aggravation with inspiration, severity and duration provide valuable information for the probability assessment of acute coronary syndrome, pulmonary embolism and aortic dissection. It follows that the relevance of information from the history, physical examination and point-of-care sources hinges on the patient's problem.

Chapter 08 presents suggestions for 'problem-driven' history, physical examination and tests. The 'problem-driven' history can often be organized according to the mnemonic OPQRST+:

- **O**nset: when the problem started, activity at the time, how rapidly the problem reached its maximal degree
- **P**osition: location of the problem (e.g. abdominal pain, weakness, visual loss), radiation/migration
- **Q**uality: subjective experience of the problem (e.g. pressure vs burning pain, weakness vs numbness)
- **R**elieving and aggravating factors: the relevant questions (e.g. worse with inspiration) are problem-specific
- **S**everity: subjective severity (e.g. of the pain), how the problem affects function (e.g. in the case of weakness)
- **T**emporal factors: whether the problem is constant or intermittent, waxing or waning, new or recurrent
- + stands for additional relevant, problem-specific questions, e.g. leg swelling in the case of dypnea.

A good physical examination can reveal pivotal findings that have a substantial effect on patient care [40], especially when the history that can be obtained from the patient is limited (e.g. unconscious, confused, demented, intoxicated or very young patient). In these settings, a generic physical examination that may reveal unexpected but diagnostically important findings. Performing a basic neurological examination on a demented patient may reveal hemiparesis. Examining the ears of a one-year-old may reveal an otitis media. The ABCDE presented in Chapter 03 may severe as a generic physical examination in these settings. The ABCDE is remarkably similar to the '3 minute tool-kit,' a routine pediatric physical examination recommended for general practitioners in the United Kingdom (Davies). One of the other hand, when detailed information can be obtained from the history, it is dubious that a generic physical examination adds value to more focussed problem-driven physicial examination.

Finally, some information is only relevant when a specific diagnosis is suspected. Carrying out the Dix-Hallpike examination is of value when benign paroxysmal positional vertigo is a potential diagnosis but not otherwise. 'Hypothesis-driven' investigations are covered in Chapter 09, which deals with specific 'don't miss' diagnoses.

In summary, Bayes' theorem provides a framework for assessing diagnostic probability. The probability of a diagnosis given a test result depends on the pretest probability and the test characteristics. The main goal of diagnostic assessment in EM is to determine the likelihood of 'don't miss' diagnoses. MAPLES is a mnemonic for the background information that is, as a rule, necessary to determine the pretest probability of all 'don't miss' diagnoses. Given a specific problem, the number of 'don't miss' diagnoses is usually limited and some common, problem-driven information impacts on the diagnostic probabilities of these conditions. Additional, specific information may then be gathered to fine-tune the likelihood of specific diagnostic hypotheses.

Fig 1-9: Bayes' Theorem

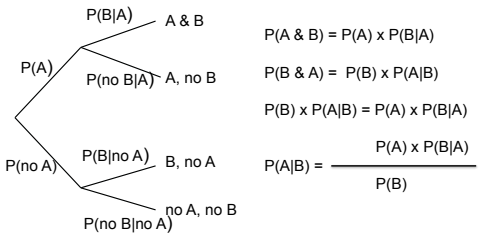
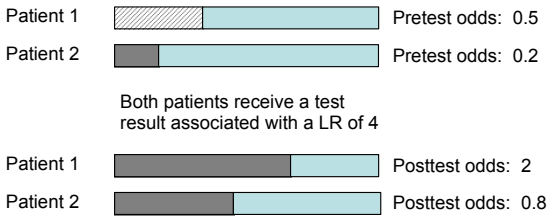


Fig 1-10: Likelihood Ratio (LR)



Pretest Probability: Prevalence, Odds, Relative Risk & Odds Ratio

Prevalence, relative risk and odds ratios allow the emergency physician to estimate the pretest probability of don't miss diagnoses.

"Five out of four people have trouble with fractions." Steven Wright

According to Bayes' theorem, the likelihood of a disease depends not only on test results but also on the patient's pretest probability of having the disease. Physicians can estimate the patient's pretest likelihood for don't miss diagnoses by knowing:

- the prevalence of the disease in the patient population most suited to the patient
- how risk factors affect the likelihood of a disease

Prevalence

One study looked at 2830 patients > 65 years who presented to the Emergency Department with chest pain. Roughly 360 patients had an acute coronary syndrome. The prevalence of acute coronary syndrome among this patient population, expressed as a percentage, was 360/2830 = 12.8% [41]. A 70 year women presents to a similar ED with chest pain. Assuming that there are no fundamental differences between this woman and the study population, one may assume that the patient's pretest probability of acute coronary syndrome is 12.8%.

Odds

The likelihood that a patient has a condition can also be expressed as an odds. In the study, roughly 2470 of the 2830 patients had no acute coronary syndrome. A 70 year women presents to a similar ED with chest pain. Assuming that there are no fundamental differences between this woman and the study population, one may assume that the patient's likelihood of acute coronary syndrome, expressed as an odds, is 360/2470 = 0.15.

Probability (P) can be converted to odds (O) using the following formula: $O = P / (1 - P)$. A probability of 0.2 corresponds to an odds of 0.2 / (1-0.2) = 0.25. Odds can be converted to probability using the following formula: $P = O / (1 + O)$. An odds of 2 corresponds to a probability of 2 / (1 + 2) = 0.67 (67%).

Relative Risk & Odds Ratio

The Relative Risk (RR), also known as Risk Ratio, and the Odds Ratio (OR) are used to express the association between exposure and disease in a given patient population. Patients can be categorized in a 2x2 table according to disease status and exposure status:

	DISEASE PRESENT	DISEASE ABSENT
EXPOSURE POSITIVE	a	b
EXPOSURE NEGATIVE	c	d

The RR is the incidence of disease in the exposed group divided by the incidence of disease in the nonexposed group [42]. Numerically, the RR is [a / (a+b)] / [c / (c+d)]. RRs are used in **randomized controlled trials** and **cohort studies** to quantify the association between exposure and disease.

When **case-control studies** are carried out, members of the patient population are selected on the basis of disease status. In these studies, the association between disease and exposure can

be estimated by dividing the odds of exposure among patients with the disease (a/c) by the odds of exposure among patients without the disease (b/d). This ratio, the OR, is numerically (a/c) / (b/d). When exposure is rare in relation to non-exposure, i.e. when a and b are small in relation to c and d, (a/c) / (b/d) is roughly equal to [a / (a+c)] / [b / (b+d)], i.e. the OR is roughly equal to the RR.

Posttest Probability: Sensitivity, Specificity, Predictive Values & Likelihood Ratios

Likelihood ratios allow the emergency physician to estimate the magnitude of change in diagnostic probability associated with test results.

"Likelihood ratios (LRs) . . . combine the stability of sensitivity and specificity to provide an omnibus index of test performance far more useful than its constituent parts. Application of Bayes' theorem to LRs produces the following summary equation: Clinically estimated pretest odds of disease x LR=Posttest odds of disease. This simple equation illustrates a concordance between the mathematical properties of likelihood ratios and the central strategy underlying diagnostic testing: the revision of disease probability." E John Gallagher [43]

Patients can be categorized in a 2x2 table according to disease status and test result:

	DISEASE PRESENT	DISEASE ABSENT
TEST POSITIVE	a	b
TEST NEGATIVE	c	d

Sensitivity & Specificity

- The **sensitivity** (SN) of a test is a / (a+c). A highly sensitive test can be used to rule-out a disease (mnemonic 'SNOUT')
- The **specificity** (SP) of a test is d / (b+d). A highly specific test can be used to rule-in a disease (mnemonic 'SPIN')

Positive and Negative Predictive Values

- The **positive predictive value** (PPV) of a test is a / (a+b), i.e. the percentage of patients with a positive test who actually have the disease.
- The **negative predictive value** (NPV) of a test is d / (c+d), i.e. the percentage of patients with a negative test who actually do not have the disease.

The positive and negative predictive values of a diagnostic test vary depending on the prevalence of the disease in the population:

Disease Prevalence: 50%

	DISEASE +	DISEASE -
TEST +	90	10
TEST -	10	90

Sensitivity: 90% PPV: 90%
Specitivity: 90% NPV: 90%

Disease Prevalence: 5%

	DISEASE +	DISEASE -
TEST +	9	19
TEST -	1	171

Sensitivity: 90% PPV: 32%
Specificity: 90% NPV: 99%

The sensitivity and specificity of a diagnostic test are not affected as much by disease prevalence as predictive values (although disease severity and prevalence do impact on sensitivity and specificity [44, 45]). Sensitivity and specificity are useful when their values are high, i.e. when a disease can be ruled-in or ruled-out in one step. However, there are many tests that do not have high specificity or sensitivity but that make a valuable contribution to the diagnostic process when combined with other tests. Regretably, sensitivity and specificity are not user-friendly when it comes to interpreting the results of a combination of tests.

Likelihood Ratios

Likelihood ratios (LR) incorporate sensitivity and specificity and thus are not as affected by disease prevalence as PPV and NPV:

- The **positive likelihood ratio** (LR+) of a test is [a / (a+c)] / [b / (b+d)]. The LR+ is the percentage of patients who have the disease testing positive divided by the percentage of patients who do not have the disease testing positive. The LR+ is mathematically equivalent to SN / (1-SP).
- The **negative likelihood ratio** (LR-) of a test is [c / (a+c)] / [d / (b+d)]. The LR- is the percentage of patients who have the disease testing negative divided by the percentage of patients who do not have the disease testing negative. The LR- is mathematically equivalent to (1 – SN) / SP.

Likelihood ratios have the following advantages:

- Unlike PPV and NPV, likelihood ratios are not as affected by disease prevalence [43]
- Unlike SN and SP, LRs can be used for quantitative diagnostic reasoning to calculate a posttest odds that can in turn be used as a pretest odds when another diagnostic test is applied [46].
- 'Interval likelihood ratios' can be used to interpret test results expressed on a continuous scale with less distortion than by picking a single cutoff and reducing the test result to a dichotomous variable in order to generate a sensitivity and specificity [47].

In order to use LRs quantitatively, disease prevalence needs to be expressed as odds (Fig 1-10). When the pretest probability of a disease P(A) and the posttest probability of the disease P(A|B) are expressed as odds, the factor P(B|A) : P(B) in Bayes theorem is a likelihood ratio. Physicians are more used to thinking about prevalence in terms of percentages. The following table provides a short-cut for estimating the change in prevalence, expressed as a percentage, corresponding to the likelihood ratio [48]:

LR	0.1	0.2	0.3	0.4	0.5	2	3	4	5	6	8	10
Change (%)	-45	-30	-25	-20	-15	+15	+20	+25	+30	+35	+40	+45

Occam's Razor, Hickam's Dictum & Schrödinger's Cat

- Occam's Razor encourages physicians to seek a unifying diagnosis that explains all of the patient's problems. If a patient suffers from only one diagnosis, information that decreases the likelihood of one potential diagnosis affects the likelihoods of competing diagnostic hypotheses.
- Hickam's Dictum reminds the physician that patients may suffer from several diagnoses.
- Schrödinger's Cat is a metaphor for the fuzzy interdependency of the probabilities for competing diagnoses.

Occam's Razor: "Pluralitas non est ponenda sine necessitate."
Kline's Closer Shave: "Occam missed stuff." [26]

Occam's Razor, "plurality must not be posited without necessity", enjoins physicians to seek a single unifying diagnosis that explains all of the patient's findings. For example, acute onset of aphasia, right-sided arm weakness and facial droop may jointly result from a left-sided cortical stroke. Concurrent severe chest pain and a pulse deficit may be explained by an aortic dissection resulting in a left-sided cortical stroke. The assumption underlying Occam's Razor is that the patient is suffering from only one diagnosis. If the physician assesses that one of three potential diagnoses accounts for the patient's findings, the sum of the pretest probabilities of these competing diagnostic hypotheses is 1. Information that increases or decreases the likelihood of a given diagnosis will impact on the likelihoods of competing diagnostic hypotheses. The physician assessing a 50 year-old woman with chest pain and shortness of breath may consider acute coronary syndrome, pulmonary embolism, aortic dissection and pneumonia. If a d-dimer is measured and is negative, the likelihoods of pulmonary embolism and aortic dissection decrease and the likelihoods of competing diagnoses such as acute coronary syndrome and pneumonia increase as a result.

The interdependency of the probabilities of competing diagnoses explains why the history and physical examination are valueable diagnostic tools, despite the fact that many of the LRs associated with items from the history and physical examination range between 0.5 and 2. One study reported that the experienced physician's diagnostic impression that a patient suffers from acute cholecystitis is associated with a LR+ of 25-30, despite the fact that no individual symptom, sign or laboratory result carried sufficient weight to rule-in the diagnosis [49]. The experienced physician's diagnostic accuracy is presumably due to his or her ability to combine small LR as well as to rule out alternative diagnoses, leaving acute cholecystitis as the dominant diagnostic hypothesis. This phenomenon also explains why emergency physicians should be proficient at diagnosing common, non-urgent conditions. Being able to rule-in such conditions helps rule-out don't miss diagnoses.

In reality, matters are not as straight-forward. Some patients may suffer from several concurrent conditions, some acute and some chronic, resulting in the observed clinical findings. Gout and septic arthritis may coexist [50]. Pulmonary embolism and pneumocystis carinii pneumonia may become symptomatic simultaneously; older patients, especially those with chronic diseases, may be more likely to develop concurrent conditions [51]. Hickam's dictum—"a patient can have as many diagnoses as he darn well pleases"—cautions physicians against assuming that patients suffer from only one diagnosis. In summary, Occam's razor enjoins physicians to 'connect the dots' and use the power of pattern recognition during the diagnostic process, while Hickam's dictum cautions physicians against being blinded by the first recognizable pattern and relying exclusively on System-1 processes.

Schrödinger was an Austrian physicist who played an important role in the development of quantum mechanics during the first half of the twentieth century. Schrödinger's cat refers to a thought experiment in which a cat is placed in a box alongside a bottle filled with hydrocyanic acid. A hammer is placed such that it will smash the bottle—resulting in the cat's death—should a radiation source emit a particle. The probability that this particle is emitted during the hour following the onset of the experiment is 50%. After an hour, the box is opened and reveals a live or a dead cat. The probability that the cat will survive is 50%. Schrödinger's thought experiment is meant to illustrate the bizarreness of quantum mechanics. Experiments demonstrate that quantum particles, in distinction to macroscopic objects, can exist simultaneously in several quantum states (so-called 'quantum superposition' or 'quantum indeterminancy'). With each state is attached a probability and the sum of the probabilities is 1. When a quantum particle is forced to adopt a specific state, the probability of other potential states drops to 0.

Schrödinger's cat is a metaphor for the fuzzy interdependency of the probabilities of competing diagnoses. Despite the fact that patients may suffer from one or several diagnoses, information that argues for or against certain diagnoses affects the probabilities of alternative diagnoses and is hence of diagnostic value. Given that the probability of competing diagnoses is interrelated, physicians should acquire the necessary clinical information before jumping to premature probability assessments. Weighing all the acquired information at the same time may guard against 'the anchoring heuristic,' a cognitive falacy whereby the physician fixates on a diagnosis early on and interprets new information as supportive of this diagnosis, even when the new information suggests an alternative diagnosis [52].

Treatment Value: Absolute & Relative Risk Reduction, Number-Needed-to-Treat

The risks and benefits of various treatments can be quantified in several ways, resulting in different subjective impressions of benefit.

"There are three kinds of lies: lies, damned lies and statistics." Mark Twain

Clinical trials compare the risks and benefits of treatments in a specific population by measuring the frequencies of specific outcomes at specific time points among patients assigned to different treatment groups. The trial might compared an experimental treatment with a control treatment. For example, the PEITHO study [53] assessed the risks and benefits of thrombolysis (experimental treatment) versus placebo (control treatment) in normotensive patients with intermediate-risk pulmonary embolism. The primary outcome measure was death or hemodynamic decompensation within 7 days. Patients in the trial can be categorized in a 2x2 table according to treatment arm and outcome:

	Death/decompensation	**No death/decompensation**
Fibrinolysis	13	493
No fibrinolysis	28	471

The treatment effect can be expressed in several ways.

Absolute Risk Reduction/Increase and Relative Risk Reduction/Increase

- The **absolute risk reduction** (ARR) or **absolute risk increase** (ARI) relate to the difference in percentages of patients with the outcome measure between treatment arms. If the experimental treatment resulted in a decrease in the outcome measure, the term ARR is used; if the experimental treatment resulted in an increase in the outcome measure, the term ARI is used. In the PEITHO trial, 2.6% of patients in the fibrinolysis arm suffered from death / decompensation (13/506) vs 5.6% of patients in the no fibrinolysis arm (28/499). The ARR is thus 5.6% - 2.6% = 3.0%.
- The **relative risk reduction** (RRR) is calculated by dividing the ARR by the percentage of patients with the outcome measure receiving the control treatment. Likewise, the **relative risk increase** (RRI) is calculated by dividing the ARI by the percentage of patients with the outcome measure receiving the control treatment. In the PEITHO trial, the RRR was 3.0% / 5.6% = 54%. Data from the PEITHO trial illustrates the fact that the RRR may be an impressively high number (54%) while the ARR (3%) may be quite modest. The ARR is more clinically relevant.

Number-Needed-to-Treat and Number-Needed-to-Harm

- The **number-needed-to-treat** (NNT), i.e. the number of patients who need to be treated to prevent 1 primary outcome, is calculated by dividing 1 by the ARR. In the PEITHO trial, the number of patients with intermediate-risk pulmonary embolism who need to be treated with fibrinolysis to prevent one patient from dying or decompensating hemodynamically within 7 days is 33 (1/3%). The appeal of the NNT is that it provides the information represented by the ARR in a more intuitive manner. NNTs do not convey any measure of statistical significance. In the PEITHO trial, 2.4% of patients who had received thrombolysis died by day 30 versus 3.2% in the placebo group. This difference was not statistically significant, yet an NNT of 125 can be calculated (1/(3.2%-2.4%)).

- The term **number-needed-to-harm** (NNH) is used when the experimental treatment increases the risk of a negative outcome. In the PEITHO trial, stroke at 7 days occurred in 2.4% of patients who received thrombolysis compared with 0.2% of patients in the placebo group. The NNH for stroke was therefore 45 (1/2.2%). One interpretation of the findings in the PEITHO study is that fibrinolysis increases the risk of stroke at 7 days without decreasing mortality at 30 days.

Relative Risk, Odds Ratio and Hazard Ratio

- **Relative Risk** or **Risk Ratio** (RR) can also be used to report treatment effect. The RR is calculated by dividing the percentage of patients with the outcome in one treatment arm by the percentage of patients with the outcome in the other treatment artm. In the PEITHO study, the RR of death/decompensation when treated with fibrinolysis as opposed to placebo is (13/13+493) / (28/28+471) = 0.46.
- **Odds ratios** (OR) can also be used to report treatment effect. The OR is calculated by dividing the odds of the outcome if the patient received one treatment with the odds of the outcome if the patient did not receive the treatment. In the PEITHO study, the OR of death/decompensation when treated with fibrinolysis as opposed to without fibrinolysis is (13/493) / (28/471) = 0.44.
- **Hazard ratios** (HR) are used in so-called survival analyses that examine time to an event (e.g. death, remission of a disease, cancer recurrence). The term 'hazard' refers to the rate at which events occur. Hazard ratios represents the chance of an event occurring in the treatment arm of a study divided by the chance of the event occuring in the control arm [54].

The Medium is the Message

The statistical measures used to report beneficial and detrimental outcomes may illicit different subjective impressions of benefit or detriment. Consider how data from a meta-analysis of the value of thrombolysis (rt-PA) within 3 hours of stroke onset can be presented [55]:

	rt-PA	No rt-PA	OR/HR	RRI	NNT/H
Good outcome at 3-6 months	32.9%	23.1%	1.75 (1.35-2.27)	42%	10
Fatal intracranial hemorrhage by 7 days	2.7%	0.4%	7.14 (3.98-12.79)	575 %	43
Mortality at 90 days	17.9%	16.5%	1.11 (0.99-1.25)	8.5 %	71

Clinical Decision Rules & Clinical Gestalt

Clinical decision rules (CDRs) evaluate and validate the prognostic value of combinations of clinical data. They are best used in combination with the physician's general clinical impression (gestalt).

“Know the rules well, so you can break them effectively.” Dalai Lama XIV
“the [pirates'] code is more what you'd call 'guidelines' than actual rules.” Barbossa in Pirates of the Caribean: the Curse of the Black Pearl

Most of the LRs associated with individual elements from history, physical examination and point-of-care technology are not sufficient, in and of themselves, to rule-in or rule-out don't miss diagnoses. The combined impact of several clinical variables on diagnostic probability can be calculated by multiplying the LR's, as long as these variables are independent from one another. Multivariable analyses help tease apart which clinical variables impact on diagnostic probability and which clinical variables do not add diagnostic value. These analyses can then be used to construct a Clinical Decision Rules (CDR), defined as "a decision-making tool for clinicians that included 3 or more variables obtained from the history, physical examination, or simple diagnostic tests and that either provided the probability of an outcome or suggested a diagnostic or therapeutic course of action" [56].

CDRs are then evaluated in various patient populations and their impact on physician behaviour assessed. CDRs can be categorized according to how generalizable they are and to what degree they influence care in clinical practice [57]:

Level 4: Derivation	Rules that need further evaluation before they can be applied clinically	Derived but not validated or validated only in split samples, large retrospective databases, or by statistical techniques
Level 3: Narrow validation	Rules that clinicians may consider using with caution and only if patients in the study are similar to those in the clinician's clinical setting	Validated in only 1 narrow prospective sample
Level 2: Broad validation	Rules that can be used in various settings with confidence in their accurary	Demonstrated accuracy in either 1 large prospective study including a broad spectrum of patients and clinicians or validated in several small settings that differ from one another
Level 1: Impact analysis	Rules that can be used in a wide variety of settings with confidence that they can change clinician behavior and improve patient outcomes	At least 1 prospective validation in a different population and 1 impact analysis, demonstrating change in clinician behavior with beneficial consequences

Clinical gestalt refers to the physician's intuitive, summative clinical assessment. In essence, clinical gestalt is pattern recognition (System 1 thinking) [58]. Critics of CDRs argue that CDRs do not provide added value beyond clinical gestalt. For example, some studies suggest that clinical gestalt is just as good as CDRs for estimating diagnostic probability of pulmonary embolism [59-61]. In fact, some CDRs incorporate elements of the clinical gestalt in the scoring system. For example, the Wells score to estimate the probability of pulmonary

embolism assigns three points when alternative diagnoses are deemed less likely than pulmonary embolism [28].

Critics also argue that CDRs may lead to diagnostic errors if they are not applied in the appropriate context, a phenomenon referred to as 'rule creep' [62]. For example, a systematic review of the San Francisco Syncope Rule showed that the rule has poor sensitivy for the prediction of serious outcomes (sensitivity of 87%) when it is applied broadly, while the probability of a serious outcome given a negative score was ≤ 2% when the score was applied only to patients for whom no cause of syncope was identified after the initial evaluation in the ED [63]. Certain CDRs such as the Ottawa Subarachnoid Hemorrhage Rule specify clearly the patient population for which the CDR is intended. The Pulmonary Embolism Rule-out Criteria (PERC) CDR [24] is intended to be used for patients with a pretest probability for pulmonary embolism of < 10%, but it is not specified how this probability can be estimated without using the criteria in the rule itself. Finally, some critics consider CDRs an encroachment on their ability to think independently, refer to CDRs as 'cookbook medicine,' and argue that the heterogeneity of patients in the ED limits as one-size-fits-all approach.

Proponents argue that CDRs provide a way of standardizing risk-taking that can prevent both under- and over-utilization of investigations and treatments. They point to evidence suggesting that clinicians' ability to evaluate risk-benefits of treatment is poor. For example, in a survey including emergency physicians and neurologists, only 11% (0–22) could correctly identify the magnitude of the benefit with tPA in patients with acute stroke [64]. Proponents also point to evidence suggesting that CDRs do in fact improve patient management. One observational study showed that the lack of availability of CDRs in the ED was associated with inappropriate diagnostic management of patients with suspected pulmonary embolism [65]. In particular, CDRs may reduce unnecessary investigations in low-risk patients. In one study, the provision of clinical decision rules reduced unnecessary medical radiation exposure for patients with chest pain and dyspnea assessed in the ED [66]. Other studies suggested that access to CDRs may reduce uncessary investigations and antibiotic prescriptions in cases of suspected streptococcal pharyngitis [67] and increase the proportion of low-risk pneumonia patients treated as out-patients [68].

In summary, CDRs can guide decisions regarding investigations and management, and improve resource utilization, but they do not obviate the need for relevant clinical information-acquisition, clinical gestalt and sound clinical judgement. In particular, CDRs may be most useful in situations where the population to which the rule applies is clearly defined (e.g. isolated ankle sprain within 48 hours) and there is only one clinically relevant condition that needs to be ruled out (e.g. fracture), yet even in this setting, the physician needs to interpret the degree of pain expressed upon palpation of the ankle to rule-out fracture using the Ottawa ankle rule [69]. In situations were the patient population is ill-defined (syncope without obvious cause after work-up) and where several clinically relevant conditions need to be considered and weighed against each other (transient loss of consciousness), the added value of CDRs over clinical gestalt may be significantly less. Integrating CDRs into the clinical workflow with automatic provision of advice at the location and time of clinical decision-making may allow for better use of CDRs, better use of clinical resources and better patient outcomes [70].

Decision-Making & Utilitarianism

Decisions regarding investigation, treatment and resource allocation should be guided by the

potential consequences of these decisions and chosen to maximize well-being.

”In few other domains of medicine, indeed in few other domains of human endeavor, is there such variety, novelty, distraction, and chaos, all juxtaposed to a need for expeditious and judicious thinking. Good decisionmaking is the ultimate arbiter of a well-calibrated clinical performance, yet, historically, the emphasis it has received compared with other aspects of clinical performance appears wanting.” Pat Croskerry, 2006[71]

"human decision making, and, particularly, decision making in the face of uncertainty, inaccurate, and imperfect information, remains absolutely vital to the life of medicine." Siddhartha Mukherjee, 2016[72]

" . . . the reality is that doctors continually have to make decisions on the basis of imperfect data and limited knowledge, which leads to diagnostic uncertainty, coupled with the uncertainty that arises from unpredictable patient responses to treatment and from health care outcomes that are far from binary." Arabella L. Simpkin, and Richard M. Schwartzstein, 2016 [73]

"The good physician treats the disease; the great physician treats the patient who has the disease." - William Osler

Once clinical information has been acquired and the probabilities of don't miss diagnoses assessed, the physician needs to decide whether further investigations and treatments are required (i.e. determine where the testing and test-treatment thresholds lie for the individual patient) and how urgently they need to be carried out. Factors that need to be taken into account include:

- Whether one or several don't miss diagnoses are under consideration, and their respective likelihoods
- The patient's prognosis without further investigations or treatments
- The diagnostic value of potential investigations and their side-effects
- The risks and benefits of potential treatments

When clinical trials are critically assessed, attention is paid to the patient population, the intervention, the control treatment and the outcome measure. The practical value of clinical trials when making decisions may be limited by the following:

- Patients may not meet the inclusion and exclusion criteria of the trials; the patient's current medications and past medical conditions may interact with the potential investigations and treatments.
- The investigations and treatments may not be readily available.
- The outcome measure may not be patient-oriented, i.e. not improve the patient's well-being. Patient's values and preferences, and to some extent those of relatives and care-givers, should be taken into account during the decision-making process.
- When health-care resources are limited, the physician should take into account how resource utilization affects the well-being of other patients.
- Medico-legal aspects should be taken into account.

Decisions regarding disposition, i.e. whether the patient needs to be admitted for the sake of carrying out investigations and treatments, are conceptually no different than decisions regarding investigations and treatment. One may speak of an 'admission threshold' and a

'discharge" threshold' (Fig 1-8). Some patients may need to be admitted regardless of their diagnosis simply because they can no longer perform their activities of daily living at home. The EM physician should determine the degree of monitoring required during the initial admission. Admission provides continuing care and obviates the planning required for a safe discharge. Martin Fischer argued that "Diagnosis is not the end, but the beginning of practice." From the perspective of EM, diagnosis is the beginning of someone else's practice.

The goal of health care is arguably to maximize the patient's future well-being, not simply to prolong life. Utilitarianism is "a theory in normative ethics holding that the proper course of action is the one that maximizes utility, usually defined as maximizing happiness and reducing suffering" (Wikipedia utilitarianism). While trial results, clinical practice guidelines (CPGs) and CDRs may provide guidance as to how patients should be managed, they are poorly tailored to patients with multiple multimorbidity [74]. In particular, the value of CPGs and CDRs may be especially limited when it comes to frail, elderly patients with multiple chronic diseases and polypharmacy. Utilitarianism should the guiding principle in decision-making. Difficult decisions are best made with the help of other experienced physicians, the patient (when possible) and the patient's relatives.

Stay-and-Play vs Scoop-and-Run

Stay-and-Play versus Scoop-and-Run are two different prehospital management strategies. Which strategy is most appropriate ultimately depends upon where the critical treatments can be provided. This concept applies even in the Emergency Department.

"Quote"

"Stay-and-Play" and "Scoop-and-Run" are terms referring to two prehospital management strategies of the trauma patient. According to the Stay and Play approach, patients are stabilized in field (e.g. through the performance of endotracheal intubation, chest drain insertion) prior to transport to the hospital. Proponents of the "stay-and-play" strategy argue that procedures addressing life-threatening injuries should be carried out at the scene of the trauma prior to transport. According to the proponents of the "scoop-and-run" strategies, patients should be transported as soon as possible to the hospital to minimize the time between injury and definitive surgical care. Which strategy is optimal will depend on the factors such as the type of injury and transport times to the hospital.

The dilemna as to whether or not to attempt to "stabilize" an unstable patient prior to transport to another location which can provided more advanced care extends beyond the prehospital arena. For example, a patient with severe hemorrhagic shock due to intraabdominal bleeding should not remain in the ED "until stabilized" but rather transported urgently to the operating room.

Errors & Checklists

Medical checklists have the potential to reduce errors of omission, prevent premature closure, improve communication and teamwork, and promote efficiency during the practice of EM.

Quote from Checklist Manifesto.

EM is a high intensity field of work, similar in that regard to the military and the airline industry. EM physicians often need to handle several tasks simultaneously; they work under constant interruption [75] and constant time pressure. Patients present with a wide variety of problems, some trivial and others life-threatening. EM is a 24/7 specialty, and most brains do not function optimally during the early hours of the morning. Such an environment is ripe for diagnostic and treatment errors.

The rate of diagnostic errors in the ED ranges from 0.6% to 12% [76], but given that diagnostic errors are often unrecognized or underreported, the exact frequency is unknown [77]. A prospective observational study reported a missed diagnosis in the ED for acute respiratory distress among patients ≥ 65 years of 20%, an inappropriate treatment among 32% coupled with a higher mortality (25% vs 11%) [78]. Diagnostic errors are the leading cause of emergency department malpractice claims in the United States [79]. Misdiagnoses presumably cause significant preventable mortality, morbidity and costs [77]. Diagnostic errors may classified as [18]

- No-fault errors, e.g. due to an unusual disease presentation or a deceptive patient
- System-related errors stemming from equipment problems and organizational flaws
- Cognitive errors stemming from faulty data gathering, faulty synthesis and/or faulty knowledge

Cognitive factors contribute to 96% of diagnostic errors in the ED [21]. Some studies suggest that incomplete information acquisition from the history and physical examination contribute to 40% of diagnostic misstakes [18, 21]. One retrospective chart review of 83 patients with aortic dissection revealed an association between the quality of the initial history and the accuracy of the initial clinical impression: aortic dissection was correctly suspected in 91% of patients when the history included pain quality, location and onset, but only in 49% of patients when the history included zero, one or two of these questions [80]. Another study reported that problems with the history were present in 40% of cases of diagnostic errors related to acute abdominal pain in the ED [81].

Faulty information interpretation results from cognitive biases:

- **Framing effect** refers to a failure to consider the correct diagnosis due to contextual information. For example, labelling a patient as suffering from ’flank pain’ as opposed to ’thoracic pain’ may contribute to the misdiagnosis of pulmonary embolism as renal colic.
- **Triage cuing** refers to the phenomenon whereby patients triaged higher are subjected to more investigations with more serious diagnoses being considered than patients with a lower triage [82]. Triage cuing may account for an underestimation of the severity of trauma when the patient walks in to the Emergency Department as opposed to when the patient is brought into the ED by ambulance.
- **Diagnostic momentum** refers to the influence of prior decisions or labels on the clinician's diagnostic reasoning, making it more difficult for the physician to consider alternative diagnoses [82].

- **Availability** refers to the phenomenon whereby ease of recollection influences diagnostic reasoning. Recently encountered diagnoses, prominent, frequently encountered or easily searchable diagnoses influence the final selection of diagnosis [82].
- **Premature closure** refers to the premature abrogation of information acquisition and diagnostic reasoning once the physician comes up with a plausible diagnosis [83]. In one study, premature closure was the single most common cause of diagnostic error attributed to cognitive factors [18].
- **Anchoring and under-adjustment** occurs when physicians anchor their diagnosis on initial information and fail to revise their diagnosis upon acquisition of subsequent information [82]. The anchoring heuristic is fallible because "it conflicts with the scientific principle of checking for disconfirming evidence" [52].
- **Search satisficing** refers to the tendency to halt the diagnostic process once an abnormality is found, even when the abnormality does not explain the patient's problem[82].
- **Outcome bias** is present when a clinician overestimates the probability of good outcomes and underestimates the probability of bad outcomes [82].

The common outcome of cognitive biases is that the patient's actual diagnosis is not consciously considered using System 2 thinking. Several authors argue that Emergency Physicians can guard against cognitive biases by practising 'metacognition', i.e. being aware of whether they are reasoning in an analytical (System 2) or intuitive (System 1) mode [84]. However, there does not seem to be a simple, effective, generic debiasing strategy [85] [86]. The work environment in the Emergency Department, full of noise, interruptions, parallel tasking, makes additional System 2 thinking difficult.

A checklist can be defined as “a list of action items, tasks or behaviours arranged in a consistent manner, which allows the evaluator to record the presence or absence of the individual items listed” [87]. The airline industry, the military, the construction industry use checklists to decrease errors of omission and improper implementation of procedures and protocols under stressful conditions [88]. Within health-care, checklists have been shown to decrease the complication rates relating to central venous catheter insertion [89-91] and reduced the morbidity and mortality from surgery [12, 92, 93]. One study showed that access to checklists improved patient care during simulated surgical crises [94].

Checklists may play a role in decreasing diagnostic mistakes [77, 95]. In particular:
- Checklists associated with broadly-defined problems (e.g. chest or thoracic pain / discomfort) may mitigate the effects of framing and diagnostic momentum.
- Checklists may prevent incomplete information acquisition by ensuring that a resonably complete initial history and physical examination are performed; an initial focus on information-acquisition as opposed to diagnostic reasoning may decrease the risks of premature closure, anchoring and under-adjustment.
- Checklists that enjoin physicians to consciously consider selected don't miss diagnoses may decrease the risks of premature closure, search satisficing, outcome bias and anchoring. One study suggests that consciously considering alternative diagnoses reduces diagnostic errors [96].

Checklists may have other advantages in EM:
- Checklists may improve the care of patients with syndromes (e.g. severe sepsis, hemorrhagic shock) requiring numerous diagnostic and therapeutic measures.
- Checklists may improve the safety of therapeutic procedures and the interpretation of diagnostic tests such as the electrocardiogram [97].

- Checklists may allow junior colleagues to be more productive in the ED by ensuring that they gather all the relevant information prior to reviewing the patient with an attending physician.
- Checklists have the potential to increase efficiency in the ED: first, doing a task repeatedly in the same manner reduces the time required by the process. Second, a checklist can spare time by omitting items that are not relevant to the process at hand.
- EM is a team sport. Checklists—such as the generic ABCDE checklist presented in Chapter 03—can facilitate team dynamics by ensuring that all team participants are on the same page.
- Checklists can be a concrete starting point for the continuous improvement of processes in the ED and for the evaluation of cases where malpractice is suspected. Describing processes in a concrete manner with the use of checklists imposes a structure that allows for the incremental improvement of specific processes.
- Checklists can ensure that information is gathered in a systematic way suitable for research purposes.

There are a number of barriers to the implementation of checklists. Checklists may contain items that most physicians consider irrelevant to the situation when the checklist is supposed to be implemented. For example, asking every patient when they last ate is irrelevant when it comes to the vast majority of patients. Irrelevant items on a checklist reduce the value of the checklist as whole and lead to physicians 'throwing out the baby with the bathwater.' In addition, checklists may be time-consuming, poorly organized, unclear and unavailable at the point-of-care. For checklists to become established, it is essential that the checklists are felt to increase efficiency and safety by those that use them as opposed to considered an additional administrative task. It should be emphasized that checklists do not remove the onus on the physician for sound judgement. Every patient is unique and under certain circumstances, carrying out some of the items on the checklist may be inappropriate or harmful. One study showed that the overwhelming majority of departures from medical checklists are appropriate [98].

Chapters 02-09 present checklists that correspond to various processes in EM.

- the colour **red** symbolizes **information** to be acquired, **assessments** to be made, **diagnoses** or **measures** to be considered
- the checkbox (☐) symbolizes that the order in which the checklist items are carried out is not important

numbers (**1. , 2. , 3.**) symbolize that there is a preferential order in which the checklist items are to be carried out.

CHAPTER 02—GENERIC APPROACHES

This chapter proposes generic approaches to the following two situations:
- Managing the individual patient
- Organisational tasks, whereby the challenge lies in prioritizing between and within health-care needs and optimally allocating health-care resources.

The concepts that underlie these approaches are covered in Chapter 01.

APPROACH TO THE INDIVIDUAL PATIENT

The approach to the individual patient can be organized according to the mnemonic **D^4**:

1. Danger?
- ☐ **Safety? Consider protective gear and other safety issues**
- ☐ **Support? Consider requesting additional resources and carrying out a Sign-In**
- ☐ **Stability? Consider catastrophic hemorrhage control, CPR, ABCDE**

2. Data: problem-driven information-acquistion
3. Diagnosis? Deliberate consideration of selected don't miss diagnoses
4. Decisions: risk-benefit assessment of different management strategies; Sign-Out

1. DANGER?

The first step in the management of the individual patient is to determine whether acute measures are indicated.

☐ Safety?
Within the ED, the major safety threats to health-care personnel are infectious diseases, sharp instruments, violent patients or relatives, high voltage equipment such as defibrillators and fires/explosions. As a general rule, it is wise to wear gloves whenever dealing with potentially critical patients. Other protective gear (gowns, face-shields, masks) may be indicated depending on the circumstances. Calling for assistance may be required in the case of the belligerent patient.

The out-of-hospital environment exposes health-care personnel to numerous hazards in addition to those found in the ED, for example violent animals, high-speed traffic, chemicals, fires, explosions and exposure to high voltage. Aside from donning appropriate protective gear (e.g. gloves, helmet), the physician should ‘read the scene’ with caution prior to patient management and have a low threshold to postpone health-care delivery until the fire department or the police have secured the scene. Calling for additional manpower and postponing further management until their arrival may be necessary, as well as relocating prior to extensive patient management.

☐ Support?
It may be obvious from the start that additional resources (personnel, equipement) are going to be required. Calling for additional resources immediately may allow for faster definitive measures.

Sign-In
Personnel working in the Emergency Department often get a couple of minutes to prepare for the arrival of a critically ill patient. These minutes allow for a 'Sign-In,' a structured team-

building process whereby team-members are informed of the relevant available information, the team may speculate about possible diagnoses and measures, rolls are assigned, and team-members are encouraged to voice suggestions. A Sign-In may also be carried out during patient resuscitation as new team members arrive and as a method of updating the team on the current situation. The Sign-In corresponds to the 'Time-Out' of the WHO (World Health Organization) Surgical Safety Checklist that occurs prior to the operation [1] and is structured according to SBAR [2]:

Table 2.2: Sign-In

1. Situation	☐ Team-member introduction (name, specialty) ☐ Patient's age and main problem
2. Background	☐ Relevant background patient information ☐ Information about the current situation
3. Assessment	☐ Speculation about possible diagnoses ☐ Speculation about potential measures
4. Recommendation	☐ Rolls are assigned ☐ Team-members are asked for further suggestions

Mentally refreshing the doses of medications that may be required is advantageous (mnemonic **As**):

Table 2.3: Resuscitation Medications

	Condition	Drug	Adult	Child
	Cardiac arrest	**A**drenalin 0.1 mg/ml	1 mg (10 ml) IV	10 ug/kg (0.1 ml/kg) IV
	Cardiac arrest	**A**miodarone	300 mg IV	5 mg/kg in 5% glucose
A	Anaphylaxis	**A**drenalin 1 mg/ml	0.5 mg IM	10 ug/kg IM
	Airway edema	**A**drenalin 1 mg/ml	1 mg Neb	1 mg Neb
B	Asthma / COPD	**A**lbuterol	5 mg Neb	2.5 mg < 5 yrs; 5 mg > 5 yrs
	Asthma / COPD	**A**trovent	0.5 mg Neb	0.25 mg < 5 yrs
C	Bradycardia	**A**tropine	0.5 mg	20 ug/kg
	PSVT	**A**denosine IV push	5-10-15 mg	100-200-300 ug/kg
D	Status epilepticus	**A**nticonvulsant, IV	Diazepam 10 mg IV*	Diazepam 0.2 mg/kg IV*
	Status epilepticus	**A**nticonvulsant, no IV	Midazolam 10 mg IM	Midazolam 0.2 mg/kg IM
E	Severe Pain	**A**nalgesic, IV	Morphine 0.1 mg/kg IV	Morphine 0.1 mg/kg IV
	Severe Pain	**A**nalgesic, no IV	Ketamine 2 mg/kg IM	Ketamine 2 mg/kg IM

* Alternative: Lorazepam 4 mg IV (0.1 mg/kg)

The weight of a child can be estimated based on the child's age [3], with the caveat that ge-based formulae without habitus adjustment predict ideal as opposed to actual body weight [4].

- < 1 year: (months / 2) + 4 kg
- 1-5 years: (years x 2) + 8 kg
- 6-12 years: (years x 3) + 7 kg

☐ Stability?

The purpose of the stability assessment is to determine whether the patient requires urgent measures prior to problem-driven information acquisition. A patient with active bleeding or a decreased level of consciousness is obviously not a candidate for history-taking. Abnormal vital signs (e.g. heart rate of 220/min) may also suggest that the patient is potentially unstable. The patient's general appearance and behaviour may also reveal signs suggesting that urgent measures are required. When in doubt about the patient's stability, the physician should implement the resuscitation algorithm ABCDE (see below and Chapter 03).

Catastrophic Hemorrhage

Arterial bleeding can rapidly lead to hypovolemia, shock and brain hypoperfusion. Arterial bleeding may be rapidly and effectively managed initially by wound packing, pressure and /or application of a tourniquet proximal to a catastrophic limb injury [5, 6]. In certain circumstances, prioritizing hemorrhage control over airway assessment makes logical sense; a free airway does not help a patient who has exsanguinated. Experience from recents wars has led to the development of so-called Battlefield ATLS (BATLS) where the primary assessment is abbreviated as <C> ABC. <C> stands for 'catastrophic haemorrhage:' "The aim is to rapidly deal with life-threatening external bleeding using the field-dressing, tourniquet and topical haemostatic agents. When control of catastrophic haemorrhage has been achieved, ABC is dealt with along the conventional trauma paradigm." [7]

Cardiopulmonary Resuscitation

For patients with cardiac arrest, prompt initiation of cardiopulmonary resuscitation (CPR) is prognostically crucial. If the patient is in cardiac arrest, the initial priority is to minimize brain ischemia by attempting to reinstate some circulation. The priority is therefore to initiate CPR as opposed to carrying out the ABCDE algorithm. Patients in cardiac arrest may initially be misdiagnosed, e.g. as being post-ictal, or because the cardiac monitor reveals organized electrical activity. The steps that should be followed to recognize and manage cardiac arrest are covered in Chapter 07-Cardiac Arrest.

ABCDE

The physical examination begins the moment the physician sees the patient. The general level of consciousness, the facial expression and the skin color are some of the 'variables' that can be assessed at a single glance. Registering the behaviour of the patient is of value, especially when it comes to children. It is a reassuring sign to see a child at play or a child who is appropriately curious and aware of his or her surroundings. If the first impression suggests that the patient is unstable or potentially unstable, the next step should be to carry out the ABCDE; in contrast to the history, the ABCDE is more than an information gathering process; it is also a process whereby treatment of physiological disorders is initiated (Chapter 03). If, on the other hand, the patient looks stable, the next step is to carry out problem-driven information acquisition.

2. DATA

Under the second step, problem-driven information is acquired using minimally-invasive, fast-yield, cheap sources such as the history, the physical examination, and point-of-care investigations such as bedside blood tests, the EKG and ultrasound. Chapter 08 provides checklists for some common presenting problems.

3. DIAGNOSIS?

By the time problem-driven information-acquisition has been carried out, System-1 will inevitably have generated one or several diagnostic hypotheses. The main function of the third step in the management of the individual patient is to activate System-2 by consciously considering selected don't miss diagnoses, and estimating their likelihoods using the data acquired so far. A list of don't miss diagnoses is provided with each problem in Chapter 08 and specific clinical decision rules are provided in Chapters 08 and 09.

4. DECISIONS

During the fourth step, the physician decides upon an appropriate management plan. This step involves determining the risks-benefits of various investigational and treatment strategies, e.g. whether additional investigations are required (e.g. CT scan), whether admission is warranted, what the level of care should be, the ultimate goal being to maximize patient well-being. The variables that need to be considered are presented in Chapter 01 (Decision-Making & Utilitarianism). The Sign-Out provides a template for discussing further management with other team members.

Table 2.4: Sign-Out

1. What?	☐ What is the patient's main syndrome?
2. What?	☐ What does the patient need now in terms of investigations and treatments?
3. Where?	☐ Where can the patient get these investigations and treatments?
4. Whom?	☐ Whom should be contacted to take over responsibility for further patient care?
5. How?	☐ How is that arranged? If transfer is required, by whom, with what equipment?
6. +?	☐ Suggestions from the team

APPROACH TO ORGANIZATIONAL TASKS

Specialists in EM are faced with a plethora of tasks. Some of these tasks are simple and short (e.g. managing a patient who has twisted his ankle, interpretating an EKG). Others are complex and require the coordinated activity of several health-care personnel, such as managing a patient with severe shortness of breath, organizing the out-of-hospital management of patients involved in a multivehicle traffic accident, or redistributing health-care resources in the ED in response to a change in the volume and nature of health-care needs. Some tasks are urgent and require early measures to maximize overall utility. Other tasks can wait.

Organizational tasks may be defined as tasks requiring prioritizing between health-care needs and optimal disposition of health-care resources. Orchestrating the health-care response, in the out-of-hospital arena or in the ED, to a major incident is an extreme type is organizational task. EDs may have predetermined plans for managing major incidents where multiple critical patients present to the ED within a short time span. However, there may be situations in which the plan is not applicable or for which there is no ready-made plan (see [8] as an example). EM physicians may therefore benefit from a generic approach to tasks in EM, which can be organized according to the mnemonic **MNOP**:

Table 2.5: Generic Approach to Organizational Tasks

STEPS	NEEDS	RESOURCES
1. Measures!	☐ Consider acute measures to reduce or prevent escalation of health-care needs	☐ Consider measures that increase / prepare resources (personnel + equipment)
2. Numbers?	☐ Inventory the number and nature of health-care needs	☐ Inventory the number and nature of resources (personnel + equipment)
3. Optimize	☐ Prioritize among health-care needs	☐ Match resources to the prioritized needs taking into consideration competence
4. Plan	☐ Plan for how other needs are to be met	☐ Anticipate the need to replenish resources (personnel & equipment)

1. MEASURES!

The purpose of this step is to prevent the escalation of the number, complexity and urgency of the health-care tasks at hand through immediate measures. Securing the scene of a multivehicle accident is a top priority. As part of this step, health-care personnel should take their own safety into consideration and consider doning gloves, gown, mask or in extreme situations postponing patient management until the work environment is safe. Another aspect of this step consists in "flying ahead of the plane" by requesting additional resources when it is obvious from the outset that they will be needed. An overview of a traffic accident involving several vehicles may prompt an early request for several ambulances and the involvement of a regional health-care coordinator. News of a major incident may prompt a request for heath care personnel to postpone leaving after their shifts until the degree of the health-care needs and the amount of available health-care resources are better defined.

Examples of immediate measures that may reduce or prevent the escalation of health care needs include:

- Safety / security measures against a potential secondary explosive device
- Increasing the safety in the Emergency Department

- Reducing workload by arranging for the immediate admission of patients in the ED waiting for a bed

Examples of immediate measures that can increase or prepare available resources include:
- Activating the local major incident plan
- Informing staff
- Asking staff at end of shift to stay
- Calling in other staff if necessary
- Creating capacity by arranging for the immediate admission of patients in the ED waiting for a bed
- Calling the blood bank in anticipation of the need for 0- and 0+ blood

2. NUMBERS?

Information is necessary to make sound decisions. This step consists in an inventory of the number and nature of the health care needs, and the number and nature of the health care resources ('hardware', e.g. equipment, number of ICU beds; and 'software', i.e. personnel and competence). The information required concerning the number and nature of the health care needs and resources depends on the situation. When the numbers of patients and personnel is substantial, the inventory process may need to be delegated by implementing delegation pyramids (Chapter 01-Delegation Pyramids & Closed-Loop Communication).

In mass casualty situations, information acquisition for individual patients is limited to a few vital parameters and functions (Table 2.6). Health care personnel carrying out this inventory step need to resist the temptation of getting bogged down in direct patient care. A rapid inventory of health care needs will allow for a better allocation of health care resources that may result in a better overall patient outcome. During this inventory process, health care measures may be limited to placing the patient in the recovery position and hemorrhage control (e.g. delegating wound compression to someone nearby).

3. OPTIMIZE

The purpose of this step is to prioritize between and among health-care needs and allocate health-care resources to optimally meet these needs. The term 'triage' refers to the process of selective information-acquisition (step 2. Numbers) combined with an assignment of priority (step 3. Optimize). There are several triage systems that use different discriminating variables, usually vital signs and features of the history. If the overwhelming majority of patients receive the same priority, the chosen triage system is not appropriate. The implication is that the triage system used needs to be tailored to the patient group as a whole. In a mass casualty situation, a patient who can walk will be assigned the lowest priority (Table 2.6). In the ED on a normal day, a walking patient ought to receive the highest priority level if he or she presents with a wide complex tachycardia and a heart rate of 220 beats/min.

The triage process is thus permeated by an apparent catch-22. The amount and nature of the information required to adequately triage each task depends on the number and nature of all the tasks that need to be triaged. There is no triage system that fits all situations, since the nature of the tasks which physicians are faced with are variable and not restricted to patients. A way out of this catch-22 is to note that prioritization is a dynamic process—the condition of some patients may rapidly deteriorate following triage--and that the whole process (steps 1-4) need to be regularly reiterated. One may argue that it is neither possible nor appropriate to

'get it right' during the first pass. It is better to implement rapid measures (1. Measures!), carry out a superficial inventory of tasks and resources (2. Numbers), start prioritizing and delegating (3. Optimize), start planning for the sign-over of tasks and the turn-over of personnel and equipment (4. Plan), and then, armed with a better overview of the situation, repeat and refine the inventory, prioritization and delegation processes.

Once the tasks have been prioritized, they need to be delegated among the available health-care personnel in order to maximize utility. Task delegation should take into consideration

- The competences required by each task
- The competences of the health-care personnel and availability of health-care equipment

Table 2.6: Mass Casualty Triage According to START (Simple Triage And Rapid Treatment)

ASSESSMENTS		FINDINGS	PRIORITY
1. Ambulation	☐ Can the patient ambulate?	Yes	**Priority 3**
		No	Assess Airway
2. Airway	☐ Is the patient breathing?	No AND not breathing when airway freed	**Dead**
		No AND breathing when airway freed	**Priority 1**
		Yes	Assess Breathing
3. Breathing	☐ What is the respiratory rate?	≥ 30 breaths/min	**Priority 1**
		< 30 breaths/min	Assess Circulation
4. Circulation	☐ Radial pulse present? What is the CRT?	No radial pulse OR CRT > 2 sec	**Priority 1**
		Radial pulse present AND CRT ≤ 2 sec	Assess Disability
5. Disability	☐ Able to follow simple commands?	No	**Priority 1**
		Yes	**Priority 2**

Adapted from [9]. CRT = Capillary Refill Time

4. PLAN

This final step deals with setting up a plan for unfinished tasks (e.g. further investigations and treatments) and signing over the responsibility for these tasks to someone else. The step deals also with the replenishment of health-care resources ('hardware:' replacing used equipment; 'software:' food and drink for health care personnel, fresh personnel). Flight pilots are encouraged to "fly ahead of the plane" in order to minimize response time to potential situations [10]. Emergency physicians should likewise be "managing ahead of the situation" in order to promote work efficiency.

CHAPTER 03–ABCDE

Neurolog: "Det är hjärnan som är huvudsaken."
Woody Allen: "My brain? That's my second favourite organ."

Some patients suffer from 'poisoned arrows,' i.e. problems or syndromes where acute measures (on the order of seconds to minutes) decrease morbidity and mortality (Chapter 01 Problems & The Buddha's Poisoned Arrows). These patients benefit from an initial management algorithm that focuses on identifying and treating problems and syndromes where acute therapy can be motivated regardless of the root cause of the problem/syndrome (Chapter 02 Danger). In other words, such an algorithm should focus on problems/syndromes whereby the treatment threshold has been exceeded simply by identifying the problem/syndrome (Chapter 01 Don't Miss Diagnoses & Decision Thresholds). This chapter presents:

- a priori desirable criteria for the assessments and measures in such an algorithm
- a generic resuscitation algorithm (ABCDE)
- the problems that may be identified during the ABCDE and their differential diagnoses
- the measures that may be indicated during the ABCDE

The syndromes that may be identified during the ABCDE, with or without the contribution of bedside blood tests, a 12-lead EKG and point-of-care ultrasound, are presented in Chapter 07.

A PRIORI CRITERIA

Which assessments and therapeutic measures should be part of this resuscitation algorithm? A case can be made that the assessments and therapeutic measures in a generic resuscitation algorithm should satisfy five a priori criteria.

1-Poisoned Arrow
The assessments in the resuscitation algorithm should detect poisoned arrows, i.e. problems or syndromes where acute therapy decreases morbidity and mortality. The therapeutic measures in the resuscitation algorithm should decrease the morbidity and mortality of patients suffering from poisoned arrows. Assessments and therapeutic measures that are not linked to poisoned arrows delay the acute assessments and therapeutic measures that lead to an improved prognosis.

2-Universality
The assessments and therapeutic measures should be of applicable to all patients and yield reliable results under a wide variety of circumstances. A single algorithm, as opposed to several distinct algorithms, facilitates recall and implementation under stressful circumstances. A single algorithm facilitates teamwork for the same reasons. The logic behind separate algorithms for ‘traumatic’ vs ‘atraumatic’ circumstances is tenuous. Trauma patients may suffer from hypoglycemia while a patient with sepsis may develop a tension pneumothorax as a complication of central line placement [1]. Assessing critically ill patients differently from the outset predisposes to premature closure (Chapter 01 System-1 & System-2).

3-Availability
The equipment required to carry out the assessments and therapeutic measures should be available in a standard emergency room, ward or ambulance. In addition, the majority of

health-care personnel should have the competence required to carry out the assessments and therapeutic measures. There is limited value in having a resuscitation algorithm that cannot be carried out because the required equipment (e.g. ultrasound) is only found in selected environments or because the competence required is only mastered by a select few. The management of potentially critical patients is often carried out by a multidisciplinary team; restricting the assessments and therapeutic measures to those that most health-care personnel can carry out allows for flexibility and improved team-efficiency.

4-Expediency
The assessments and therapeutic measures should be performable and yield results within minutes. Assessments and therapeutic measures that take a long time to perform or a long time to yield results impede the identification and management of other poisoned arrows.

5-Value-Addedness
The assessments should yield information over and beyond that conveyed by other assessments. The therapeutic measures should yield results over and beyond those produced by other interventions and not create new problems or impede the effect of other measures.

Determining whether and to what degree assessments and therapeutic measures fulfil these five criteria is not straightforward. Two physicians may reasonably disagree about whether specific assessements and measures meet the criteria sufficiently to be part of a generic resuscitation algorithm. However, if the a priori criteria are agreed upon, the content of the algorithm is not arbitrary.

Organisation
In which order should the assessments and associated measures be carried out? The initial assessments of critical patients taught by courses such as ATLS®, APLS® and PHTLS® are organized according to the **ABCDE sequence** whereby:

A stands for Airway & cervical spine
B stands for Breathing
C stands for Circulation
D stands for Disability
E stands for Exposure

The top priority of the resuscitation algorithm is to preserve or improve oxygen delivery to the brain. Oxygen delivery to the brain is contingent upon a free upper airway (A), adequate ventilation (B) and adequate perfusion (C). The rational behind the ABC sequence is that removing certain poisoned arrows is ineffective unless other arrows have previously been removed. As an example, deliverying supplemental oxygen to the hypoxic patient is ineffective if the patient does not have a free airway. The sequence of the resuscitation algorithm should also take pratical considerations into account. Applying a leg splint for a fractured femur reduces bleeding and may therefore be considered a C measure, but a sensory and motor examination of the limb distal to the fracture--a D or E measure--should be carried out prior to fracture reduction. In addition, systemic pain relief should be considered prior to fracture reduction. It makes therefore sense to carry out leg splinting under E.

During the ABCDE, information is acquired that allows for the recognition of problems that should be managed directly. The information acquired, augmented by bedside blood tests, the electrocardiogram and the ultrasound when available, also allows for the identification of

syndromes (e.g. anaphylaxis, foreign body aspiration, tension pneumothorax) that should also be managed as soon as they are recognized. These syndromes, referred to as 'Resuscitation syndromes', are covered in Chapter 07, while the rest of this chapter focuses on the identification, interpretation and immediate management of problems identified during the ABCDE.

The resuscitation algorithm is usually carried out by a team of health-care professionals. It is often optimal to engage some team members in B or C assessments / measures from the start, such as establishing intravenous access, as long as this does not impede the assessment and management of A and the completion of the algorithm. When resuscitation syndromes are identified, team members may be assigned the task of carrying out specific assessments and measures while the ABCDE is being completed concurrently.

The clinical course of critically ill patients is often dynamic. Reevaluations are essential. In particular, the effect of therapeutic measures should be evaluated after a suitable time period (immediately in the case of an airway measure, after several minutes in the case of a fluid bolus). Patients who remain potentially unstable after the ABCDE should undergo continuous monitoring of vital signs.

GENERIC ABCDE

ASSESSMENTS	MEASURES TO CONSIDER

1. Airway & C-Spine

☐ **Head and neck inspection** ☐ **Airway sounds // Capnometry*** ☐ **Oral cavity inspection // ET tube inspection***	☐ **Manual stabilisation of the cervical spine?** ☐ **Airway opening measures, Adrenalin 1 mg Neb?** ☐ **Lateral decubitus, suction, MaGill forceps?**

* If the patient is already intubated

2. Breathing

☐ **SpO2** ☐ **Respiratory rate** ☐ **Chest wall examination** ☐ **Lung auscultation**	☐ **Supplemental oxygen?** ☐ **Mask ventilation?** ☐ **Ventilate (low tidal volume)? Seal (open chest)?** ☐ **Salbutamol 5 mg Neb (< 5 years 2.5 mg)?**

3. Circulation

☐ **Pulse, blood pressure, CRT** ☐ **Heart rate** ☐ **3-lead-EKG (regularity, QRS width)**	☐ **Hemostasis? IV/IO access?** ☐ **Crystalloid 500 ml bolus (10 ml/kg)?** ☐ **Atropine 0.5 mg IV, external pacing?**

4. Disability

☐ **Level of consciousness** ☐ **Eyes (opening, gaze, pupil size & reactivity)** ☐ **Distal sensation & strength** ☐ **Glucose level**	☐ **Glucose 300 mg/ml 30 ml (100 mg/ml 2 ml/kg)?** ☐ **Benzodiazepine?**

5. Exposure

☐ **Front of the body examination** ☐ **Back of the body examination** ☐ **Temperature**	☐ **Stabilisation measures: pelvis, limbs?** ☐ **Log-roll, stabilisation of the spine?** ☐ **Treat hypo- hyperthermia? Prevent hypothermia?**

Normal Vital Signs

Age (years)	Respiratory Rate (breaths/min)	Heart Rate (beats/min)	Systolic Blood Pressure (mm Hg)	Temperature (oral, ° C)
Fetus		120-160 [2]		
0	35-60 [3]	110-150 [3]	> 65 [4]	
1	30-50 [3]	110-150 [3]	> 70 [4]	37.6 [5]
2	25-40 [3]	100-140 [3]	> 75 [4]	
6	20-30 [3]	80-130 [3]	> 80 [4]	37 [5]
Adult	12-24 [6]	50-90 [7]	90 - 140 [6]	36.4 - 37.6 [6]
Pregnancy	12-24 [6]	+ 10-20 [8]	- 10-15 (T2)[1] [8]	"Increased" [6]
> 60-70	12-24 [6]	67-80 [5]	> 110[2]	36 [5]

1-T2 stands for second trimester. Blood pressure during pregnancy reaches a nadir during the second trimester and then normalizes during the rest of pregnancy [9]

2-Given the prevalence of hypertension in the elderly, a systolic blood pressure of < 110 mm Hg should be regarded with suspicion.

1. AIRWAY & C-SPINE

Within the context of the ABCDE, A refers to the upper airway, from the nose and pharynx to the carina. The focus is on confirming or establishing patency of this portion of the respiratory tract. There is no watertight distinction between A and B (Breathing), since the ability to ventilate ultimately confirms a patent airway. The cervical spine (C-spine) is assessed and managed during A for the following reasons:

- inspection of the head and neck is part of the assessment of both the upper airway and the C-spine.
- the choice of basic airway maneuvers depends on whether the C-spine may be injured.

Head and Neck Inspection

Inspection of the head and neck may reveal the following:

- **Trauma** (bruising, bleeding) to the head or neck may indicate injury to the C-spine.
- **Trauma** and **swelling** of the neck may indicate a threat to the airway, e.g. secondary to a larynx fracture.
- **Soot** around the mouth and nostrils, **facial burns** and **singed nasal hair** suggests smoke inhalation injury [10] and the risk for acute upper airway obstruction due to pharyngeal and supraglottic edema.
- **Venous stasis** may suggest tension pneumothorax, cardiac tamponade, right ventricular dysfunction, massive pulmonary embolism.
- **Tracheal tugg**, i.e. supraclavicular recession on inspiration, suggests an upper airway obstruction.

Inspection of the head and neck is hindered by the presence of a cervical collar and sandbags. When the patient arrives in the ED fully immobilized on a spineboard with sandbags and body straps, the sandbags should be removed first and the head subsequently immobilized manually before the body straps are removed. The rational behind this sequence is to avoid a situation where the head alone is fixated to the spine board and urgent log-rolling is required because of vomiting. The cervical collar provides limited stabilization of the C-spine [11] and impairs airway management, and once manual immobilization is established, the collar may be opened to allow for adequate inspection of the neck.

Manual Stabilisation of the C-Spine

If the inspection of the head and neck reveals signs of trauma or if the mechanism of injury is associated with an increased risk of spinal injury, the C-spine should be stabilised until it can be further assessed clinically or radiographically (Chapter 08 Trauma to the Head or Neck). Information regarding the mechanism of injury may be supplied by bystanders, the out-of-hospital team or by inspecting the trauma scene. According to the Canadian C-spine Rule [12], the following mechanisms of injury warrant radiography (and hence stabilization until then):

- Fall from an elevation of ≥ 1 meter or 5 stairs
- Axial load to the head (e.g. diving accident)
- Motor vehicle collision at high speed (> 100 km/h) or with rollover or ejection
- A collision involving a motorized recreational vehicle
- A bicycle collision

The speed at which a collision occurred is often not known with certainty, and the probability of injury depends on the characteristics of the vehicles involved. Less dramatic mechanisms

of injury may result in fractures in susceptible patients, such as the elderly or patients with ankylosing spondylitis. It is justifiable to have a low threshold for C-spine stabilization during A until further information is available.

The most immediate way of stabilising the C-spine is **manually**. The goal is to immobilise the C-spine relative to the thorax. If the patient is supine, the health-care personnel holds the patient's head, preferably without covering the patient's ears. Anticipating vomiting and the need for log-rolling the patient may improve response time. If the patient is standing, the hands of the health-care personnel are placed on either side of the patient's head while the health-care personnel's forearms are placed against the patient's upper chest. As a rule, the head is immobilized in a neutral position but the head may be immobilized in another position if the patient is actively resisting moving the head.

There are a number of reasons for not placing a **cervical collar** immediately on the patient:

- A cervical collar impedes the assessment and management of the airway by reducing mouth opening and actually results in increased upper cervical spine motion upon mouth opening [13].
- A cervical collar hinders a proper inspection of the anterior and posterior aspects of the neck.
- A cervical collar does not afford, alone, sufficient stabilization of an injured cervical spine [11] and thus does not obviate the need for manual immobilisation until the whole spine is immobilized.
- Immobilizing the C-spine of an agitated patient may result in added torque to a damaged spine and more harm than good [4]. In this case, manual immobilization alone is preferable.

Airway Sounds

The term 'airway sounds' refers here to the sounds coming from the patient's mouth and nose.

- If the patient **can speak** (of if the child can cry), the airway is free.
- **Snoring** sounds in the unconscious supine patient suggest an obstructed upper airway due to loss of muscle tonus.
- **Stridor** is a musical, high-pitched sound that results from turbulent, high velocity air flow through a narrow segment of the upper respiratory tract (laryngeal level or above). As a rule, the obstruction is extrathoracic when stridor is heard on inspiration, intrathoracic when stridor is heard on expiration, and associated with a fixed lesions when biphasic [14].
  Causes of stridor include:
  - foreign body aspiration
  - swelling of the airway, e.g. anaphylaxis, angioedema, croup syndromes, epiglottitis, bacterial tracheitis, upper airway edema from a thermal injury, retropharyngeal or peritonsillar abscess
  - vocal cord dysfunction
  - compression of the airway, e.g. from tracheal carcinoma, thyroiditis, mediastinitis
- **Gurgling** sounds suggest that the upper aiway is partially obstructed by liquid, e.g. blood or emesis.
- **Grunting**, an end-expiratory sound in children, is a sign of advanced respiratory failure and is caused by the child's attempt to increase end-expiratory pressure in the lower airway.

Airway Measures

The airway can be opened using mechanical measures and/or pharmacological measures (Adrenalin, see below). Mechanical measures can be carried out in the following sequence, from least to most invasive and complex, until the airway is opened:
1-[Head-tilt/chin-lift or jaw thrust] and/or [oral pharyngeal airway or nasal pharyngeal airway].
2-Extraglottic device (e.g. laryngeal mask airway)
3-Endotracheal intubation
4-Surgical or needle cricothyrotomy

Head-tilt/chin-lift: an obstructed airway due to loss of muscle tonus is initially managed by moving the patient's jaw anteriorly. In the absence of potential C-spine injury and when the patient is > 1 year old, the head-tilt / chin-lift maneuver may be used. One hand is placed on the patient's forehead and used to extend the neck, while the fingers of the other hand are placed under the patient's chin and used to move the jaw anteriorly.

Jaw-thrust: when C-spine injury is possible and when the patient is an infant (< 1 year old), the head should be maintained in neutral position and the jaw moved anteriorly using the jaw-thrust maneuver. The index and middle fingers of both hands are placed under the angles of the jaw and used to move the jaw anteriorly, while the rest of the hands are used to maintain the head in neutral position. Applying counter-pressure on the maxilla with the thumbs allows for better spinal immobilization while the mandibel is thrust anteriorly.

Flexing the lower cervical spine and extending the upper cervical spine places the head in the so-called **sniffing position.** Some sources suggest that the most effective airway maneuver consists in positioning the neck in the sniffing position and moving the jaw anteriorly ('jaw thrust'), a combination referred to as the **triple airway maneuver** [15].

An **oral pharyngeal airway** can be used in unconscious patients. It is contraindicated in patients who are not unconscious since it may induce vomiting and aspiration. A **nasal pharyngeal airway** may be used in patients who are not unconscious. According to classic teaching, the nasal pharyngeal airway is contraindicated in patients with basal skull fractures, but the risk of intracranial placement may be overdriven [16]. **Suctioning the nares** may alleviate respiratory distress in infants and newborns who are obligate nasal breathers [4].

If basic airway measures and adrenalin are insuffiency to establish a patent airway, advanced airway measures are required. These measures required equipment that is not ubiquitous in health care settings and competence that not all health care professionals master.

Extraglottic airway (EGA) devices (e.g. laryngeal mask airway, laryngeal tube, i-gel, King LT) are blindly placed above or posterior to the larynx. They may allow for emergency, temporary rescue ventilation in situations where patients cannot be ventilated with a face mask [15]. One source reported insertion of laryngeal mask airways in < 30 seconds and effective ventilation in > 98% of patients [17]. EGA do not protect against aspiration of gastric contents. Use of an intubating laryngeal mask airway (ILMA) allows for subsequent intubation.

Endotracheal intubation should be attempted if the above measures are insufficient to establish a patent airway and ventilate the patient. Endotracheal intubation can, for example, push a foreign body in the upper airway into one bronchi and allow for ventilation of the other

lung. Endotracheal intubation is the gold-standard procedure for *securing* the airway. However, endotracheal intubation is not a benign procedure:

- Unrecognized misplaced tracheal tube is obviously harmful to the patient.
- Intubation will narrow the lumen through which ventilation occurs and thereby increase resistance; in certain circumstances, endotracheal intubation can be hinder adequate ventilation (e.g. [18]).
- Securing the airway by inserting an endotracheal tube requires the administration of intravenous medications if the patient is not in cardiac arrest. The appropriate choice of medications depends upon the patient's hemodynamic status. In one series, emergency endotracheal intubation in the ED lead to cardiac arrest in 1.7% of cases; a systolic blood pressure < 90 mm Hg was associated with cardiac arrest and the authors suggest that patients with hypotension ought to be preload optimized prior to intubation [19].
- Medications that paralyse the patient may mask a symptomatic spinal cord lesion that can be identified during D.

There are thus logical and logistical reasons for postponing the endotracheal intubation of patients who are not in cardiac arrest until after the ABCDE has been completed. Even in patients with cardiac arrest, endotracheal intubation has no proven benefit [20]. It may be obvious from the outset that endotracheal intubation will be warranted after the completion of the ABCDE, and personnel may start preparing the equipment for intubation while the ABCDE is being carried out. Endotracheal intubation is warranted under A when it is required not simply to *secure* the airway but rather to *open* it (Chapter 07-Foreign Body Aspiration).

Cricothyrotomy: surgical cricothyrotomy is a measure of last resort in the "can't ventilation / can't intubation" situation in which all above measures have failed. Needle cricothyrotomy may allow for percutaneous translaryngeal ventilation of patients < 5 years or jet ventilation of patients > 5 years as a bridge to a surgical airway [21].

Adrenalin

Nebulized adrenalin may reduce some of the upper airway edema resulting from an allergic reaction, inhalation injury or infection. APLS® recommends nebulized adrenalin for children with anaphylaxis and a compromised upper airway and for children with croup [4]. There is no evidence that epinephrine benefits patients with epiglottitis, but neither is there evidence that inhaled epinephrine harms these patients. One can thus motivate administering nebulized adrenalin to all patients with stridor of uncertain etiology. A reasonable starting dose for adults is Adrenalin 1 mg/ml 1 ml Neb diluted with normal saline. The dose for children according to APLS® is Adrenalin 0.4 mg/kg Neb up to a maximum dose of 5 mg [4].

Intramuscular adrenalin may be administered in the setting of stridor if anaphylaxis is suspected. The dose is Adrenalin 1 mg/ml 0.5 ml IM (10 ug/kg for children) in the midlateral thigh (Chapter 07-Anaphylaxis).

Oral Cavity Inspection

Inspecting the oral cavity may be of diagnostic and therapeutic value. On the other hand, routinely examining the throat with a spatula is of dubious value and it may precipitate total airway obstruction in a patient with epiglottitis [4].

- The inspection may reveal **fluid**, e.g. blood or vomit, or **solid bodies** such as chewing gum, loose teeth.

- A **swollen tongue** suggests an allergic reaction or angioedema.
- A **lateral tongue bite** in a patient with temporary loss of consciousness strongly suggests seizure [22] whereas a **bite at the tip** of the tongue suggests syncope [23].
- **Soot** in the mouth and **carbonaceous sputum** suggest smoke inhalation injury [10]. The presence of **oropharyngeal blisters** resulting from smoke inhalation is an indication for endotracheal intubation to prevent acute airway obstruction from pharyngeal and supraglottic edema.
- **Drooling** suggests the inability to swallow saliva due to pharyngeal obstruction from a retropharyngeal abscess or epiglottitis.
- **Frothing**, sometimes blood-tinged, may be present in severe pulmonary edema.
- **Mucosal bleeding** suggests a thrombocyte disorder [24].

Suction, Lateral Decubitus, MaGill Forceps

- Fluid, e.g. blood or vomit, should be removed to prevent an aspiration pneumonia. Small amounts of fluid can be **suctioned** to prevent an aspiration pneumonia.
- Placing the patient in the **lateral decubitus** (log-rolling the patient with potential spinal pathology) is preferable when large amounts of fluid are present in the oral cavity. If the patient is immobilized on a spine board, the entire board can be tipped to one side. Placing the patient in the **Trendelenburg** position may also prevent aspiration until the fluid is removed.
- **MaGill forceps** can be used to remove solid bodies from the oropharynx (e.g. chewing gum, loose teeth). False teeth should be left in place initially to facilitate bag-valve-mask ventilation. False teeth are removed prior to endotracheal intubation.

Intubated Patient

Certain patients are brought the ED already intubated. It is imperative to ensure, under A, that the endotracheal tube is in the trachea and that it is patent. Endotracheal tubes can be misplaced from the start or become disloged during transportation, especially with the uncuffed tubes used in children. Unrecognized misplaced intubation may have rates as high a 10% [25]. Endotracheal tubes may also become clogged with secretions.

Capnometry is a highly reliable method to distinguish between tracheal versus esophageal intubation in patients with spontaneous circulation [26]. A qualitative assessment of end-tidal CO2 can be carried out using disposable, colorimetric CO2 detectors [26]. Most EDs and an increasing number of ambulances are equipped with end-tidal CO2 detectors and an assessment of end-tidal CO2 replaces the assessment of airway sounds in the intubated patient when the equipment is available. When in doubt, the tube should be removed and the patient reintubated while or after the ABCDE is carried out.

Tube depth at the level of the front teeth should be noted. A normal intubation's depth for an orotracheal tube is [27]:

- 22 cm for an average-sized adult
- (age in years/2) + 12 cm for children

A patient who is already intubated may have blood or vomit in the endotracheal tube requiring **suction**.

2. BREATHING

Within the context of the ABCDE, B refers to ventilation, i.e. the process by which oxygen is delivered to the blood and carbon dioxide removed from it. Anatomically, B deals with the airway from the carina to the alveoli, the lung parenchyma, the pleural space, the chest wall (ribs, intercostal and accessory respiratory muscles), the diaphragm, the parts of the nervous system that innervate the respiratory muscles and the respiratory center in the brain.

SpO2

Pulse oximeters have become ubiquitous in health-care and can rapidly measure heart rate and SpO2. The peripheral probes of pulse oximeters emit light at different frequencies and measure tissue absorption during the arterial phase to calculate the relative quantities of oxyhemoglobin and deoxyhemoglobin.

- **SpO2** is the percent saturation of oxygen bound to hemoglobin in arterial blood as measured by a pulse oximeter [28].
- **SaO2** is the percent saturation of oxygen bound to hemoglobin in arterial blood [28].
- **PaO2** is the partial pressure of oxygen in the arterial blood [28].
- **Hypoxemia** refers to low PaO2.
- **Hypoxia** refers to oxygen deficiency at the tissue level; hypoxia may result from low SaO2 but also from anemia, non-functional hemoglobin and poor perfusion.

In summary, the SpO2 is an indirect measure of the percentage of oxyhemoglobin in arterial blood (SaO2), and a low SaO2 is an important cause of hypoxia.

Differential Diagnosis of Low SpO2

Pathophysiology	Examples
Low FiO2	• Low fraction (or percentage) of oxygen in the inspired air (FiO2) may result from high altitute, diving, use of inhaled anesthetics
Decreased Minute Ventilation	• Central nervous system causes, e.g. stroke, intoxications • Peripheral nervous system causes, e.g. neuropathies, neuromuscular junction causes • Chest wall causes (muscular, skeletal, pleural causes) • Airway causes (upper airway, lower airway)
Ventilation / Perfusion Mismatch	• Pneumonia • Pulmonary embolism • Emphysema • Asthma • Pulmonary fibrosis
Diffusion Impairment	• Interstitial fibrosis
Right-to-Left Shunt	• Intra-cardiac shunt (e.g. right-to-left shunt throught a patent foramen ovale after a massive pulmonary embolism, cyanotic congenital heart disease) • Intra-pulmonary shunts • Arteriovenous fistulae (pulmonary, cerebral, hepatic, peripheral)
Falsely Low [28]	• Poorly placed pulse oximeter or pulse oximeter of wrong size • Low perfusion: peripheral vasoconstriction (e.g. secondary to hypothermia or vasoconstricting drugs), hypotension, concurrent blood pressure measurement • Certain nail polishes

	• Intravenous dyes (e.g. methylene blue, fluorescein) [29] • Increased venous pulsations (e.g. tricuspid regurgitation) [29] • Methemoglobinemia at low levels (< 10%) [29]

The SpO2 may suggest a **falsely high** SaO2 in the following settings:

- **Mechanical / environmental** causes: poorly placed probe or probe of the wrong size [28], high-intensity ambient light, motion artifacts [29]
- **Carbon monoxide poisoning**; carboxyhemoglobin (hemoglobin bound to carbon monoxide) has similar light absorption at 660 nm to oxyhemoglobin [28] (BG 36 yo)
- **Methemoglobinemia**; methemoglobin (hemoglobin containing the ferric iron Fe^{3+} as opposed to the oxygen-carrying ferrous ion Fe^{2+}) at high levels (> 30%) results in a SpO2 of 85% regardless of the actual SaO2 [29, 30] (BG 20 yo)

In addition, it is worth emphasizing that adequate SpO2 on high-flow oxygen may lull physicians into a **false sense of security**. SpO2 on high-flow oxygen may be normal despite hypoventilation, a rising respiratory acidosis and the development of carbon dioxide narcosis [31].

Supplemental Oxygen

The administration of **high flow supplemental oxygen** during the initial assessment of potentially critical patients can be motivated, even for patients with a normal SpO2, in order to replace the nitrogen reservoir in the functional residual capacity of the lung with oxygen. Should the patient suddenly develop an A or B problem, the reservoir prolongs the interval between deterioration and hypoxia. Once the ABCDE has been completed and the patient has been assessed, the need for further oxygen therapy needs to be reexamined. Prolonged high-flow supplemental oxygen may be detrimental in certain circumstances, e.g. leading to CO2 narcosis in COPD patients or increasing ischemia in the setting of an acute coronary syndrome [32]. If acute respiratory collapse is deamed unlikely, it is reasonable to titrate supplemental oxygen to maintain an SpO2 ≥ 90%.

FiO2 stands for the fraction (or percentage) of oxygen in the inspired air. The FiO2 of room air is 21%.

- Nasal prongs with an oxygen flow rate of 2-6 L/min deliver an FiO2 of 35-40% (Wikipedia).
- Simple face masks with an oxygen flow rate of 5-8 L/min deliver an FiO2 of 30-50% (Wikipedia).
- Non-rebreather masks with an attached reservoir with an oxygen flow rate of 8-10 L/min deliver an FiO2 approaching 100% when properly fitted (Wikipedia).
- The FiO2 can be roughly estimated with the formula FiO2% = 20 + (5 x oxygen flow in L/min) [33].

High-flow nasal canual oxygen therapy may decrease the need for escalation of therapy and intubation compared with conventional oxygen therapy in patients with acute respiratory failure needing therapy for ≥ 24 hours [34].

Respiratory Rate & Breathing Patterns

The respiratory rate of a patient can be assessed by counting the number of breaths taken over 15 seconds and multiplying by four. Placing a hand on the patient's chest facilitates the assessment. If the patient's respiratory rate is irregular (e.g. a patient with Cheyne-Stokes respiration), the assessment should be carried out over one minute. Changes in respiratory rate may be more revealing than absolute values. For example, an increasing rate in a trauma patient or a decreasing rate in a child with bronchiolitis may herald decompensation.

- **Tachypnea** refers to a respiratory rate greater than normal whereas **bradypnea** refers to a respiratory rate lesser than normal.
- **Tidal volume** refers to the amount of air inspired with each breath.
- **Minute volume**, the amount of air that moves in and out of the patient's lungs during one minute, is the product of the tidal volume and the respiratory rate. A normal minute volume is 7-10 L/min [35].
- **Hyperpnea** refers to greater than normal minute ventilation required to meet metabolic requirements, whereas **hyperventilation** refers to minute ventilation in excess of that required to meet metabolic requirements [36].
- **Hypoventilation** refers to decreased minute ventilation unable to meet metabolic requirements.

Differential Diagnosis of Increased Minute Ventilation (Tachypnea and/or Increased Tidal Volumes)

Pathophysiology	Examples

Hypoxia-Driven	• Intrinsic lung disease and/or ventilation-perfusion mismatch, e.g.
	  ○ pulmonary edema
	  ○ pneumonia
	  ○ pulmonary embolism
	  ○ aspiration
	• Severe anemia

Non Hypoxia-Driven	• Pain • Anxiety • Medications: salicylates, methylxanthines (theophyllamine, koffein), nicotine • Pregnancy (progesterone) • Gram-negative sepsis • Hepatic encephalopathy • Brainstem pathology
Metabolic Acidosis	Tachypnea and/or increased tidal volumes as manifestation of a respiratory compensation to a metabolic acidosis, e.g. diabetic ketoacidosis (Chapter 04)

Differential Diagnosis of Decreased Minute Ventilation (Bradypnea and/or Decreased Tidal Volumes)

Anatomy	Examples
Central Nervous System	• Vascular problems, e.g. stroke, hemorrhage • Infectious conditions, e.g. encephalitis, transverse myelitis • Primary tumors or metastases • Degenerative conditions, e.g. amyotrophic lateral sclerosis

	• Drugs, e.g. opioids, alcohol, benzodiazepines, barbiturates • Trauma to the brain or spinal cord • Metabolic encephalopathies, e.g. hepatic encephalopathy
Peripheral Nervous System	• Nerve dysfunction, e.g. phrenic nerve paralysis, Guillain Barré syndrome • Neuromuscular junction conditions, e.g. myasthenia gravis, botulism
Chest Wall	• Muscular conditions, e.g. myopathies, muscular dystrophy, fatigue • Skeletal: kyphoscoliosis, ankylosing spondylitis • Pleura: pneumothorax, hemothorax
Airway	• Upper airway obstruction, e.g. angioedema • Lower airway obstruction, e.g. COPD*, life-threatening asthma

* COPD: Chronic Obstructive Pulmonary Disorder

Several **abnormal breathing patterns** have been described [37]:

- **Cheyne-Stokes** breathing refers to a breathing pattern with a waxing and waning respiratory rate followed by apnea or hypopnea. The cycle lasts usually less than one minute. The pattern persists in sleep. Cheyne-Stokes breathing is found in patients with heart failure, toxic metabolic encaphalopathies and CNS pathology such as stroke, traumatic brain injuries and brain tumors.
- **Cluster** breathing (**Biot's** respirations) consists of irregular clusters of breaths followed by apneic periods of variable duration. Cluster breathing suggests bihemispheric or pontine pathology.
- **Ataxic** breathing consists of irregular respiratory rate, rhythm; amplitudes interrupted by apnea. Ataxic breathing suggests nonlocalizing or dorsomedial medulla pathology.
- **Apneustic** breathing consists of prolonged inspiration with a 2-3 second pause, then expiration. Apneustic breathing suggests pathology in the lateral tegmentum of the lower pons.
- **Central neurogenic hyperventilation** consists in sustained hyperventilation, respiratory rates exceeding 40/min. It suggests bihemispheric, pons, or midbrain pathology.

Chest Wall Examination

Inspection of the chest wall, with the addition of palpation and percussion as needed, convey information regarding:

- tidal volume
- the effort and efficacy of breathing
- the presence of trauma to the chest wall
- the presence of pneumothorax or pleural fluid

Kussmaul breathing refers to breathing pattern characterized by large tidal volumes and a normal or reduced breathing rate that occurs in the setting of severe metabolic acidosis, e.g. diabetic ketoacidosis but even severe metabolic acidoses caused by intoxications or renal failure.

Paradoxical breathing refers to indrawing of the chest wall upon inspiration.

- Paradoxical breathing may occur in the setting of a cervical spinal cord injury resulting in the absence of intercostal muscle activity.

- Indrawing of the lower ribs may occur in patients with COPD due to contractions of a depressed and flattened diaphragm (Hoover's sign).

Chest wall recessions (intracostal, subcostal, sternal, suprasternal) are mainly found in children due to increased chest wall compliance. The presence of chest wall recessions indicate that the patient is generating increased intrathoracic negative pressures during inspiration and suggests airway obstruction resulting from:
- Upper airway obstruction, e.g. due to a foreign body
- Lower airway obstruction, e.g. due to severe asthma or bronchiolitis

The pronounced use of accessory respiratory muscles also suggests an increased effort of breathing.

Asymmetrical chest wall movements may result from:
- Tension pneumothorax
- Unilateral diaphragmatic pathology (phrenic nerve damage, rupture)
- In the presence of three or more adjacent ribs each fractured in two places, a section of the chest wall may be 'sucked inward' during inspiration as opposed to expanding outward. This condition is known as **flail chest** and leads to decreased tidal volume. The acute management is noninvasive positive airway pressure ventilation with bag-valve-mask [38].

Penetrating trauma to the chest wall increases the likelihood for
- Pneumothorax; the percussion tone is typically hyperresonant
- Hemothorax; the percussion tone is typically dull
- Cardiac tamponade
- Liver damage if the penetrating trauma affects the right lower thorax
- Splenic damage if the penetrating trauma affects the left lower thorax
- Kidney damage if the penetrating trauma affects the lower posterior thorax

Open chest or **open pneumothorax** refers to the entry of air into the thorax through a wound in the chest wall. An open chest wound may create a 'sucking' sound upon inspiration. The Tactical Combat Casualty Care guidelines recommend applying a vented chest seal to prevent the development of tension pneumothorax during initial care[39]. An improvised vented chest seal consists of a patch closed on three sides.

Mask Ventilation

Mask ventilation is indicated when the patient is suffering from low SpO2 combined with decreased minute ventilation, i.e. low respiratory rate or decreased tidal volume. There is a variable lag time between the onset of hypoventilation and a decrease in SpO2, justifying mask ventilation in the setting of rapidly decreasing minute ventilation to maintain SpO2.

Mask ventilation may be carried out by one or two health-care personnel using a **bag-valve-mask** contraption. Alternatively, mask ventilation may be carried out using a **pocket-mask**. The goal is to provide tidal volumes that result in normal chest excursions and avoid abrupt insufflations that increase the risk of gastric insufflation and subsequent emesis. The target respiratory frequency depends on the situation; in the setting of diabetic ketoacidosis, hyperventilation may be desirable. Ventilations can be timed to coincide with the patient's spontaneous breaths to increase the tidal volume and delivered between the patient's spontanous breaths to increase the respiratory rate.

Pulmonary Auscultation

Normal lung sounds are soft, nonmusical, and heard only on inspiration and on early expiration [14]. When the patient is supine, pulmonary auscultation may be carried out by listening bilaterally to:

- the anteroapical aspect of the chest, under which air from a pneumothorax accumulates
- the posterolateral chest wall where pleura fluid accumulates

If the patient can sit upright, listening bilaterally to the posterior chest wall provides often better information than listening over the anterior or lateral chest wall.

Differential Diagnosis of Decreased Breath Sounds on Pulmonary Auscultation Adapted from[14]

Pathophysiology	Examples
Decreased Air Entry	• Poor inspiratory effort, e.g. secondary to intoxication, diaphragmatic paralysis • Airway obstruction, e.g. foreign body, severe asthma (so called 'silent chest') • Disruption of the mechanical properties of the lung parenchyma, e.g. emphysema • Bronchial or esophageal intubation
Decreased Sound Transmission	• Pneumothorax • Pleural effusion • Extrapulmonary conditions, e.g. obesity, kyphoscoliosis, ascites

Bronchial breathing refers to soft, nonmusical breath sounds, heard on both inspiration and expiration. They indicate a patent airway surrounded by consolidated lung tissue (e.g. pneumonia) or fibrosis [14].

Wheeze refers to a musical, high-pitched sound heard on inspiration, expiration or both [14]. It suggests airway narrowing and airflow limiting in the branches between the second and seventh generations of the airway tree, due e.g to:

- asthma exacerbation
- exacerbation of chronic obstructive pulmonary disease
- bronchiolitis, which typically occurs in 1-9 month olds during the annual winter epidemic
- foreign body, mucous plug or tumor in the lower airway, which result in unilateral, localized wheezing
- pulmonary edema (so-called 'cardiac asthma') [40]
- pulmonary embolism and pneumonia [41]

Crackles are short, explosive, nonmusical sounds.

- **Fine crackles** are heard on mid-to-late inspiration over dependent lung regions. They resemble the sound heard when joined strips of Velcro are gently separated. They are likely due to the sudden inspiratory opening of small airways held closed by surface forces during the previous expiration [14]. They are associated with various diseases such as interstitial lung fibrosis, congestive heart failure, pneumonia [14].
- **Coarse crackles** are heard on early inspiration and throughout expiration. They are transmitted to the mouth and clear or change with coughing. They are likely due to boluses

of gas passing through airways as they open and close intermittently [14]. Coarse crackles are associated with COPD, bronchiectasis, asthma, pneumonia and congestive heart failure.

Ronchus refers to a musical, low-pitched sound, similar to snoring, heard on inspiration, expiration or both. It is associated with rupture of fluid films and abnormal airway collapsibility. It often clears, with coughing, suggesting a role for secretions in larger airways, and is nonspecific [14].

3. CIRCULATION

Within the context of the ABCDE, C (Circulation) refers to:
- perfusion, the means by which oxygen is delivered to the vital organs
- cardiac function (rate and rhythm)

When perfusion is compromised, cells switch from aerobic to anaerobic metabolism, and shock ensues if perfusion is not re-established. There is no simple, reliable way to determine whether perfusion is adequate. Peripheral pulses may be present and blood pressure and heart rate may be normal in the face of established shock [42]. Blood pressure is a poor measure of actual tissue perfusion (ATLS 9th ed). Clinically, shock is a syndrome which can be identified by taking into consideration all the information acquired during the ABCDE, in conjunction with bedside blood tests (Chapter 07 Shock).

Hemostasis

Bleeding from a limb injury can be stopped or mitigated by [43]:
- Elevating the wounded limb
- Direct pressure over the wound, e.g. using a pressure dressing
- Applying a tourniquet (or blood pressure cuff)

Pulse

Feeling for a pulse allows for a rapid estimation of the blood pressure. A small observational study assessed the presence of the radial, femoral and carotid pulse in 20 sequential patients with hypovolemic shock (age 18-79 years) in whom invasive arterial blood pressure monitoring had been established [44]:
- the radial pulse always disappeared before the femoral pulse, which always disappeared before the carotid pulse.
- all but one patient with a **radial** pulse had a systolic blood pressure ≥ 65 mm Hg
- all but one patient with a **femoral** pulse but no radial pulse had a blood pressure between 60 and 80 mm Hg
- all patients (n = 4) with a palpable **carotid** pulse but no femoral pulse had a blood pressure < 60 mm Hg

Pulsus paradoxus refers to a decrease in the systolic blood pressure exceeding 10 mm Hg upon inspiration. **Total paradox**, also known as **pulse obliteration**, refers to the refers to the disappearance of the brachial and radial pulse upon inspiration and the absence of Korotkoff sounds upon inspiration [45].

Differential Diagnosis of Pulsus Paradoxus [45, 46]

Pathology	Examples
Cardiac	• Cardiac tamponade • Mitral stenosis
Pulmonary	• Acute pulmonary hypertension, e.g. secondary to a massive pulmonary embolism • Severe asthma and exacerbations of COPD
Other	• Severe hypovolemic chock • Obesity

	• Tense ascites

Conditions that may mask the presence of a pulsus paradoxus include [45]:
- Hypotension
- Pericardial adhesions
- Aortic regurgitation
- Atrial septal defects
- Right ventricular hypertrophy

Blood Pressure

Blood pressure (BP) is proportional to **cardiac output** (CO) and **systemic vascular resistance** (SVR): BP = CO x SVR. Cardiac output is proportional to the **heart rate** (HR) and the **stroke volume** (SV), i.e. the amount of blood pumped from the left ventricle with each heart cycle: CO = HR x SV. Stroke volume depends on **preload** (the amount of blood in the left ventricle upon end diastole), **contractivity** and **afterload** (the difference between systemic arterial pressure and intrathoracic pressure).

Blood pressure is usually measured by applying a cuff to the upper arm at the midpoint between the acromion and the olecranon process [47]. Undersized cuffs relative to arm circumference will result in an overestimation of blood pressure. The patient's arm should be level with the heart. The pulse-obliteration pressure, i.e. the pressure at which the radial pulse disappears, provides a rapid estimate of the systolic blood pressure.

Differential Diagnosis of High Blood Pressure

Pathophysiology	Examples
Vascular	• Essential hypertension • Renal artery stenosis • Coarctation of the aorta • Vasculitis, e.g. polyarteritis nodosa, takayasu arteritis • Preeclampsia, eclampsia
Neurological	• Head injury • Cerebral infarction and hemorrhage • Brain tumor
Drugs	• Intoxications, e.g. with amphetamine, cocaine • Withdrawal, e.g. alcohol withdrawal, discontinuation of antihypertensive medication
Renal	• Glomerulonephritis • Thrombotic thrombocytopenic purpura and hemolytic uremic syndrome • Renal cell carcinoma
Endocrine	• Pheochromocytoma • Cushing syndrome • Renin-secreting tumor, primary hyperaldosteronism
Other	• Pain • Anxiety

Hypertensive crisis refers to an abrupt rise in blood pressure (usually SBP > 180 mm Hg and/or DBP > 120 mm Hg) and encompasses hypertensive urgency and hypertensive emergency[48].

Hypertensive urgency refers to a hypertensive crisis in the absence of signs of end-organ damage. Patients may suffer from a mild headache but no other symptoms, signs or test findings suggesting end-organ damage. Blood pressure should be reduced gradually over hours to days-rapid blood pressure lowering may precipitate cerebral or myocardial ischemia. Blood pressure lowering options include Furosemide 20 mg (if the patient is volume overloaded), oral Captopril 6.25 or 12.5 mg (if the patient is not volume overloaded), reinstating the patients antihypertensive medications, increasing their doses, adding a diuretic. Management in the ED consists in initiating blood pressure lowering measures, ensuring that the blood pressure is stable or improving, and arranging for out-patient follow-up [49]. Screening for end-organ damage (e.g. EKG, urinalysis, creatinine) is of no proven benefit [50].

Hypertensive emergency refers to a hypertensive crisis with signs of acute end-organ damage. The most common types of end-organ damage are cerebral infarction (24%), pulmonary edema (23%), hypertensive encephalopathy (16%) and congestive heart failure (12%) [51].

- Visual disturbances, altered level of consciousness, nausea and vomiting, focal neurological deficits, seizures suggest brain pathology. **Increased intracranial pressure**, **ischemic and hemorrhage stroke** can lead to hypertension. Hypertension itself can lead to **hypertensive encephalopathy**, characterized by headache, confusion, nausea and vomiting. Fundoscopy may reveal retinal hemorrhages, exudates, or papilledema.
- Chest and/or back pain suggest **myocardial ischemia** or **aortic dissection** while dyspnea suggests **pulmonary edema**.
- Dyspnea suggests **pulmonary edema**. Clinical examination may reveal jugular venous distension and crackles on lung auscultation.
- Acute hypertension-induced renal damage, referred to as **acute hypertensive nephrosclerosis**, is characterized by hematuria and elevated serum creatinine of recent onset.
- Pregnancy-induced hypertension > 160/110 mm Hg suggests **severe preeclampsia** with risk to the mother and fetus.

The antihypertensive medication of choice, target blood pressure and rate of decrease depend upon the suspected etiology and end-organ at risk (see relevant sections: hypertensive encephalopathy, aortic dissection, status epilepticus, myocardial infarction). In the setting of hypertensive emergency in pregnancy, recommended first-line therapies include Labetalol (with starting dose of 20 mg IV), Hydralazine (with starting dose 5-10 mg IV) and Nifedipine (with starting dose 10 mg PO) [52].

Differential Diagnosis of Hypotension

Pathophysiology	Examples
Hypovolemia	• **Hemorrhagic shock**: gastrointestinal, intraperitoneal, retroperitoneal, intrapleural, in the thigh muscle; the bleeding may result from trauma or rupture (e.g. ruptured ectopic pregnancy, ruptured abdominal aortic aneurysm) • **Intravascular volume depletion** (non-hemorrhagic): decreased fluid intake, vomiting, alcohol abuse, diabetic ketoacidosis, hyperglycemic

	hyperosmotic syndrome, diabetes insipidus, diuretics, diarrhea, systemic inflammatory response syndrome (SIRS)
Obstructive Causes of Decreased Preload	• Massive pulmonary embolism • Cardiac tamponade • Tension pneumothorax • Breath stacking in a patient with asthma undergoing positive pressure ventilation • Vena cava syndrome in third trimester pregnancy • Tension gastrothorax [53]
Cardiac Causes of Decreased Stroke Volume	• **Decreased contractility** secondary to acute myocardial ischemia, myocarditis, cardiomyopathy, contusion, sepsis, hypoxia • **Structural problems** e.g. papillary muscle rupture, free-wall rupture, infective endocarditis, hypertrophic obstructive cardiomyopathy • **Arrhythmias**: tachyarrhythmias and bradyarrhythmias, hyperkalemia • **Poisoning** with substances that affect conduction and contractility, e.g. beta-blockers, calcium antagonists, sodium channel blockers
Decreased Systemic Vascular Resistance	• Systemic Inflammatory Response Syndrome, e.g. sepsis, severe pancreatitis • Anaphylaxis • Neurogenic shock • Transfusion reaction • Adrenal crisis • Medications (e.g. dihydropyridines)

Intravenous & Intraosseous Access

Intravenous access is necessary for blood tests and delivery of fluids and medications. Critically ill patients need two intravenous accesses or more. Patients who need rapid fluid infusion should ideally have short, large bore catheters, given that resistance to flow is proportional to catheter length and inversely proportional to its diameter raised to the 4th power (Poiseuille's law). The first choice for intravenous access is a peripheral venous catheter (PVC) in the antecubital vein just below the elbow crease. If the insertion of a PVC cannot be carried out, the second choice is an intraosseous needle 1 cm caudal and 1 cm medial to the tibial tuberosity. In case of bilateral leg fractures, the intraosseous needle can be inserted anterolaterally in the humeral head with the arm adducted and internally rotated.

Use of ultrasound can facilitate peripheral intravenous access, most commonly in the upper arm (e.g. the basilic vein). According to one study, vessels > 1.6 cm in depth were not successfully cannulated [54]. When vessel depth was < 1.6 cm, success depended on vessel size; vessel diameter > 0.6 cm was associated with a 92% success rate. Catheters > 5 cm in length are needed to avoid dislodgement.

Crystalloid Bolus

The optimal management of a patient with hypotension depends on its cause. As a rule, it is appropriate to administer a bolus of 500 ml crystalloid (10 ml/kg in children) to a patient with severe hypotension of unknown cause (e.g. SBP < 80 mm Hg, absent radial pulse). The use of a three way stopcock is advantageous to ensure that a child receives all of the fluid bolus during a short time-span.

Heart Rate

Palpating the pulse allows for a rapid estimation of heart rate and rhythm. The pulse oximeter also provides a measurement of the heart rate. However, the pulse and pulse oximeter may underestimate the true heart rate when not all heart contractions are felt peripherally, a phenomenon known as **pulse deficit**. Pulse deficit occurs e.g. in patients with atrial fibrillation, due to the beat-to-beat variability in duration of diastole, and hence variability in preload and stroke volume. The same mechanism accounts for failure to palpate extrasystolic beats in patients with bigeminy. Auscultating the heart sounds in the resuscitation room may be difficult. The use of a 3-lead electrocardiogram is a more reliable way of determining the heart rate and rhythm, yet it may overestimate the heart rate if T waves or pacemaker spikes are misinterpretated as QRS complexes.

Tachycardia in adults has been defined by consensus as a heart rate > 100/min, although some have suggested that 90-95 beats/min is a more evidence-based upper limit for sinus rhythm [6, 7]. In children, tachycardia is a heart rate exceeding the age-appropriate normal range. Numerous conditions can lead to sinus tachycardia. These factors may also precipitate or exacerbate tachyarrhythmias.

Differential Diagnosis of Tachycardia Precipitants

Pathophysiology	Examples
Vascular	• Hypovolemic shock, e.g. bleeding • Obstructive shock, e.g. pulmonary embolism • Myocardial pathology, e.g. ischemia • Distributive shock, e.g. sepsis
Infectious	• Pneumonia • Urinary tract infection • Exacerbation of chronic obstructive pulmonary disorder
Toxic	• Digoxin intoxication • Antiarrhythmic medications • Cocaine intoxication, amphetamine intoxication • Alcohol abstinence
Metabolic	• Hypoxia • Thyrotoxicosis • Hypokalemia, hypomagnesemia, hypocalcemia
Other	• Pain • Anxiety • Fever

The heart rate's regularity and the QRS width can help categorize the tachycardias to determine whether a tachyarrhythmia is present and narrow the differential diagnosis (Chapter 07).

Differential Diagnosis of Tachyarrhythmias [55]

	Regular	Irregular
QRS < 120 msec	• Sinus tachycardia • Atrial flutter • Ectopic atrial tachycardia (EAT) • AVNRT • AVRT, orthodromic	• Atrial fibrillation • Atrial flutter with varying AV block • Multifocal atrial tachycardia (MAT)

QRS ≥ 120 msec	• Ventricular tachycardia (VT), monomorphic
	• Sinus tachycardia, atrial flutter, EAT with
	  ○ Bundle branch block
	  ○ Accessory pathway
	  ○ Membrane stabilisation (intoxication, hyperkalemia)
	• AVRT, antidromic
		• VT, polymorphic (e.g. torsade de pointes)
		• Atrial fibrillation with
		  ○ Bundle branch block
		  ○ Accessory pathway
		  ○ Membrane stabilisation (intoxication, hyperkalemia)

AVNRT: atrioventricular nodal reentry tachycardia; AVRT: atrioventricular reentry tachycardia.

Bradycardia in adults has been defined by consensus as a heart rate < 60 beats/min in adults. Well-conditioned athletes may have a normal resting heart rate of 30-40 beats/min and some have suggested redefining bradycardia as a heart rate < 50 beats/min [6, 7]. In children, bradycardia is a heart rate below the age-appropriate normal range. The differential diagnosis of bradycardia is equally broad.

Differential Diagnosis of Bradycardia

Pathophysiology	Examples
Vascular	• Myocardial ischemia (e.g. involving the right coronary artery), myocardial infarction, sick-sinus syndrome [20]
Infectious	• Pericarditis, myocarditis, infective endocarditis, Lyme disease
Infiltrative	• Amyloidosis
Neurologic	• Raised intracranial pressure (Cushing's reflex), neurogenic shock, pain (through increased vagal tone)
Degenerative	• Lev's disease (idiopathic fibrosis and calcification of the heart's electrical system)
Intoxication	• ß-blockers, calcium antagonists, digitalis, clonidine, amiodarone, other antiarrhythmics, acetylcholinesterase inhibitors
Metabolic, Endocrine, electrolytes	• Hypoxia (pre cardiac arrest), hypothermia • Hypothyroidism, hypoglycemia • Hyperkalemia

The following measures may be indicated in the setting of bradycardia:

- **Atropine** 0.5 mg is the first line treatment for bradycardia in adults. The dose can be repeated every 3-5 min up to a maximum of 3 mg for adults [20]. Children lacking shock,

in which the bradycardia is caused by increased vagal tonus, are treated initially with 20 µg /kg IV [4].

- **Isoprenalin** can be administered to patients with severe bradycardia not responding to atropine. Isoprenalin 0.2 mg/ml 25 ml are mixed with Glucose 50 mg/ml 500 ml yielding a 10 ug/ml solution. The solution is initially infused at 30 ml/hr, i.e. 5 µg/min [20] (0.05 µg/kg/min in children) and titrated to effect.
- **Adrenalin** 2-10 ug/min is an alternative to isoprenaline [20].
- **Dopamine** 2-10 ug/kg/min [20]
- **Glucagon** 1-5 mg IV may be indicated when bradycardia is caused by calcium channel blocker or beta-blocker overdose [20]
- **Theophylline** 100-200 mg by slow intravenous infusion may be considered in the setting of inferior myocardial infarction, cardiac transplant or spinal cord injury [20].
- **External (transcutaneous) pacing** if Atropine (+/- isoprenalin infusion) is ineffective. Capture should be confirmed by feeling for a femoral pulse matching the pacing frequency. Temporary transvenous pacing should then be considered.
- **Fist pacing** can be attempted if atropine is ineffective and transcutaneous pacing is not available. The procedure consists in administering serial rhythmic blows with the closed fist over the left lower edge of the sternum to pace the heart at a rate of 60 beats/min [20].
- Children with shock and a heart rate of < 60 beats/min are treated as though they had pulseless electrical activity, i.e. with **chest compressions** 100-120 /min and **adrenalin** 10 ug/kg IV/IO [56].
- **Calcium**: symptomatic bradycardia resulting from severe hyperkalemia may fail to respond to atropine or external pacing [57]. In this setting, calcium (e.g. Calcium Gluconate 10% 30 ml IV) is the drug of choice.

QRS Width

The QRS width can be obtained with the use of the three lead EKG, or if necessary by connecting the patient to a defibrillator with a display. The QRS width helps categorize the tachyarrhythmias (Chapter 07). Wide QRS complexes can occur in a variety of settings (Chapter 05).

Differential Diagnosis of Wide QRS Complex

Pathophysiology	Examples
Depolarization originates in the ventricle	• Premature ventricular beat (EKG 79 yo) • Ventricular escape rhythm in AV block III (EKG 45 yo) • Paced ventricular beats (EKG 95 yo) • Ventricular tachycardia (EKG 61 yo)
Bundle branch block	• Left bundle branch block (LBBB) (EKG 25 yo) • Right bundle branch block (RBBB) +/- left fascicular block
Accessory pathway	• Wolff-Parkinson-White syndrome (EKG 83 yo, EKG 56 yo) • Antidromic atrioventricular reentry tachycardia (AVRT)
Metabolic	• Hyperkalemia (EKG 78 yo)
Membrane stabilization	• Intoxication with sodium channel blocking agents (EKG 54 yo)

4. DISABILITY

The assessments under D constitute a rapid screening examination of the nervous system, but one that can provide a wealth of clinical information. The assessments should be carried out prior to the administration of sedative or paralytic medications when possible. The following are assessed:

- level of consciousness, language and articulation
- eye opening, gaze & spontaneous movements, pupillary size and reactivity to light
- sensation and motor function in the hands and feet
- capillary or plasma glucose

The information obtained can then be used to assign a summative grading of the patient's neurological state according to two scoring systems, the Reaction Level Scale (RLS-85) [58] and the Glasgow Coma Scale (GCS) [59]. Abnormal findings motivate a more detailed neurological examination (Chapter 08-Weakness & Paresthesia).

Level of Consciousness

The patient's level of consciousness can usually be determined by talking with the patient, and if necessary, by applying a painful stimulus to the supraorbital nerve and noting the patient's verbal and motor responses. The level of consciousness of patients with suspected expressive aphasia can be assessed through simple questions, such as asking the patient to point to the ceiling. The level of consciousness can be graded using the AVPU score:

- A if the patient is **A**lert
- V if the patient responds to **V**oice
- P if the patient only responds to **P**ainful stimuli
- U if the patient reponds to neither verbal nor painful stimuli and is therefore deemed **U**nconscious

Differential Diagnosis of Altered Consciousness

Pathophysiology	Examples
Vascular Cardiac	• Arterial: basilar artery thrombosis, diffuse bilateral stroke (including SAH) • Venous: cerebral sinus thrombosis • Systemic: cardiogenic chock, TTP, hypertensive encephalopathy
Infectious **I**nfiltrative	• Intracranial infections: meningitis, encephalitis, cerebral abscess • Extracranial infections: pneumonia, urosepsis
Neurological **N**eoplastic	• Seizures: status epilepticus including non-convulsive status, post-ictality • Increased intracranial pressure: brain tumor, hydrocephalus, subdural/epidural hematom
Degenerative **D**eficiency	• Degenerative: Alzheimer's dementia • Deficiency: Wernicke's encephalopathy, depression
Intoxication Withdrawal	• Traditional medications vs other substances • Overdose vs withdrawal (e.g. alcohol or benzodiazepine abstinence)
Collagen Vascular **C**ongenital	• Vasculitides affecting the brain, e.g. primary CNS vasculitis, temporal arteritis • Lupus cerebritis
Trauma Mechanical	• Intracranial: concussion, shunt dysfunction • Extracranial: urinary retention, long-bone fractures, post-operative states

	[60]
Electrolytes **E**ndocrine-metabolic	• Electrolytes: hypo- & hypernatremia, hypo- & hypercalcemia • Endocrinological: hypoglycaemia, hypothyroidism, thyrotoxicosis • Metabolic: uremia, hepatic encephalopathy, hypoxia, hypercapnia, hypothermia, heatstroke, porphyria

Language

Dysphasia refers to an impairment in understanding language (impressive dysphasia), use language to communicate (expressive dysphasia) or repeat phrases (conduction dysphasia):

- impressive dysphasia suggests pathology in Wernicke's area (left superior temporal gyrus).
- expressive dysphasia suggests pathology in Broca's area (left posterior inferior frontal gyrus).
- conduction dyphasia suggests pathology in the temporal cortex

A patient who appears to be awake but who neither follows simple directions ("raise your right hand") nor answers questions may be suffering from a psychological or psychiatric condition instead of a neurological deficit.

Articulation

Dysarthrias refer to an impairment in the ability to articulate. Dysathrias suggest impairment of the function of cranial nerves VII, IX and XII, resulting from either peripheral nerve, brainstem, subcortical or cortical pathology:

- difficulty articulating the sound "pa" suggests impaired cranial nerve VII function.
- difficulty articulating the sound "ga" suggests impaired cranial nerve IX function.
- difficulty articulating the sound "la" suggests impaired cranial nerve XII function.

Eye Examination

Patients whose eyes are closed should be asked to open them. If the eyes do not open to voice, a central painful stimulus can be applied to the supraorbital nerve and the physician notes whether the patient's eyes open. If the eyes do not open to pain, the eyelids are manually retracted in order to examine the eyes for gaze deviation, abnormal movements, pupillary size and reactivity to light.

Eye Opening

Ptosis refers to drooping of the upper eyelid. Ptosis results from decreased function of the levator palpebrae superioris (innervated by the 3rd cranial nerve) or decreased function of the superior tarsal muscle (innervated by the sympathetic nervous system). The differential diagnosis of ptosis includes:

- damage or trauma to the levator palpaebrae superioris and/or superior tarsal muscle
- impairment of the neuromuscular junction, e.g. secondary to myasthenia gravis or botulism
- pathology affecting the third cranial nerve or cranial nerve nucleus in the brainstem
- decreased sympathetic innervation of the eye, as part of the Horner's syndrome (see below). In this context, the patient can widen the gap between the eyelids upon exhortation and the condition is technically referred to as 'pseudoptosis.'

Retraction of the eyelid suggests thyroid eye disease [61].

Gaze & Eye Movements

Conjugate gaze deviation refers to both eyes looking in the same direction and the examiner not being able to get the patient to look to the other side of midline. Conjugate gaze deviation suggests:

- **ipsilateral stroke** affecting areas involved in either spatial attention or control of eye movements: the basal ganglia, the frontal eye fields, the parietal eye field as well as neighboring temporoparietal cortical regions involved in spatial attention [62]
- **ipsilateral post-ictal state** involving the above areas
- **contralateral seizure** involving the above areas
- **contralateral pontine stroke** [63] involving the paramedian pontine reticular formation

Jerking eye movements may be a subtle cue to on-going non-convulsive status epilepticus.

Nystagmus refers to oscillations of the eyes whereby the velocity is faster in one direction [64]. The direction of the nystagmus is by definition that of the fast movement, while the pathological component is the slow movement [64]. Nystagmus may be horizontal, vertical or torsional. Acquired nystagmus can be caused by [64]:

- lesions in the brainstem (medulla, pons) or cerebellum
- lesions of the vestibular nerve
- disease of the labyrinth
- toxic exposures
- defective retinal impulses

Vertical (upbeat, downbeat) nystagmus suggests an upper brainstem or cerebellar lesion [65].

There are a number of pathological eye movements that have been described in patients with coma. For example, **roving eye movements** are slow, random predominantly horizontal conjugate eye movements that suggest metabolic encephalopathy or bilateral supranuclear lesions (Lifeinthefastlane). Most pathological eye movements suggest bihemispheric or brainstem pathology [37].

Pupillary Size & Reactivity to Light

Both pupils may be abnormally large or small.

Differential Diagnosis of Abnormal Bilateral Pupillary Size

Pathophysiology	Mydriasis: examples	Miosis: examples
Drugs/Withdrawal	• Sympathomimetics • Anticholinergics • Serotonergics • Barbiturates (late stage) • Sedative withdrawal	• Sedative • Cholinergic • Opioid
Metabolic	• Hypothermia • Hypoxia	• Metabolic causes of coma
Neurologic	• Generalized seizure	• Pontine pathology
Infectious	• Botulism [66] • Tick paralysis [66]	

The most common cause of **anisocoria** (different sized pupills) is physiologic anisocoria [67]; 20% of the population may have anisocoria > 0.4 mm at any given examination [64]. In this setting, there is no loss of vision or diplopia. When the anisocoria is pathological, the abnormal pupil is [64]:

- the one that reacts poorly to light or that does not dilate when shaded from light
- the smaller pupil if the anisocoria is more pronounced in a dark room
- the larger pupil if the anisocoria is more pronounced in a bright room (or after the administration of opoids)

Unilateral mydriasis combined with lack of pupillary response to light suggests compression of the parasympathetic fibers which run along the exterior of the third (oculomotor) cranial nerve.

- In an alert patient, the compression may be due to a **saccular aneurysm** which is classically located in the posterior communicating cerebral artery [68]
- In an unconscious patient, the compression may be due to **ipsilateral uncal herniation**, i.e. compression of the oculomotorius between the inner part of the temporal lobe and the tentorium.
- With a **third-nerve palsy**, other signs of third nerve involvement are usually present, e.g. ptosis and extraocular muscle dysfunction (the eye may be "down and out") [64].
- **Adie's tonic pupil** results from cholinergic supersensitivity. Patients have blurred near vision but normal distant vision. The pupil constricts slowly to near testing and redilates slowly when distant vision is then tested.

Unilateral miosis combined with ptosis suggests **Horner's syndrome**, which refers to the constellation of unilateral [69]

- **Miosis**, which may be more obvious when examining the patient in a dark room [70]
- **Pseudoptosis** from drooping of the eyelid due to loss of sympathetic innervation to the superior tarsal muscle; the affected eyelid may be slightly raised voluntarily [71], as opposed to true ptosis resulting from pathology resulting in paresis to the levator palpebrae superioris. In addition, the lower eyelid is usually elevated [72], also refered to as "upside-down" ptosis
- **Anhidrosis**, i.e. dryness of the skin over the face; anhidrosis is absent if the lesion is distal to the point along the carotid artery where the sympathetic innervation to the face and the eye separate [71]

Horner's syndrome results from the interruption of sympathetic innervation to the eye and face. The sympathetic innervation to the eye follows a U-shaped pathway, descending along the dorsolateral tegmentum of the brainstem, down the cervical spinal cord, exiting the spinal cord at nerve roots T1-T3, traveling up the cervical sympathetic chain to the synapse in the superior cervical sympathetic ganglion, and then coursing along the outside of the carotid artery and ophthalmic artery towards the eye.

Differential Diagnosis of Horner's Syndrome

Anatomy	Examples
Brainstem	• A lateral medullary infarct may result in a Horner's syndrome, vertigo, nystamus, ataxia and other symtoms (**Wallenberg syndrome)**
Cervical spinal cord	• Ipsilateral trauma (e.g. [73])

Brachial plexus	• Ipsilateral trauma e.g. during delivery [64]
Superior sympathetic ganglion	• **Pancoast tumor** (apical superior sulcus lung cancer)
Carotid	• **Carotid dissection** may lead to a pseudoaneurysm affecting the sympathetic fibers traveling on the outside of the artery towards the eye • **Villaret's syndrome** refers to unilateral cranial nerves 9-12 dysfunction combined with Horner's syndrome [72]. The syndrome can be caused by a carotid dissection with pseudoaneurysm or a retropharyngeal abscess (de Beer 2010). • Inadvertant injection of anesthetic into the carotid sheath during dental block [64]
Other	• **Horton's (cluster) headache** (20% have a Horner's syndrome) • **Migraine** headache [65]

- **Previous eye surgery** may be the cause of an irregular pupil [67].

Peripheral Weakness & Sensory Loss

The motor and sensory examinations carried out during the ACBDE constitute screening examinations of the motor and sensory pathways between the cortex and the extremities. Detecting pathology warrants additional physical examination to determine the likely location of the lesion (e.g. brain, spinal cord, nerve root, peripheral nerve).

In the conscious patient, gross sensation and strength in the upper and lower extremities can be assessed by:
- squeezing each hand and asking the patient which hand is being squeezed.
- asking the patient to grasp and squeeze the physician's index and middle fingers.
- squeezing both feet and asking the patient which foot is being squeezed.
- asking the patient to plantar flex the feet against resistance.

In the unconscious patient, sensation and motor function can be assessed by applying a painful stimulus to the nail bed of the finger or toe and noting the motor (and/or verbal) response. The response may involve withdrawal, flexion or extension of the stimulated limb or a motor response of the contralateral limb:
- flexion of the arms in response to pain and extension of the legs is referred to as a **decorticate response**
- extension of the arms and extension of the legs in response to pain is referred to as a **decerebrate response**

Pathological patterns and follow-up investigations are covered in Chapter 09-Weakness and Paresthesias. As examples:
- **Hemiplegia** refers to unilateral weakness. It suggests pathology in the contralateral forebrain or brainstem or ipsilateral hemilesion of the spinal cord.
- **Paraplegia** refers to bilateral leg weakness in the absence of arm weakness. It suggests a spinal cord lesion below the brachial plexus (T1 and below).

- **Tetraplegia** refers to weakness of all four extremities. It may result from systemic problems affecting the central nervous system (e.g. intoxications) or transection of the spinal cord above the brachial plexus (C5 and above).

Glucose

The ability to measure either capillary or plasma glucose and the ability to treat hypoglycemia are widely available within health-care settings. Hypoglycemia may manifest as decreased or altered level of consciousness and even as focal neurological deficits that may be misinterpretated as resulting from a stroke. Severely ill infants and children ar prone to hypoglycemia [4]. Detecting hyperglycemia may help diagnose diabetic ketoacidosis, hyperosmolar hyperglycemic syndrome or an infection. A case can therefore be made for routinely measuring glucose in patients who are obviously or potentially unstable.

Hypoglycemia can be the result of:
- Insulin overdose or insulinoma
- Sulfonylurea or beta-blocker [74] overdose
- Alcohol intoxication
- Cirrhosis
- Adrenal insufficiency [75]
- Severe illness (e.g. sepsis) in infants and children [4]

Measures for the acute management of hypoglycemia include:
- **Oral glucose** is preferable if possible, since extravasation of glucose administered intravenously results in tissue necrosis.
- **Glucose 300 mg/ml** (30%) 20-30 ml IV for adults
- **Glucose 100 mg/ml** (10%) 2 ml/kg IV for children followed by a maintenance glucose infusion of 100 mg/kg/day of 10% glucose [4].
- **Glucagon** 1 mg IM or SC to adults or children > 25 kg, 0.5 mg to children < 25 kg [4].
- **Octreotide** 100 ug IM or SC (1 ug/kg) should be added to glucose therapy in the case of sulfonylurea overdose. Overdose with sulfonylureas leads to increased release of endogenous insulin; treatment with glucose alone results in transient hyperglycemia, which in turn increases insulin secretion and leads to recurring episodes of hypoglycemia [76].
- **Thiamine** 500 mg IV should be given in conjunction with glucose if thiamine deficiency is suspected (e.g. chronic alcohol abuse, malnutrition, possible Wernicke's encephalopathy) [77-79].

When the patient has an impaired level of consciousness and glucose measurement is unavailable, glucose should be administered, given that the costs of untreated hypoglycemia are high while the costs of transient hyperglycemia are negligeable.

Hyperglycemia occurs in the setting of:
- Diabetic ketoacidosis (DKA)
- Hyperglycemic hyperosmotic syndrome (HHS)
- Undertreated diabetes mellitus in the absence of DKA or HHS
- Corticosteroid therapy
- Acute stress, e.g. infection.

Reaction Level Scale (RLS-85) & Glasgow Coma Scale

The Reaction Level Scale (RLS-85) [58] and the Glasgow Coma Scale (GCS) [59] are two scoring systems that provide a summative grading of the patient's neurological state. The summative grade does not provide as much information as the separate examination of eyes-level of consciousness-peripheral neurological function, but it facilitates communication between emergency physicians and other health-care professionals such as neurosurgeons and anesthesiologists.

RLS-85

Criteria	RLS
Vaken. Ej fördröjd reaktion. Orienterad	1
Slö eller oklar. Kontaktbar vid lätt stimulering. Tilltal, enstaka tillrop, beröring	2
Mycket slö eller oklar. Kontaktbar vid upprepade tillrop, ruskning, kraftig smärtstimulering	3
Patienten lokaliserar smärta men avvärjer ej	4
Patienten drar undan armen vid smärtstimulering av fingernagelbädd	5
Patienten böjer armbågen (flexion) vid smärtstimulering	6
Patienten sträcker armbågen (extension) vid smärtstimulering	7
Ingen reaktion vid smärtstimulering	8

Om patienten kan ge blickkontakt / följa med blicken, lyda uppmaning eller avvärjer smärta är patienten RLS 1-3. Patienten är definitionsmässigt medvetslös vid RLS ≥ 4.

The **Glasgow Coma Scale** is obtained by adding the points obtained from assessing eye opening, best verbal response and best motor response:

Eye opening

< 4 years	Points	> 4 years
Spontaneously	4	Spontaneously
To verbal stimuli	3	To verbal stimuli
To pain	2	To pain
No response to pain	1	No response to pain

Best Verbal Response

< 4 years	Points	> 4 years
Alert; babbles, coos words to usual ability	5	Oriented and converses
Less than usual words, spontaneous irritable cry	4	Disoriented and converses
Cries only to pain	3	Inappropriate words
Moans to pain	2	Incomprehensible sounds
No response to pain	1	No response to pain

Best Motor Response

< 4 years	Points	> 4 years
Spontaneous or obeys verbal command	6	Obeys verbal command
Localises to pain or withdraws to touch	5	Localises to pain
Withdraws from pain	4	Withdraws from pain
Abnormal flexion to pain (decorticate)	3	Abnormal flexion to pain

		(decorticate)
Abnormal extension to pain (decerebrate)	2	Abnormal extension to pain (decerebrate)
No response to pain	1	No response to pain

Benzodiazepine

Benzodiazepines may be indicated during the ABCDE:

- when patient agitation impairs the ability to assess and manage the patient **and** the agitation is not related to a life-threatening A, B or C problem such as hypoxia or impending circulatory collapse
- when continuous or intermittent seizures have lasted for over 5 minutes **and** hypoglycemia has been ruled out. At that point, the patient fulfills the criteria for 'impending status epilepticus' [80] (Chapter 07-Seizure syndromes)

Benzodiazepines are advantageous as first-line agents for the treatment of agitation and impending status epilepticus since the various options have different half-lives and can be administered via different routes, and that a reversal agent, Flumazenil, is available. The American College of Emergency Physicians recommends a benzodiazepine (lorazepam or midazolam) or a conventional antipsychotic (e.g. haloperidol) as first line monotherapy for the acutely agitated, undifferentiated patient in the ED [81].

For the treatment of **agitation**, the dose depends on the patient's age, weight and degree of agitation. As a rule of thumb, 50% of the dose for status epilepticus may be administered first, and repeated as necessary after 15 minutes. The following doses are recommended for the initial management of **impending status epilepticus** [82]:

IV Access	No IV Access
• Lorazepam 4 mg IV (0.1 mg/kg) • Diazepam 10 mg IV (0.15 mg/kg)	• Midazolam 10 mg IM (0.2 mg/kg) • Midazolam 0.5 mg/kg buccal • Diazepam 10-20 mg PR (0.2-0.5 mg/kg)

Simplified alternative:

- IV access: Diazepam 10 mg IV (0.2 mg/kg)
- No IV access: Midazolam 10 mg IM (0.2 mg/kg)

5. EXPOSURE

Within the context of the ABCDE, E (exposure) refers to:

- a superficial examination of the front and back of the body
- temperature measurement
- measures depending on findings

Superficial Examination of the Body

A rapid but systematic superficial examination of the front and back of the body may benefit all patients, and not simply patients exposed to trauma. As a rule, a complete exposure of the body is not carried out in the prehospital arena, where it is impractical to do so and may aggravate hypothermia, and deferred instead to the ED. The examination focusses on identifying inflammation (redness, swelling, tenderness) suggesting infection or trauma, rashes (e.g. petechiae, urticaria), deformities (suggesting dislocations or displaced fractures) and focal bone tenderness (suggesting nondisplaced fractures). The extent to which the superficial examination should be carried depends on:

- the patient's problem; for example, a more thorough examination of the limbs is justified in the setting of trauma than in the setting of acute shortness of breath
- the patient's ability to localize and communicate pain; patients who are very young, confused, demented, intoxicated, sedated or who have neurological deficits precluding pain sensation require a more thorough superficial examination.

Head & Neck

- In the setting of head trauma, the examination should include looking for signs facial fractures, nasal septal hematoma, and basilar skull fracture such as blood in ear canal, otorrhea, hemotympanum, rhinorrhea, Battle's sign (retroauricular hematoma), Raccoon sign (periorbital ecchymosis) [83]
- In the setting of trauma to the head or neck, the cervical spinal processes should be palpated for bony tenderness in order to assess the need for radiography of the cervical spine (Chapter 08 Trauma to the Head or Neck).

Trunk

- In the setting of thoracic trauma, the clavicles and chest wall should be palpated.
- A routine palpation of the abdomen may reveal unexpected signs of peritonitis. However, in the early stages after trauma, the abdominal examination may be unremarkable despite the presence of intraabdominal bleeding [84].
- In the setting of trauma, the pelvic ring should be palpated for signs of tenderness, crepitus and instability. The stability of the pelvic ring is examined by grasping the innominate bones and applying gentle lateral-to-medial compression. If stable, anteroposterior pressure is applied. Vertical instability is assessed by pushing the bones cephalad and then pulling them caudad. Movement or pain suggests pelvic ring fracture [85]. The examination should be carried out gently and interrupted if findings suggest fracture, so as not to disrupt clots and increase bleeding. A meta-analysis reported that the physical examination has SN 90% and SP 90% for pelvic fractures, and that the sensitivity is nearly 100% in stable and alert trauma patients [86].
- The perineum and external genitalia should be inspected for signs of inflammation or bleeding.

Limbs

In the absence of trauma, signs of limb inflammation (swelling, redness, increased warmth, tenderness) suggest infection, deep vein thrombosis, rhabdomyolysis, hemorrhage. In the setting of trauma, signs of inflammation and/or deformity and bony tenderness upon palpation suggest fracture or dislocation, e.g.

- **Squaring of the shoulder** suggests dislocation of the humeral head. In the setting of an anterior dislocation, the arm is typically externally rotated and mildly abducted, while in the setting of a posterior dislocation, the arm is typically internally rotated and adducted.
- **Prominent olecranon** suggests supracondylar fracture in a child and posterior elbow dislocation (+/- fracture) in an adult.
- **Dinner fork deformity** of the distal arm suggests a Colles fracture of the distal radius
- **Leg length discrepancy** suggests hip fracture, hip dislocation or a cephalad migration of an unstable hemipelvis [87]. A shortened, externally rotated leg may suggest hip fracture or anterior dislocation, while a shortened, internally rotated and adducted leg suggests posterior hip dislocation.
- **Swelling of the thigh** suggests a femur fracture.
- **Misalignment at the knee** suggests dislocation, with a concomitant high risk of damage to the popliteal artery; of note, knee dislocation may be difficult to detect in the obese patient and may have spontaneously reduced itself prior to arrival in the ED [88].
- **Joint effusion** raises the possibility of septic arthritis in the setting of shock and hemarthrosis in the setting of trauma
- **Exquisite tenderness** upon palpation suggests necrotizing fasciitis / myositis or compartment syndrome.

When limb fracture or dislocation is suspected, a neurovascular examination of the limb distal to the injury should be carried out. Further management is covered in Chapter 07-Fractures & Dislocations.

Back

- Ultrasound examination of the abdomen looking for intraperitoneal fluid should be performed prior to examining the back, since rolling the patient may limit the sensitivity of the ultrasound examination [89].
- If the patient can sit, the back can then be examined. Other patients should be rolled onto their sides to allow for an examination of the back. Patients with potentially unstable spinal fractures should be log-rolled. The degree of rotation should be minimized in the setting of a suspected pelvic ring fracture, since motion may cause clot disruption and further hemodynamic instability [90].
- The occiput and back are inspected, and in the setting of trauma, the spinal processes should be palpated for bony tenderness. One retrospective study reported low sensitivity 27.5% and negative LR of 0.8 for spinal palpation in unconscious patients for the detection of bony injury to the thoracolumbar spine, and suggested that, for unconscious patients with planned CT scan, examination of the back could be limited to inspection only [91].
- digital rectal examination (DRE) can be justified in the setting of major trauma, suspected gastrointestinal bleeding and suspected myelopathy. A high riding prostate suggests urethral injury. Hematochezia or melena suggest an upper gastrointestinal bleed. The DRE correlates moderately well with anal manometric measurements in determining anal sphincter tone [92]. Absent sensation and/or tonus strenghtens the case for spinal cord pathology. Under other acute circumstances, the DRE is of limited value and not worth the discomfort it causes the patient [93, 94]. The examiner can instead assess sensation in the S3 dermatome by simply placing his or her hand between the patients buttocks and asking the patient where the examiner's hand is located.

Skin

- **Pale, gray** skin suggests anemia and shock
- **Cyanosis** is a blue or purple discoloration of the skin and mucous membranes. Cyanosis occurs when the amount of unoxygenated hemoglobin exceeds 50 g/L [95]. Patients with low hemoglobin levels will develop cyanosis at a lower PaO2 than patients with normal or high hemoglobin levels. The presence of cyanosis thus suggests low PaO2 and hypoxia but it is an insensitive marker of tissue oxygenation [95]. Cyanosis also occurs in the setting of methemoglobinemia (the hemoglobin iron in the ferric state Fe^{3+} is unable to bind O2 and CO2) when 10-25% of the hemoglobin (approximately 15 g/L) is methemoglobin [95].
- **Central cyanosis,** i.e. cyanosis of the oral mucosa, perioral skin and conjunctivae, is often secondary to the shunting of venous unsaturated hemoglobin into the arterial circulation or the presence of abnormal hemoglobin.
- **Peripheral cyanosis**, i.e. cyanosis of the extremities and nail beds, results from vasoconstriction and slow flow of arterial blood in the extremities, allowing for greater oxygen extraction by the tissues [95].
- **Differential cyanosis**, i.e. cyanosis restricted to half of the body (upper vs lower, right vs left), suggests cyanotic heart disease with multiple anomalies [95]
- **Urticaria** suggests an allergic reaction
- **Icterus** suggests hepatitis, advanced cirrhosis, biliary tree pathology or hemolytic anemia
- **Diffuse red, salmon-colored rash** suggests toxic shock syndrome
- **Telangiectasias** suggest cirrhosis
- **Petechiae** are small (1-2 mm) red or purple spots on the skin caused by a minor hemorrhage. The discoloration does not disappear when pressure is applied to the skin (Pic 22 yo)
- **Purpura** is the term used when the discoloration is 3-10 mm
- **Ecchymosis** is the term used when the discoloration is > 1 cm.
- **Hematomas** and **hemarthroses** may result from trauma or from defects in the coagulation cascade, which result in poor stabilization of the primary platetet plug in joints and other anatomic regions exposed to minor repetitive trauma [24].

Differential Diagnosis of Petechiae / Purpura

Pathophysiology	Examples
Coagulopathy	• Thrombocytopenia • Deficiency of coagulation factors
Emboli	• Fibrin (disseminated intravascular coagulation, upon starting treatment with Warfarin) • Thrombocytes (thrombotic thrombocytopenia purpura, hemolytic uremic syndrome) • Thrombi (non-bacterial thrombotic endocarditis), fat, cholesterol
Vascular fragility	• Trauma, senile purpura • Steroid purpura, solar purpura • Amyloidosis, collagen problem (e.g. Ehlers Danlos, scurvy)
Vasculitis	• Primary small vessel vasculitis (ANCA-associated e.g. Churg-Straus vs immune complex e.g. Henoch Schönlein Purpura) • Secondary vasculitides (systemic lupus erythematosus, reumatoid arthritis, Sjögrens, Behcet) • Septic vasculopathy (meningococcemia, disseminated gonococcemia,

	bacterial endocarditis, Rickettsia)

Pelvic Girdle

Application of a pelvic girdle can reduce venous bleeding by decreasing the pelvic volume and stabilizing the fracture; however, a pelvic girdle cannot impede arterial bleeding. A pelvic girdle is indicated in the setting of a pelvic ring fracture sustained after high-energy trauma; it is contraindicated in the settings of [85]:

- low-energy trauma in an elderly patient with osteoporosis
- lateral compression mechanism of injury

"Effectiveness of non invasive external pelvic compression: a systematic review of the literature. Based on available literature, pelvic circumferential compression devices (PCCDs) are widely used in the initial management of patients with suspected pelvic bleeding. There is evidence to suggest that external compression reduces disrupted pelvic rings. There are some complications reported following application of PCCDs. Hemorrhagic source and physiological effectiveness of PCCDs needs to be addressed in future studies. In the meantime judicious application of PCCDs will continue to be recommended." [96]

Spinal Immobilization

When an unstable spinal fracture cannot be ruled-out clinically, the whole spine should be immobilized prior to radiography:

- the body straps are first fastened around the patient while the head is held immobilized manually.
- the head is the last part of the body to be immobilized.

The value of the semi-rigid cervical collar is controversial. One study, performed on healthy volunteers, showed that the addition of a rigid collar to head blocks strapped on a spine board did not result in extra immobilisation of the cervical spine [13]. Cervical collars may lead to pressure sores and increase intracranial pressure [13]. Some experts argue that application of a semi-rigid cervical collar is unnecessary in fully alert, stable and co-operative trauma patients, even when underlying cervical spine fracture is suspected [97]. In the context of penetrating neck trauma, one guideline argues that immobilization of the cervical spine is unnecessary unless there is overt neurologic deficit or an adequate physical examination can not be performed, e.g., when the patient is unconscious [98].

Temperature

An estimate of the body's core temperature is usually obtained using a thermometer that measures infrared radiation from the tympanic membrane (TM). The correlation between TM temperature and core temperature is poor in the pediatric population [99] but acceptable among febrile critically ill adults [100]. Some consider rectal temperature as the criterion standard for body temperature in ambulatory patients [6]. A reliable measure of core temperature can be obtained using an indwelling thermister inserted into the bladder [101].

The upper limits of a normal temperature depend on several factors such as the site of measurement and the patient's age. The following temperatures are considered elevated [6]:

- Oral temperature $\geq$ 37.8°C
- Rectal temperature $\geq$ 38.0°C

- Infrared ear temperature ≥ 37.6°C

Differential Diagnosis of Increased Body Temperature (adapted from [102])

Pathophysiology	Examples
Increased heat gain	• High ambient heat • Sun exposure (heat transfer through radiation)
Increased heat generation: central (hypothalamus)	• Infections • Stroke
Increased heat generation: peripheral	• Strenuous exercise, seizures, malignant hyperthermia • Intoxications, e.g. sympathomimetics, serotoninergics, neuroleptics, salicylates • Hyperthyroidism - thyroid storm • Pheochromocytoma
Decreased heat loss	• Intravascular volume depletion (e.g. from dehydration, diarrhea) • Impaired circulation (e.g. from cardiac disease, atherosclerosis) • Occlusive, vapor-impermeable clothing (prevents heat loss through convection and evaporation) • Anticholinergics (impaired sweating) • Skin disease (e.g. extensive burns, scleroderma) • Humid environment (decreased evaporative heat loss) • Reduced air flow, e.g. inside a car (decreased heat loss through convection)

- **Fever** refers to an elevation in body temperature due to a pyrogen-triggered reset of the thermal set-point in the hypothalamus [102]. Fever does not cause primary pathologic or physiologic damage [102]. The approach to fever is presented in Chapter 08.
- **Hyperthermia** refers to an elevation in body temperature related to the inability to dissipate heat [103]
- **Heatstroke** is a life-threatening form of hyperthermia characterized by neurological dysfunction, a body temperature usually > 40.5ºC and hot skin [102]). The management of heatstroke is presented in Chapter 07.

Hypothermia has been defined as a core temperature < 35.0°C [104].
- **Mild** hypothermia: 32-35°C
- **Moderate** hypothermia: 28-32°C
- **Severe** hypothermia: 22-28°C
- **Profound** hypothermia: < 20°C

Differential Diagnosis of Hypothermia (adapted from [105])

Pathophysiology	Examples
Environmental/iatrogenic	• Cold environment • Wet environment (increased heat loss through conduction) • Cold infusions
Impaired heat generation: central (hypothalamus)	• Cerebrovascular accident, central nervous system trauma, subarachnoid hemorrhage, hypothalamic failure, neoplasm, hypopituitarism

	• Anorexia nervosa • Alcoholic or diabetic ketoacidosis, lactic acidosis • Hypoadrenalism • Major infection (bacterial, viral, parasitic)
Impaired heat generation: peripheral	• Shock • Extreme physical exertion, hypoglycemia, malnutrition • Advanced age with inactivity • Parkinson's disease • Cholinergic toxidrome
Increased heat loss	• Acute spinal cord transection • Burns

Cooling, Rewarming & Preventing Hypothermia

Cooling measures in the setting of severe hyperthermia and heatstroke include (Chapter 07 Heatstroke):

- Evaporative cooling with fans and skin wetting
- Ice-packs applied to high heat transfer areas (neck, groin, and axillae) [102], although one study suggested that application of the ice packs to glabrous skin surfaces (cheeks, palms, soles) was more effective [106].
- Peripheral infusion of cold fluids; infusion of cold fluids via a central line may trigger arrhythmias.
- Ice water submersion [107]
- Endotracheal intubation and paralysis with non-depolarizing agents.

Antipyretics block the action of pyrogens at the level of the hypothalamus. They are effective in treating fever but not in treating hyperthermia. Since fever does not cause primary pathologic or physiologic damage [102], antipyretics are not routinely indicated.

Passive external rewarming focuses on preventing heat loss and is appropriate for most patients with mild hypothermia [104]. Measures include:

- Removal of damp clothing
- Covering the patient with an insulating material to prevent heat loss from evaporation, convection and radiation
- Increasing the room temperature

Active rewarming measures focus on heat transfer and are indicated for patients with moderate, severe or profound hypothermia. Measures include:

- Forced air-warming devices such as the Bair Hugger.
- Infusion of warm fluids (40ºC)
- Ventilation with warm air
- Body cavity (urinary bladder, gastric, esophageal, pleural, peritoneal) lavage with warm fluids
- Extracorporeal blood rewarming

Prevention of hypothermia is indicated for all critical patients, in particular in patients with shock. Hypothermia leads to coagulopathy and is one of the components of the 'lethal triad along with acidosis and coagulopathy [108].

CHAPTER 04—ACID-BASE

Many Emergency Departments are equipped with point-of-care analyzers that can measure pH, partial pressures of blood gases, and the concentrations of electrolytes and lactate within minutes. These results are valuable adjuncts to the information obtained during the ABCDE (Chapter 03) in the initial assessment of critically ill patients. This chapter focuses on the identification and interpretation of acid-base disorders from the pH and pCO2 as well as the HCO3, Na, Cl, and lactate concentrations. Examples of the various disorders (BG xx yo) are found in Appendix 1.

pH is the negative logarithm of the hydrogen-ion concentration [H+]. A normal pH lies between 7.38 and 7.42 [1]. The following definitions are fundamental to acid-base analyses:

- **Acidemia** refers to an increased [H+] in the blood resulting in a pH < 7.38
- **Alkalemia** refers to a decreased [H+] in the blood resulting in a pH > 7.42
- **Acidosis** refers to an acid-base disorder that increases [H+], thereby decreasing the pH
- **Alkalosis** refers to an acid-base disorder that decreases [H+], thereby increasing the pH

Patients can suffer from several concurrent acid-base disorders. For example, a patient may suffer from diabetic ketoacidosis and have a metabolic alkalosis due to vomiting, resulting in a normal pH. In other words, an acidosis can be present despite a normal or elevated pH, and an alkalosis can be present despite a normal or low pH.

PaCO2 denotes the partial pressure of carbon dioxide in arterial blood. A normal PaCO2 is roughly 5.3 kPa.

- **Hypercapnia** and **hypercarbia** refer to a greater-than-normal PaCO2 in blood.
- **Hypocapnia** and **hypocarbia** refer to a lower-than-normal PaCO2 in blood.

Studies **comparing arterial with venous blood gases** in the Emergency Department report the following [2-5]:

- **pH:** arterial pH is 0.03-0.04 higher than venous pH with narrow limits of agreement.
- **HCO3:** arterial HCO3 is 1.34 - 1.41 mEq/L higher than venous HCO3 with narrow limits of agreement (+/- 5 mmol/L)
- **pCO2:** arterial pCO2 is 0.8 - 1.15 kPa lower than venous pCO2 with 95% limits of agreement up to the order of 2.7 kPa. A venous pCO2 of < 6 rules out arterial hypercarbia.
- **Lactate:** the mean difference between venous and arterial lactate was 0.6 mmol/L (range 1.7 to -0.6) in one study [6]. In septic patients, a mean difference between arterial and venous lactate was 0.4 mmol/L (with 95% limits of agreement ranging from 1.2 to -0.4); in this study, a venous lactate of > 2 mmol/L had SN 100% and SP 83% for an arterial lactate > 2 mmol/L [7].

- art pH = ven pH + 0,001 x (93 - So2); konsensus är +0.03
- art pCO2 = ven pCO2 - 0,027 x (93-SO2); avdrag av 0,64 kPa (Zeserson et al) har förslagits men inte särskild bra.
- SpO2 - 2% = PaO2. The SpO2 correlates well with the PaO2 [8].

Venous pH and HCO3 are thus interchangeable with their arterial counterparts. A normal venous pCO2 effectively rules-out arterial hypercarbia [9] and venous pCO2 may be used to monitor pCO2 trends but is insufficient to determine the exact degree of hypercarbia. In this chapter, pCO2 refers to arterial values.

There are three major approaches to quantify acid-base disorders: the physiological approach, the base-excess approach, and the Stewart method [1]. This chapter presents a physiological approach to acid-base analysis, which can be organized according to the mnemonic **ACID**:

1. Acidosis/Alkalosis?
2. Compensation?
3. Ions?
4. Diagnoses?

The chapter concludes with a short section on the A-a gradient.

1. ACIDOSIS/ALKALOSIS?

The first step in acid-base analysis is to determine, from the pH, HCO3 and pCO2, whether a dominant acidosis or alkalosis is present, and if so whether the disorder is metabolic or respiratory [1]:

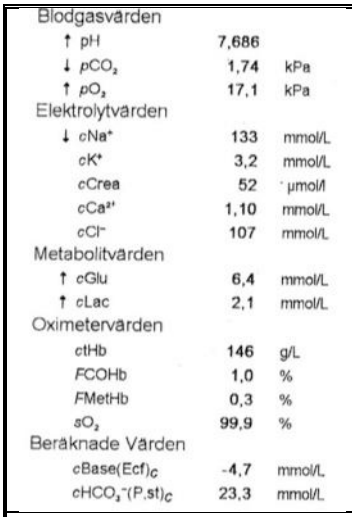
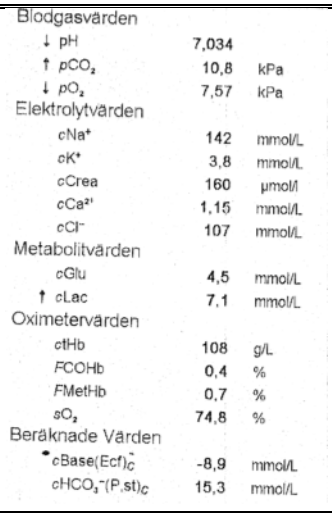
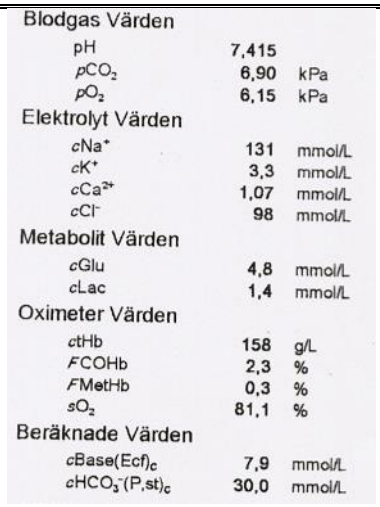
pH < 7.38	HCO3 < 22 mmol/L	Metabolic acidosis
	pCO2 > 5.7 kPa (43 mm Hg)	Respiratory acidosis
pH > 7.42	HCO3 > 26 mmol/L	Metabolic alkalosis
	pCO2 < 5 kPa (37 mm Hg)	Respiratory alkalosis

If the pH is < 7.38, the HCO3 is < 22 mmol/L and the pCO2 is > 5.7 kPa, both a metabolic acidosis and a respiratory acidosis are present (BG 70 yo). Conversely, if the pH is > 7.42, the HCO3 is > 26 mmol/L and the pCO2 is < 5 kPa, both a metabolic alkalosis and respiratory alkalosis are present.

If the pH is between 7.38 and 7.42, there are two possibilities:
- No acid-base disorder is present.
- There are at least two disorders that balance each other resulting in a normal [H+] (BG 85 yo).

Blodgasvärden			Blodgasvärden			Blodgasvärden		
pH	7,179		pH	7,221		pH	7,528	
pCO_2	5,44	kPa	pCO_2	9,94	kPa	pCO_2	6,51	kPa
pO_2	2,91	kPa	pO_2	7,12	kPa	pO_2	7,25	kPa
Elektrolytvärden			Elektrolytvärden			Elektrolytvärden		
↓ cNa^+	135	mmol/L	cNa^+	137	mmol/L	cNa^+	140	mmol/L
cK^+	4,0	mmol/L	cK^+	3,0	mmol/L	cK^+	3,0	mmol/L
cCrea	564	µmol/l	cCrea	55	µmol/l	cCrea	72	µmol/l
cCa^{2+}	1,06	mmol/L	cCa^{2+}	1,29	mmol/L	cCa^{2+}	1,07	mmol/L
cCl^-	101	mmol/L	↓ cCl^-	97	mmol/L	↓ cCl^-	89	mmol/L
Metabolitvärden			Metabolitvärden			Metabolitvärden		
↑ cGlu	6,6	mmol/L	↑ cGlu	7,3	mmol/L	↑ cGlu	8,5	mmol/L
↑ cLac	11,4	mmol/L	↑ cLac	4,0	mmol/L	↑ cLac	2,6	mmol/L
Oximetervärden			Oximetervärden			Oximetervärden		
ctHb	141	g/L	ctHb	124	g/L	ctHb	163	g/L
FCOHb	0,3	%	FCOHb	0,5	%	FCOHb	1,2	%
FMetHb	1,0	%	FMetHb	0,7	%	FMetHb	0,4	%
sO_2	26,0	%	sO_2	78,5	%	sO_2	90,6	%
Beräknade Värden			Beräknade Värden			Beräknade Värden		
$cBase(Ecf)_c$	-12,2	mmol/L	$cBase(Ecf)_c$	2,4	mmol/L	$cBase(Ecf)_c$	16,1	mmol/L
$cHCO_3^-(P,st)_c$	13,3	mmol/L	$cHCO_3^-(P,st)_c$	24,3	mmol/L	$cHCO_3^-(P,st)_c$	38,7	mmol/L
• pH < 7.38 (acidemia)			• pH < 7.38 (acidemia)			• pH > 7.42 (alkalemia)		

• HCO3 < 22 mmol/L • **Metabolic acidosis** is the dominant disorder	• pCO2 > 5.7 kPa • **Respiratory acidosis** is the dominant disorder	• HCO3 > 26 mmol/L • **Metabolic alkalosis** is the dominant disorder

		
• pH > 7.42 (alkalemia) • pCO2 < 5.0 kPa • **Respiratory alkalosis** is the dominant disorder	• pH < 7.38 (acidemia) • pCO2 > 5.7 kPa: **respiratory acidosis** • HCO3 < 22 mmol/L: **metabolic acidosis**	• pH normal • pCO2 > 5.7 kPa: **respiratory acidosis** • HCO3 > 26 mmol/L: **metabolic alkalosis**

2. COMPENSATION?

The body strives to maintain a normal pH. It has two means of altering [H+]:

- The pCO2 can be decreased through increased minute ventilation or increased through decreased minute ventilation. pCO2 combined with H2O is in equilibrium with HCO3 and H+. Reducing pCO2 results in a consumption of H+ and a rise in the pH. Increasing pCO2 results in an increase in H+ and a decrease in the pH.
- The kidneys can retain or excrete NaHCO3. The retention of HCO3- leads to a consumption of H+ and a rise in the pH. The excretion of NaHCO3 leads to a rise in the H+ and a decrease in the pH.

An acid-base disturbance should lead to a compensatory response in an otherwise functioning body:

- A metabolic acidosis should lead to a compensatory hyperventilation. With severe metabolic acidosis (HCO3 < 5 mmol/L), the pCO2 rarely, if ever, goes below 1.3 kPa [10]
- A metabolic alkalosis should lead to a compensatory hypoventilation. With severe metabolic alkalosis, neither hypoxemia nor potassium depletion prevent expression of this response [11].
- A respiratory acidosis should lead to a compensatory retention of HCO3.
- A respiratory alkalosis should lead to a compensatory excretion of HCO3.

Physiologic compensation abides by the following rules-of-thumb:

- A normal compensation does not normalize the pH (with the exception of compensation for a chronic respiratory alkalosis [1]). An arterial pH between 7.38 och 7.42 argues either for the absence of acid-base disorders or the presence of ≥ 2 disorders.
- Respiratory compensation occurs quickly and a new steady-state pCO2 is reached within hours [1].
- Renal compensation develops slowly and a new steady-state bicarbonate concentration is reached within 2-5 days [1]. The degree of renal compensation indicates therefore whether the respiratory disorder is chronic or acute.

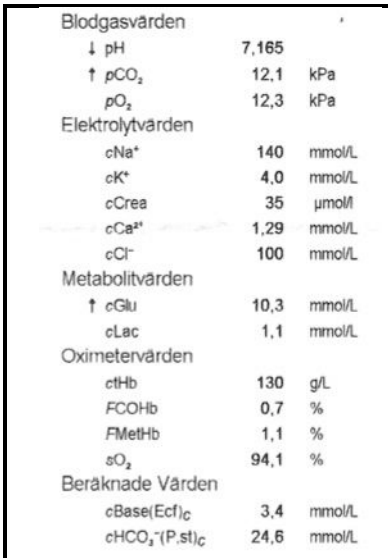
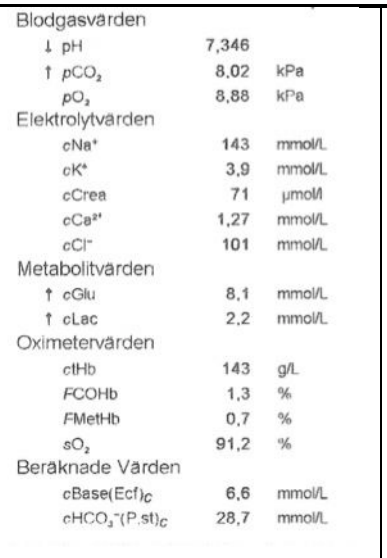
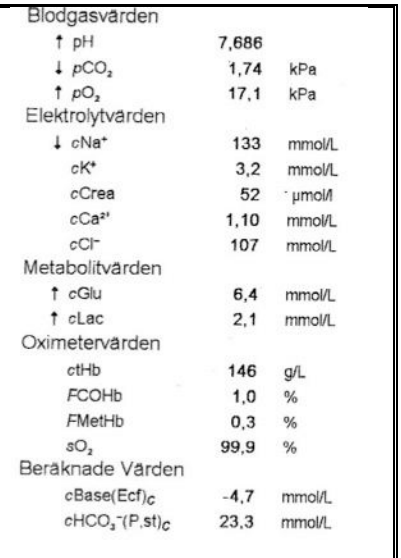
The following table features the expected compensations [11]. Δ stands for "change of". The pCO2 units are kPa. The HCO3 units are mmol/L.

Disorder	Expected Compensation	Examples
Metabolic Acidosis	$\Delta pCO_2 = \Delta HCO_3 \times 0.16$	BG 63 yo
Metabolic Alkalosis	$\Delta pCO_2 = \Delta HCO_3 \times 0.09$	BG 18 yo
Chronic Respiratory Acidosis	$\Delta HCO_3 = \Delta pCO_2 \times 2.62$	BG 85 yo
Chronic Respiratory Alkalosis	$\Delta HCO_3 = \Delta pCO_2 \times 3.0$	BG 20 yo woman

If the expected compensation is not present, then another acid-base disturbance is present. For example, a patient with a pH < 7.38 and a HCO3 of 14 has a metabolic acidosis. The Δ HCO_3 is 10 mmol/L (24-14 mmol/L). The expected Δ pCO_2 is 0.16 x 10 = 1.6 kPa. The patient's pCO2 should therefore be around 2.7 kPa (5.3-1.6). If the pCO2 is significantly greater than 2.7 kPa, a respiratory acidosis is also present. If the pCO2 is significantly below 2.7 kPa, a respiratory alkalosis is also present.

The Winters formula provides another estimation of expected pCO2 in the setting of a metabolic acidosis: pCO2 = 1.5 [HCO3] + 8 +/- 2 [12]

Blodgas Värden ↓ pH 6,780 ↓ pCO_2 1,91 kPa ↑ pO_2 19,3 kPa Elektrolyt Värden ↓ cNa^+ 132 mmol/L ↑ cK^+ 7,0 mmol/L cCa^{2+} 0,98 mmol/L ↓ cCl^- 98 mmol/L Metabolit Värden ↑ cGlu 6,6 mmol/L ↑ cLac 9,4 mmol/L Oximeter Värden ctHb 132 g/L FCOHb -0,7 % FMetHb 1,7 % sO_2 94,8 % Beräknade Värden $cBase(Ecf)_c$ -29,2 mmol/L ↓ $cHCO_3^-(P,st)_c$ 4,1 mmol/L	Blodgasvärden pH 7,179 pCO_2 5,44 kPa pO_2 2,91 kPa Elektrolytvärden ↓ cNa^+ 135 mmol/L cK^+ 4,0 mmol/L cCrea 564 µmol/l cCa^{2+} 1,06 mmol/L cCl^- 101 mmol/L Metabolitvärden ↑ cGlu 6,6 mmol/L ↑ cLac 11,4 mmol/L Oximetervärden ctHb 141 g/L FCOHb 0,3 % FMetHb 1,0 % sO_2 26,0 % Beräknade Värden $cBase(Ecf)_c$ -12,2 mmol/L $cHCO_3^-(P,st)_c$ 13,3 mmol/L	Blodgasvärden ↓ pH 7,238 ↓ pCO_2 1,07 kPa ↑ pO_2 18,8 kPa Elektrolytvärden ↑ cNa^+ 147 mmol/L cK^+ 2,4 mmol/L cCrea 105 µmol/l cCa^{2+} 1,25 mmol/L ↑ cCl^- 113 mmol/L Metabolitvärden ↑ cGlu 31 mmol/L cLac 1,5 mmol/L Oximetervärden ctHb 164 g/L FCOHb 1,7 % FMetHb 0,6 % sO_2 98,5 % Beräknade Värden $cBase(Ecf)_c$ -24,0 mmol/L $cHCO_3^-(P,st)_c$ 8,8 mmol/L
Expected Compensation • Δ HCO3 = 24 - 4 = 20 • Δ pCO2 = 20 x 0.16 = 3.2 • Expected pCO2 = 5.3 – 3.2 = 2.1 • Actual pCO2 = 1.9 **Interpretation** • Appropriate respiratory compensation: there are **no** apparent respiratory disorders	**Expected Compensation** • Δ HCO3 = 24 - 13 = 11 • Δ pCO2 = 11 x 0.16 = 1.8 • Expected pCO2 = 5.3 – 1.8 = 3.5 • Actual venous pCO2 = 5.44 • Actual arterial pCO2 approx 4.4 **Interpretation** • The patient has a respiratory acidosis	**Expected Compensation** • Δ HCO3 = 24 – 9 = 15 • Δ pCO2 = 15 x 0.16 = 2.4 • Expected pCO2 = 5.3 – 2.4 = 2.9 • Actual pCO2 = 1.07 **Interpretation** • The patient has a respiratory alkalosis

		
Expected Chronic Compensation • Δ pCO2 = 12.1 – 5.3 = 6.8 • Δ HCO3 = 6.8 x 2.62 = 18 • Expected HCO3 = 24 + 18 = 42 • Actual HCO3 = 25 **Interpretation** • Acute respiratory acidosis	**Expected Chronic Compensation** • Δ pCO2 = 8.0 – 5.3 = 2.7 • Δ HCO3 = 2.7 x 2.62 = 7.1 • Expected HCO3 = 24 + 7 = 31 • Actual HCO3 = 29 **Interpretation** • Chronic respiratory acidosis	**Expected Chronic Compensation** • Δ pCO2 = 5.3 -1.7 = 3.6 • Δ HCO3 = 3.6 x 3.0 = 11 • Expected HCO3 = 24 - 11 = 13 • Actual HCO3 = 23 **Interpretation** • Acute respiratory alkalosis

3. IONS?

Anion Gap

In order to preserve electroneutrality, the summative electrical charge of cations in the blood is equal to the summative electrical charges of cations. The following equations refer to electrical charges:

Cations = Anions
Na + Other Cations = Cl + HCO_3 + Other Anions
Na – (Cl + HCO3) = Other Anions – Other Cations

Na – (Cl + HCO3) is referred to as the **anion gap.** The anion gap represents the resulting excess of anions relative to cations in the blood were it possible to remove Na, Cl and HCO3. These anions are primarily negatively charged proteins such as albumin, which may account for up to 75% of the anion gap [1]. K is usually not factored into the anion gap calculation since it has a relatively low concentration relative to Na, Cl and HCO3 [13]. Normal anion gap values depend on the method used to measure Na, Cl and HCO3. Older methods yield a normal anion gap of 12 +/- 2 mmol/L, while ion selective electrodes yield a normal anion gap of 6 +/- 3 mmol/L [13]. If the albumin value is available, a corrected anion gap can be calculated in the following manner:
cAG = AG + 0.25 x (42 - [albumin] in g/L) [14].

Metabolic Acidosis with Elevated Anion Gap

When the **anion gap is elevated**, it suggests that additional anions are present in the blood. The presence of an elevated anion gap indicates the presence of a metabolic acidosis, regardless of the pH. Routinely calculating the anion gap may reveal the presence of a metabolic acidosis in a patient with a normal pH, pCO2 and HCO3 (BG 57 yo). The differential diagnosis of an elevated anion gap can be recalled using the **MUDPILES** mnemonic.

Differential Diagnosis of Elevated Anion Gap Metabolic Acidosis

	Substance	Pathophysiology
M	• **M**ethanol	The toxic metabolite formate and lactate account for the anion gap [15].
	• **M**etformin	Elevated lactate levels (often > 15 mmol/L) result from impairment of oxidative phosphorylation [16], enhanced conversion of glucose to lactate in the small intestine and inhibition of gluconeogenesis [17].
U	• **U**remia	The anion gap metabolic acidosis seen in advanced renal failure (glomerular filtration rate < 20 ml/min) results from retention of phosphates, sulphates, urate and hippurate anions in the plasma [18].
D	• **D**iabetic ketoacidosis	In the absence of insulin, lipolysis generates free fatty acids which are converted into the ketones ß-hydroxybutyrate and acetoacetate (BG 25 yo). The ratio of ß-hydroxybutyrate to acetoacetate is usually 3:1 [19].
P	• **P**ropylene glycol	Propylene glycol is the carrier of intravenous lorazepam and phenobarbital, and may result in an anion-gap metabolic acidosis when high doses of intravenous lorazepam are administered for 24 hours of longer [20]. Propylene glycol is metabolized into pyruvate, L-lactate and D-lactate which account for the elevated anion gap [15].
	• **P**yroglutamic	The organic acid pyroglutamic acid (5-oxoproline) accumulates in the

	acid	setting of glutathione deficiency brought on by nutritional deficiency, chronic acetaminophen ingestion, critical illness [21].
I	• **I**ron	Iron induced as lactic acidosis through gastrointestinal bleeding and hypovolemic shock, as well as through inhibition of oxidative phosphorylation [22].
	• **I**soniazid	Isoniazid interferes with vitamin B6 metabolism leading to impaired synthesis of gamma-aminobutyric acid (GABA), which results in seizures and lactic acidosis. Isoniazid also impairs conversion of lactate to pyruvate [23].
L	• L-**L**actate	See Differential Diagnosis of L-Lactic Acidosis below.
	• D-**L**actate	D-lactic acidosis occurs in patients with short bowel syndrome after consumption of a carbohydrate load. Bacteria in the colon metabolize the carbohydrates to D-lactate, which is absorbed and slowly metabolized in humans. The standard lactate level (L-lactate) remains normal [1].
E	• **E**thylene glycol	The toxic metabolites glycolate, glyoxylate and oxalate as well as lactate account for the elevated anion gap [15] (BG 63 yo)
	• **E**thanol ketoacidosis	The anion gap in ethanol (alcoholic) ketoacidosis results mainly from the ketoacid ß-hydroxybutyrate [1]. The ratio of ß-hydroxybutyrate to acetoacetate is 6:1 [19] (BG 57 yo).
S	• **S**alicylates	Salicylate toxicity leads to an uncoupling of oxidative phosphorylation, resulting in increased production of pyruvate and increased conversion of pyruvate to lactate. Increased lipolysis leads to ketone body production. [24]
	• **S**olvents	Solvents are composed of multiple hydrocarbons that contribute to the metabolic acidosis. Toluene, for example, is metabolized to hippuric acid which accumulates in the setting of hypovolemia and results in an elevated anion gap [25].
	• **S**tarvation ketoacidosis	Fasting in the absence of physiological stress rarely leads to a pH < 7.3 [26]. However, the combination of fasting and physiological stress may lead to a more pronounced metabolic acidosis [27, 28]. The elevated anion gap results from the breaddown of fat to produce beta-hydroxybutyrate, acetoacetate, and acetone [29].

There are several other mnemonics for the differential diagnosis of an elevated anion gap, among others GOLD MARK which stands for: Glycols (ethylene glycol, propylene glycol), Oxoproline, L-lactate, D-lactate, Methanol, Aspirin, Renal failure and Ketoacidosis [30].

L-Lactic Acidosis

L-Lactic acidosis is a major cause of metabolic acidosis with an elevated anion gap and has an extensive differential diagnosis.

Differential Diagnosis of L-Lactic Acidosis

Pathophysiology		Examples
Increased lactate production	Decreased O2 delivery to tissues (Type A lactic acidosis)	• Shock (hypovolemic, cardiogenic, obstructive, distributive) [31] • Severe hypoxemia [32] • Severe anemia (Hb < 50 g/L) [32] • Carbon monoxide poisoning [32]

		• Pheochromocytoma, cocaine [32] • Cancers (due to tumor tissue hypoxia) [32] • Regional ischemia (e.g. compartment syndrome, necrotizing soft tissue infections) [31]
	ATP depletion	• Seizures [32] • Vigorous exercise, shivering, excessive work of breathing [31, 32]
	Aerobic glycolysis (increased glycolysis through ß2-adreno-receptor stimulation)	• Sepsis [32] • ß2-agonists in acute asthma [32] (BG 41 yo) • Psychogenic hyperventilation [33] • Pheochromocytoma, cocaine [32] • Cancers (lymphomas, leukemias, solid tumors)
	Increased conversion of pyruvate to lactate	• Acute alcohol intoxication [34] • Isoniazid intoxication [23]
	Interference with oxidative phosphorylation	• Carbon monoxide poisoning [32] • Cyanid poisoning [32] • Metformin [16] (BG 82 yo) • Nucleoside reverse-transcriptase inhibitors [32] • Methanol, ethylene glycol (usually small increase in lactate)[32] • Salicylates (lactate elevation usually minimal) [32] • Propofol (with prolonged, high-dose infusion) [32] • Iron poisoning [35]
Impaired lactate metabolism	Decreased lactate clearance	• Liver disease e.g. fulminant liver disease, cirrhosis (in conjunction with another cause of lactic acidosis), severe liver metastases [32] • Sepsis [32] • Thiamine deficiency [32]
Falsely elevated		• Glycolate, a metabolite of ethylene glycol, is misinterpreted as lactate by some types of analyzers [36, 37] (BG 50 yo, BG 30 yo).

Decreased Anion Gap

When the **anion gap is decreased**, it suggests either hypoproteinemia, the presence of additional cations in the blood or a falsely elevated chloride value. The differential diagnosis of a decreased anion gap can be recalled using the **LIMBS** mnemonic.

Differential Diagnosis of Decreased Anion Gap

L	• **L**ithium	Decreased anion gap due to the presence of the Lithium cation (BG 54 yo)
	• **L**ow albumin	Decreased anion gap due to low levels of negatively charged proteins. The loss of 10 g/L of albumin is associated with a 2.5 mmol/L drop in the anion gap [38].
I	• **I**odide	Decreased anion gap due to falsely elevated chloride value [13]
M	• **M**yeloma	Decreased anion gap due to a positively charged monoclonal IgG gammopathy
B	• **B**romide	Decreased anion gap due to falsely elevated chloride value [13]
S	• **S**alicylates	Decreased anion gap due to falsely elevated chloride value [39, 40] (BG 52 yo)

Hyperchloremic Metabolic Acidosis

The **anion gap is normal** in the presence of a metabolic acidosis when the drop in the HCO3 level is compensated for by a rise in the chloride level. A normal anion gap metabolic acidosis is thus also referred to as a hyperchloremic metabolic acidosis.

Differential Diagnosis of Hyperchloremic Metabolic Acidosis

Pathophysiology		Examples
Chloride administration		• Aggressive fluid resuscitation with saline • Hyperalimentation (using lysine, histidine, or arginine hydrochloride)
HCO3 loss	Bowel loss	• Diarrhea (BG 91 yo; BG 93 yo) • Ureteral diversions • Biliary, pancreatic or small bowel fistulas
	Renal loss	• Renal tubular acidosis • Carbonic anhydrase inhibitor • Early renal failure (impaired acid excretion) [1]

Delta Anion Gap

The **delta anion gap** refers to the degree the anion gap is elevated or decreased compared to the patient's baseline. For example, if a patient normally has an anion gap of 8 mmol/L and now has an anion gap of 20 mmol/L, the delta anion gap is 12 mmol/L. The delta anion gap corresponds to the amount of "extra anions" (or "missing anions/extra cations" in the context of a decreased anion gap) present in the blood.

The **delta-delta** refers to the relation between the delta anion gap and the change in plasma bicarbonate concentration. In theory, the acquisition of extra anions should be matched by a commensurate drop in bicarbonate, corresponding to a delta-delta of 1. Adding the delta anion gap to the HCO3 reveals whether other metabolic acid-base disturbances are present [13]:

- If the delta anion gap + HCO3 is 24 +/- 2 mmol/L, no additional metabolic acid-base is present
- If the delta anion gap + HCO3 is < 22 mmol/L, an additional hyperchloremic metabolic acidosis
- If the delta anion gap + HCO3 is > 26 mmol/L, an additional metabolic alkalosis (BG 70 yo), or a compensation for a chronic respiratory acidosis, is present.

While the delta-delta in diabetic ketoacidosis is approximately 1 (Adrogué 2005), the delta-delta in lactic acidosis is often greater than 1 and it may vary according to the duration of the acidosis [13].

Blodgasvärden pH 7,419 ↓ pCO_2 4,54 kPa pO_2 9,11 kPa Elektrolytvärden ↓ cNa^+ 128 mmol/L cK^+ 2,8 mmol/L cCrea 39 µmol/l cCa^{2+} 0,95 mmol/L ↓ cCl^- 79 mmol/L Metabolitvärden ↓ cGlu 3,4 mmol/L ↑ cLac 3,5 mmol/L Oximetervärden ctHb 160 g/L FCOHb 2,4 % FMetHb 0,8 % sO_2 91,9 % Beräknade Värden $cBase(Ecf)_c$ -2,2 mmol/L $cHCO_3^-(P,st)_c$ 22,9 mmol/L	Blodgasvärden pH 7,179 pCO_2 5,44 kPa pO_2 2,91 kPa Elektrolytvärden ↓ cNa^+ 135 mmol/L cK^+ 4,0 mmol/L cCrea 564 µmol/l cCa^{2+} 1,06 mmol/L cCl^- 101 mmol/L Metabolitvärden ↑ cGlu 6,6 mmol/L ↑ cLac 11,4 mmol/L Oximetervärden ctHb 141 g/L FCOHb 0,3 % FMetHb 1,0 % sO_2 26,0 % Beräknade Värden $cBase(Ecf)_c$ -12,2 mmol/L $cHCO_3^-(P,st)_c$ 13,3 mmol/L	Blodgasvärden pH 7,306 pCO_2 4,71 kPa pO_2 2,10 kPa Elektrolytvärden cNa^+ 140 mmol/L cK^+ 4,5 mmol/L cCrea 364 µmol/l cCa^{2+} 1,20 mmol/L cCl^- 111 mmol/L Metabolitvärden cGlu 6,1 mmol/L cLac 1,3 mmol/L Oximetervärden ctHb 140 g/L FCOHb 0,6 % FMetHb 0,7 % sO_2 20,4 % Beräknade Värden $cBase(Ecf)_c$ -8,0 mmol/L $cHCO_3^-(P,st)_c$ 16,6 mmol/L
• pH normal • pCO2 < 5.0: *mild* respiratory alkalosis • HCO3 23 yet lactate 3.5: *mild* metabolic acidosis • AG: 128 – 79 – 23 = 26 • Expected AG ≈ 11 (57 years) • Delta AG: 15, thus ***marked* metabolic acidosis!** • Adjusted HCO3: 23 + 15 = 38: *marked* **metabolic alkalosis** • Lactate of 3,5 mmol/L • 11,5 mmol/L of anions remain to be accounted for	• pH < 7.38 & HCO3 < 22: **metabolic acidosis** • AG: 135 – 101 – 13 = 21 • Expected AG ≈ 9 (42 years) • Delta AG: 12 • Interpretation: increased AG metabolic acidosis (lactic) • Lactate accounts for DG • There is no suspicion of an alternative explanation for the increased AG	• pH < 7.38 & HCO3 < 22: **metabolic acidosis** • AG: 140 – 111 – 17 = 12 • Expected AG ≈ 12 (93 years) • Delta AG: 0 • Interpretation: **hyperchloremic metabolic acidosis** (diarrhea)

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<tr>
<td>
Blodgas Värden
pH 7,28
pCO_2 5,3 kPa
pO_2 31,9 kPa
Elektrolyt Värden
cNa^+ 123 mmol/L
cK^+ 6,2 mmol/L
cCa^{2+} 1,31 mmol/L
cCl^- 107 mmol/L
Metabolit Värden
cGlu 7,6 mmol/L
cLac 2,9 mmol/L
Oximeter Värden
ctHb 158 g/L
FCOHb 0,5 %
FMetHb 0,5 %
sO_2 99 %
Beräknade Värden
cBase(Ecf)c -7,6 mmol/L
$cHCO_3^-$(P,st)c 18 mmol/L

Anteckningar
c Beräknade värden
</td>
<td>
Blodgasvärden
↓ pH 7,024
↑ pCO_2 17,9 kPa
↑ pO_2 27,1 kPa
Elektrolytvärden
cNa^+ 143 mmol/L
cK^+ 5,8 mmol/L
cCrea 106 µmol/l
cCa^{2+} 1,32 mmol/L
cCl^- 101 mmol/L
Metabolitvärden
↑ cGlu 15,8 mmol/L
cLac 1,1 mmol/L
Oximetervärden
ctHb 174 g/L
FCOHb 0,7 %
FMetHb 0,5 %
sO_2 98,8 %
Beräknade Värden
$cBase(Ecf)_c$ 2,7 mmol/L
$cHCO_3^-(P,st)_c$ 20,2 mmol/L
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<tr>
<td>
Step 1
• pH < 7.38 & HCO3 < 22: metabolic acidosis
Step 2
• Δ pCO2 = 6 x 0.16 = 1
• Expected pCO2 = 4.3: respiratory acidosis
Step 3
• AG: 123 - 107 - 18 = - 2: lithium intoxication?
</td>
<td>
Step 1
• pH < 7.38
• pCO2 > 5.7: respiratory acidosis
• HCO3 < 22: metabolic acidosis
Step 3
• AG: 143 - 101 - 20 = 22
• Delta AG: 10 (75 years)
• Adjusted HCO3: 20 + 10 = 30
Steg 4 (pat with severe COPD)
• Chronic respiratory acidosis with metabolic compensation
• Metabolic acidosis with elevated AG: uremia?
• Acute respiratory acidosis (COPD exacerbation?)
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4. DIAGNOSES?

Diagnostic formulation (e.g. diabetic ketoacidosis and metabolic alkalosis due to vomiting) necessitates an integration of all available clinical and biochemical data.

Metabolic Alkalosis

Differential Diagnosis of Metabolic Alkalosis (adapted from Tintinalli 2011 Chapter 19)

Pathophysiology		Examples
HCO3 administration		• Overzealous correction of a metabolic acidosis
H+ shifts intracellular		• Hypokalemia
H+ loss	Gastrointestinal loss	• Vomiting • Chloride wasting enteropathy • Cystic fibrosis • Laxative abuse
	Renal loss	• Extracellular volume depletion • Diuretic therapy • Renal artery stenosis • Conn's syndrome • Cushing's syndrome • Exogenous mineralocorticoids (e.g. licorice, fludrocortisone)

Respiratory Acidosis

Differential Diagnosis of Respiratory Acidosis

Anatomy	Examples
Central Nervous System	• Vascular problems, e.g. stroke, hemorrhage • Infectious conditions, e.g. encephalitis, transverse myelitis • Primary tumors or metastases • Degenerative conditions, e.g. amyotrophic lateral sclerosis • Drugs, e.g. opioids, alcohol, benzodiazepines, barbiturates • Trauma to the brain or spinal cord • Metabolic encephalopathies, e.g. hepatic encephalopathy
Peripheral Nervous System	• Nerve dysfunction, e.g. phrenic nerve paralysis, Guillain Barré syndrome • Neuromuscular junction conditions, e.g. myasthenia gravis, botulism
Musculoskeletal	• Muscular conditions, e.g. myopathies, muscular dystrophy • Skeletal: kyphoscoliosis, ankylosing spondylitis
Pulmonary	• Upper airway obstruction, e.g. angioedema • Lower airway obstruction, e.g. COPD*, life-threatening asthma • Alveoli: pneumonia, pulmonary edema • Blood vessels: massive pulmonary embolism • Pleura: pneumothorax, hemothorax

* COPD: Chronic Obstructive Pulmonary Disorder, either as a chronic condition or as an acute exacerbation

An **acute respiratory acidosis** is typically caused by:
• airway obstruction from acute asthma exacerbation or pneumonia

- depression of the central respiratory center from cerebral disease (e.g. trauma) or drugs (e.g. sedatives)

A **chronic respiratory acidosis** is typically caused by:
- chronic obstructive pulmonary disease
- neuromuscular disease (e.g. muscular dystrophy, kyphoscoliosis)

Respiratory Alkalosis

Differential Diagnosis of Respiratory Alkalosis

Pathophysiology	Examples

Hypoxia-driven	• Intrinsic lung disease and/or ventilation-perfusion mismatch, e.g.
	  ○ pulmonary edema
	  ○ pneumonia
	  ○ pulmonary embolism
	  ○ aspiration
	• Severe anemia

Non hypoxia-driven	• Pain • Anxiety • Medications: salicylates (stimulates the respiratory center in the brainstem), methylxanthines (theophyllamine, koffein), nicotine • Pregnancy (progesterone) • Gram-negative sepsis • Hepatic encephalopathy • Brainstem pathology

An **acute respiratory alkalosis** is typically caused by:
- lung conditions such as pneumonia, pulmonary edema, pulmonary embolism, aspiration
- pain, anxiety, stroke, intoxications (e.g. salicylates)

A **chronic respiratory alkalosis** is typically caused by:
- pregnancy
- hyperthyroidism
- hepatic failure

Example #1
The following arterial blood gases came from an 82 year-old man with chronic obstructive pulmonary disease (COPD) who sought care because of shortness of the breath.

Blodgas Värden		
pH	7,425	
pCO_2	6,60	kPa
pO_2	7,46	kPa
Elektrolyt Värden		
cNa^+	138	mmol/L
cK^+	4,1	mmol/L
cCrea	67	µmol/L
cCa^{2+}	1,20	mmol/L
cCl^-	99	mmol/L
Metabolit Värden		
cGlu	12,4	mmol/L
cLac	1,9	mmol/L
Oximeter Värden		
cHb	178	g/L
FCOHb	2,1	%
FMetHb	0,1	%
sO_2	90,0	%
Beräknade Värden		
cBase(Ecf)c	7,4	mmol/L
$cHCO3^-$(P,st)c	29,9	mmol/L

Anteckningar
c Beräknade värden

Interpretation

1-The pH is > 7.42 and the HCO3 is > 26, hence a metabolic alkalosis is present.

2-The expected respiratory compensation for a metabolic alkalosis is an increase in pCO2. The HCO3 is roughly 5 mmol/L elevated. 5 x 0.08 = 0.4 Hence the expected pCO2 should be 5.3 + 0.4 = 5.7. Given that the pCO2 exceeds this value, the patient also has a respiratory acidosis.

3-The anion gap is 9 mmol/L. The delta anion gap is likely negligeable.

4-One possible interpretation is thus that of a metabolic alkalosis with an appropriate respiratory compensation. However, this interpretation does not take into account the fact that the patient has COPD, the likely cause of the patient's elevated hemoglobin value (178 g/L).

A more likely, though more complex interpretation, is that the patient has a chronic respiratory with a metabolic compensation. The patient has now developed a respiratory infection, leading to hypoxia and to an acute respiratory alkalosis. Despite the high pCO2, the patient is hyperventilating relative to baseline, accounting for the alkalemia.

Example #2

The following venous blood gas came from an 86 year-old man with chronic obstructive pulmonary disease who sought care because of shortness of the breath.

Blodgas Värden		
pH	7,350	
pCO_2	7,21	kPa
pO_2	3,91	kPa
Elektrolyt Värden		
cNa^+	140	mmol/L
cK^+	4,6	mmol/L
*c*Crea	107	μmol/L
cCa^{2+}	1,16	mmol/L
cCl^-	97	mmol/L
Metabolit Värden		
*c*Glu	7,3	mmol/L
*c*Lac	2,9	mmol/L
Oximeter Värden		
*c*Hb	140	g/L
*F*COHb	1,7	%
*F*MetHb	0,1	%
sO_2	45,3	%
Beräknade Värden		
*c*Base(Ecf)c	3,8	mmol/L
c$HCO3^-$(P,st)c	25,6	mmol/L

Anteckningar

c Beräknade värden

Interpretation

1-The pH is < 7.38 and the pCO2 i > 5.7 kPa (a venous pCO2 of 7.2 corresponds roughly to an arterial pCO2 of 6.2), hence a respiratory acidosis is present.

2-The Δ pCO_2 is 6.2 - 5.3 = 0.9. If the respiratory acidosis is acute, the expected Δ HCO_3 0.75 x 0.9 = 0.63, with an expected HCO3 of 25 mmol/L. If the respiratory acidosis is chronic, the expected Δ HCO_3 is 2.62 x 0.9 = 2.36, with an expected HCO3 of 26.4 mmo/L.

3-The anion gap is 17-18 mmol/L. The delta anion gap is therefore around 8 mmol/L. This indicates that there is a metabolic acidosis with an elevated anion gap and an additional metabolic alkalosis, since HCO3 + delta AG = 34 mmol/L.

4-How does one make sense of these findings within the clinical context? The patient's Na and K argue somewhat against dehydration and the history and physical examination may also argue against deydration. In this case, the metabolic alkalosis may be a compensation for a chronic respiratory acidosis. The patient has an additional metabolic acidosis with an elevated anion gap. The cause is unclear but the elevated lactate accounts for some of the delta AG. In this scenario, a respiratory alkalosis also needs to be invoked to account for the near normal pH. In summary, one hypothesis is that this patient with COPD has a baseline respiratory acidosis with a metabolic compensation, and now an acute respiratory alkalosis and an anion gap metabolic acidosis.

A-a GRADIENT

The **alveolar-arterial oxygen gradient** (A-a gradient) can help identify the presence of intrinsic lung disease, ventilation-perfusion mismatch, or right-to-left shunt. The A-a gradient is the difference between the partial pressure of oxygen in the alveoli (PAO2) and the partial pressure of oxygen in the arterial blood (PaO2).

When the pressures are measured in **mm Hg**, the following formulas apply:

- PAO2 = FiO2 x 713 - PaCO2 x 1.25
- PAO2 when the patient is breathing room air = 21% x 713 - PaCO2 x 1.25 = 150 - PaCO2 x 1.25
- A-a gradient = PAO2 - PaO2.
- A normal A-a gradient in young persons is < 10, whereas a normal A-a gradient in the elderly is < 20 [1]. Alternatively, a normal A-a gradient is (age +4)/4.

When the pressures are measured in **kPa**, the following formulas apply:

- PAO2 = FiO2 x 95 - PaCO2 x 1.25
- PAO2 when the patient is breathing room air = 21% x 95 - PaCO2 x 1.25 = 20 - PaCO2 x 1.25
- A-a gradient = PAO2 - PaO2.
- A normal A-a gradient in young persons is < 1.3, whereas a normal A-a gradient in the elderly is < 2.7 [1]. Alternatively, a normal A-a gradient is (age +4)/30.

The PaO2 can be estimated from the SpO2% using the table on the left below. The FiO2 can be estimated from the delivered supplemental oxygen using the table on the right below (http://www.intensive.org/epic2/Documents/Estimation%20of%20PO2%20and%20FiO2.pdf)

SpO2%	PaO2 (mm Hg)	PaO2 (kPa)
80	44	5,9
81	45	6,0
82	46	6,1
83	47	6,3
84	49	6,5
85	50	6,7
86	52	6,9
87	53	7,1
88	55	7,3
89	57	7,6
90	60	8,0
91	62	8,3
92	65	8,7
93	69	9,2
94	73	9,7
95	79	10,5
96	86	11,5
97	96	12,8
98	112	14,9
99	145	19,3

Method	O2 flow (L/min)	Estimated FiO2%
Nasal cannula	1	24
	2	28
	3	32
	4	36
	5	40
	6	44
Face mask	5	40
	6-7	50
	7-8	60
Face mask with reservoir	6	60
	7	70
	8	80
	9	90
	10	95

CHAPTER 05–ELECTROCARDIOGRAM

The electrocardiogram (EKG) is a useful adjunct to the ABCDE. A 12-lead electrocardiogram can rapidly be acquired in the Emergency Department and is often obtainable in the prehospital arena as well, making it possible to diagnose ST-elevation myocardial infarctions and arrange for direct transport to the coronary intervention unit.

The interpretation of the 12-lead EKG benefits from a systematic approach, which can be organized according to the mnemonic **OPQRST+**:

1. Overview: Rate & Rhythm
2. P wave & PR segment
3. Q wave & QRS complex
4. R wave: QRS Axis & Ventricular Hypertrophy
5. S wave & ST-segment
6. T wave & QTc interval
7. +: Additional Findings

This chapter focuses on the interpretation of the constituent parts of the EKG. If not otherwise specified, a height of 10 mm on the EKG corresponds to 1 mV. EKGs that illustrate pathological findings (EKG xx yo) are provided in Appendix 2. The electrocardiographic changes found with specific diagnoses (e.g. hyperkalemia, pulmonary embolism, pericarditis, ST-elevation myocardial infarction) or syndromes (wide complex tachyarrhythmia) are presented in other chapters.

1. OVERVIEW: RATE & RHYTHM

Rate

When the paper speed of the rhythm strip is 25 mm/sec, one large box (5 mm per side) corresponds to 0.2 seconds. The heart rate in beats per minute (bpm) can be estimated by dividing 300 by the number of large boxes between two adjacent QRS complexes. When the paper speed is 50 mm/sec, the heart rate is 600 divided by the number of large boxes between two adjacent QRS complexes. When the paper speed is 12.5 mm/sec, the heart rate is 150 divided by the number of large boxes.

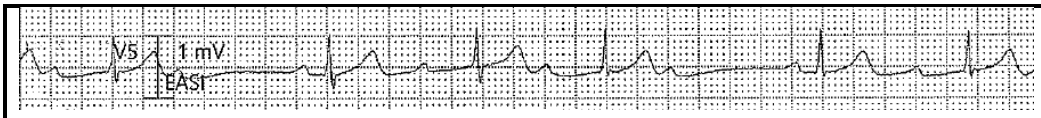
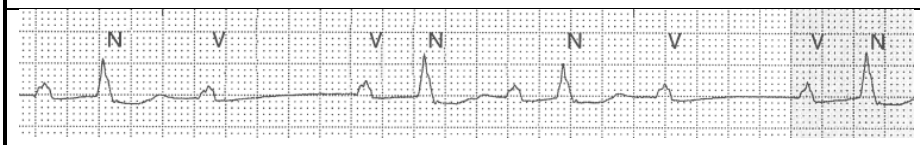
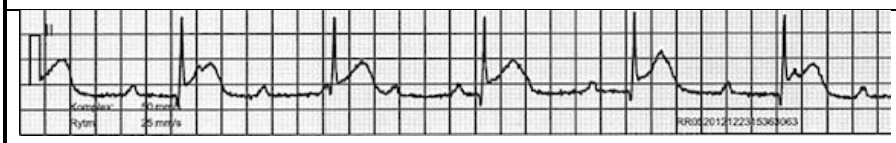
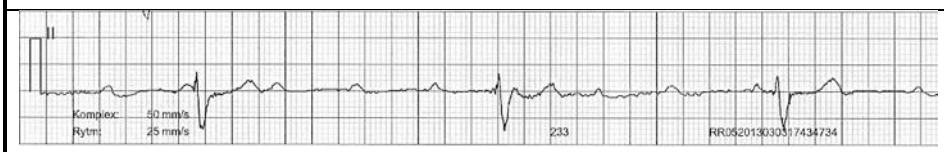
Rhythm

The rhythm can usually be determined by examining the rhythm strip and taking into account the heart rate, regularity, QRS width, presence of P waves and their relationship with the QRS complexes.

Sinus rhythm is likely when:
- there is a P wave preceding each QRS complex
- there is a QRS complex following each P wave
- the P wave is positive in lead II
- the PR interval is between 0.12 and 0.2 seconds.

Second degree AV block is present when occasional P waves are not followed by a QRS complex.
- Second degree AV block Mobitz type 1 (also known as Wenckebach) is present when the PR interval gradually lengthens until no QRS complex follows the P wave (EKG 79 yo Wenckebach, EKG 64 yo Wenckebach, EKG 20 yo Wenckebach).
- Second degree AV block Mobitz type 2 is present when the PR interval is constant (EKG 68 yo, EKG 50 yo). Second degree AV block type 2 is more likely to progress to 3rd degree AV block than type 1.

Third degree AV block is a bradyarrhythmia characterized by the absence of temporal relationship between the P waves and the QRS complexes, so-called AV dissociation.
- The QRS is narrow if generated by a pacemaker located proximal to the bifurcation of the bundle of His, in which case the heart rate is typically 40-60 beats/min and referred to as an AV nodal escape rhythm (EKG 54 yo inferior STEMI).
- The QRS is wide if generated in the ventricle, in which case the heart rate is typically 20-40 beats/min and referred to as a ventricular escape rhythm (EKG 79 yo presyncope; EKG 75 yo).

	**Second degree AV block Mobitz type 1**
	**Second degree AV block Mobitz type 2**
	**Third degree AV block**
	**Third degree AV block**

Differential Diagnosis of Conduction Blocks [1]

Pathophysiology	Examples
Vascular	**Myocardial infarction**
Infectious	**Lyme disease**, **toxoplasmosis**, **infective endocarditis**, **myocarditis**, **rheumatic fever**
Infiltrative	**Amyloidosis**, **sarcoidosis**, **lymphomas**
Neurological	Increased vagal tone with **vasovagal syncope** or **sleep apnea**
Degenerative	**Lenègre's disease**, **Lev's disease**
Intoxication	**Beta blocker**, **verapamil**, **cardizem**, **digoxin**
Collagen vascular	**Systemic lupus erythematosus**
Trauma	**Valve surgery**, **ablations** (arrhythmia ablation, ethanol septal ablation)
Electrolytes	**Hyperkalemia**

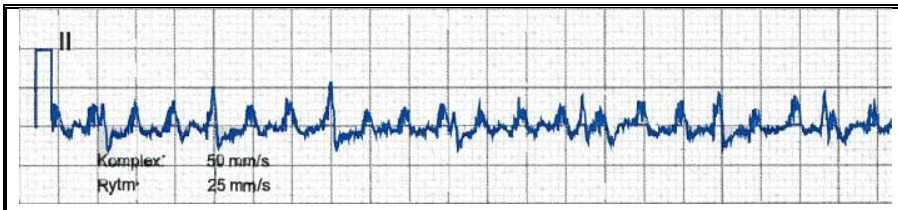
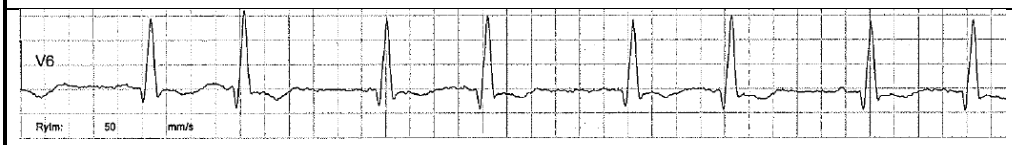
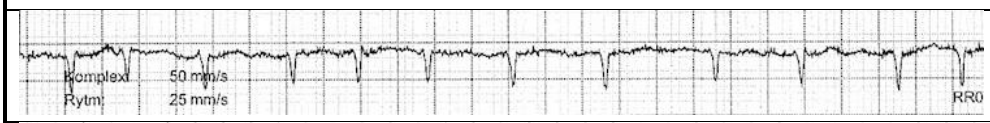
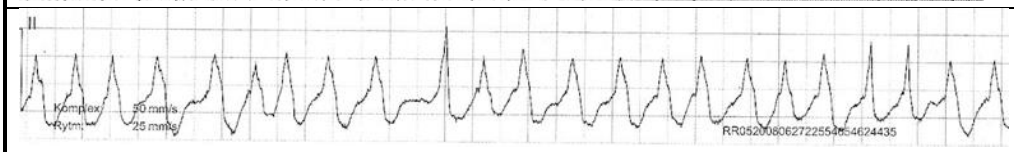
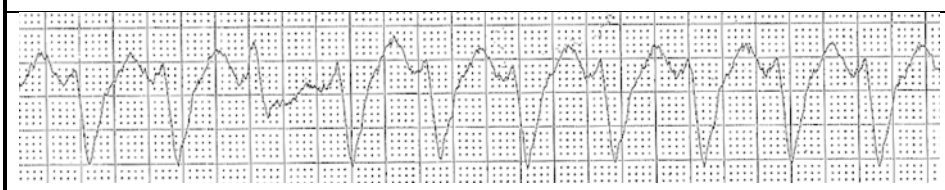
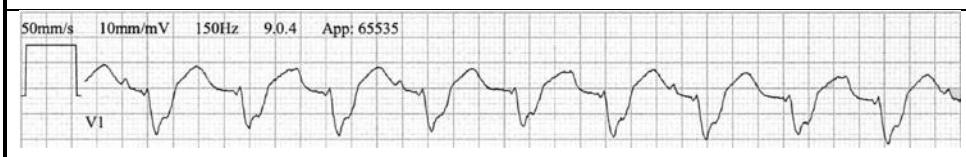
In **atrial flutter**, the atrial rate is usually 300 bpm, but it can be slower in patients taking antiarrhythmic medications. Flutter waves are best seen in lead V1; they may be superimposed upon the T waves. Patients with 2:1 blocked atrial flutter usually have a heart rate of approximately 150 bpm, while patients with 3:1 blocked atrial flutter usually have a heart rate of approximately 100 bpms (EKG 85 yo). When the blocking is not constant, the rhythm is irregular (EKG 37 yo).

Atrial fibrillation is likely when no P waves are present and the rhythm is irregularly irregular, i.e. without any discernible pattern (EKG 85 yo). When combined with a bundle branch block, inhibition of fast sodium channels or pre-excitation, atrial fibrillation results in a wide complex irregular tachycardia. Pre-excitation refers to the abnormal activation of the ventricles via an accessory pathyway. An irregular rhythm with wide QRS complexes and a heart rate > 220 bpm is pathognomonic for atrial fibrillation with pre-excitation [2]. The presence of narrow QRS complexes amid a background of an irregular tachycardia with wide,

monomorphic QRS complexes, is highly suggestive of atrial fibrillation with pre-excitation (EKG 56 yo).

Ectopic atrial tachycardia is suggested by a tachycardia with negative P wave axis in lead II (EKG 39 yo).

Ventricular tachycardia (VT) should be suspected if the heart rate exceeds 130 bpm [3], the rhythm is regular and the QRS complexes are wide (> 120 msec). The presence of P waves with a slower rate than the ventricular rate and no correlation with the QRS complexes (AV dissociation) is pathognomonic for VT (EKG 37 yo). The presence of occasional QRS complexes that are narrower than the main QRS morphology, so-called capture beats or fusion beats, is also pathognomonic for VT. (EKG ? yo capture beat, EKG 37 yo situs inversus)

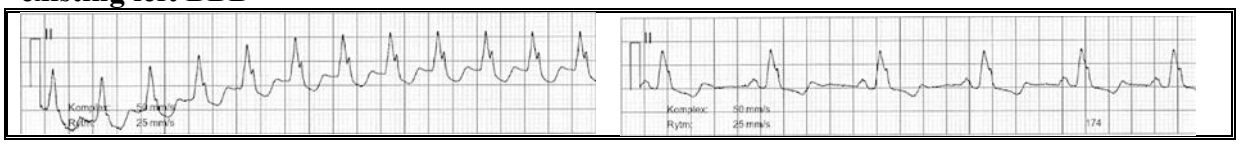
	**Atrial flutter with regular 3:1 conduction, resulting in a heart rate of 100 bpm**
	**Atrial flutter with 2:1 alternating with 3:1 conduction**
	**Atrial fibrillation (25 mm/s)**
	**Atrial fibrillation with pre-excitation (25 mm/s)**
	**Ventricular tachycardia with a capture/fusion beat (50 mm/s)**
	**Ventricular tachycardia with AV-dissociation**

A wide complex regular tachycardias may also be caused by a supraventricular tachycardia associated with:

- inhibition of fast sodium channels, due either to poisoning or hyperkalemia
- pre-excitation

- a bundle branch block (EKG 72 yo) (EKG 70 yo)

Patient presenting with a wide QRS, regular tachycardia. Prior EKG reveals pre-existing left BBB

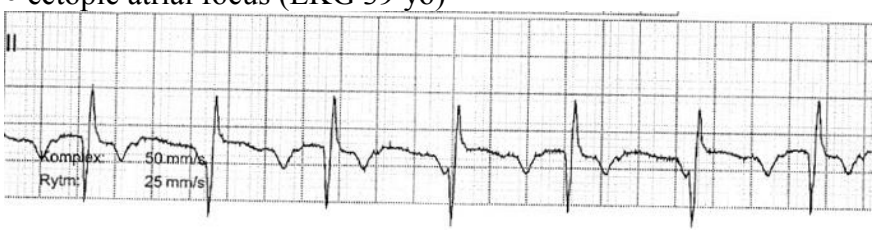


2. P WAVE & PR SEGMENT

P Wave

The P wave is a small deflection preceding the QRS complex and corresponds to atrial depolarization. A normal P wave axis is usually around 60°, and hence positive in lead II [1]. At rest, a normal P wave is < 2.5 mm (0.25 mV) in height and < 0.12 seconds in duration [1].

Negative P waves in lead II suggests one of the following:
- lead placement error
- a retrograde P wave with the atrial depolarization originating from the AV node
- ectopic atrial focus (EKG 39 yo)



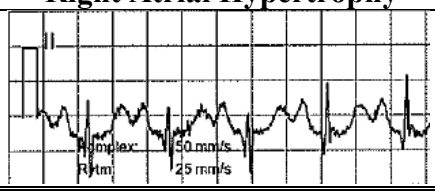
Atrial hypertrophy may be suggested by the appearance of the P waves in leads II and V1 [1]:

Left Atrial Hypertrophy (EKG 61 yo)

Suggestive Findings		Differential Diagnosis
II	Humped or notched P wave and a duration > 0.12 sec	• Hypertensive heart disease • Aortic stenosis, aortic insufficiency • Mitral stenosis, mitral insufficiency • Cardiomyopathy
V1	Biphasic P wave with a terminal negative deflection of > 0.04 sec or > 1 mm (0.1 mV) in depth	

Right Atrial Hypertrophy (EKG 85 yo; EKG 19 yo; EKG 66 yo)

Suggestive Findings		Differential Diagnosis
II	P wave > 2.5 mm, < 0.12 sec	• Pulmonary hypertension, acute or chronic • Pulmonary stenosis, atrial septal defects, Ebstein's anomaly, Tetralogy of Fallot
V1	P wave > 2.5 mm, occasionally negative, < 0.12 sec	

Left Atrial Hypertrophy	Right Atrial Hypertrophy
	

Small P waves may be caused by hyperkalemia. As hyperkalemia worsens, the P waves may disappear altogether despite the continued presence of sinus activity [4] (EKG 78 yo).

PR Segment

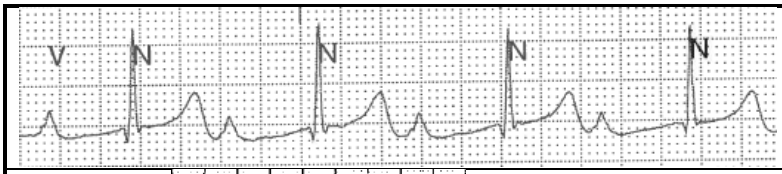
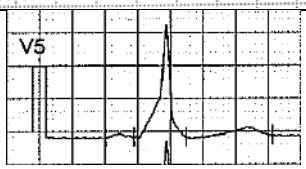
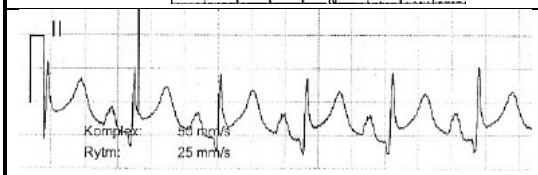
The PR interval is the time from the beginning of the P wave until the beginning of the QRS complex [1] and corresponds to the delay between the onset of atrial depolarization and the onset of ventricular depolarization. A normal PR duration is between 0.12 and 0.2 seconds [1] and the PR interval is usually isoelectric with the EKG baseline.

Prolonged PR interval, i.e. a PR interval > 200 msec, may be caused by the conditions listed above in the table Differential Diagnosis of Conduction Blocks [1]. **First degree AV block** refers to a rhythm with a uniformly prolonged PR interval (i.e. no missing QRS complexes following the P waves) (EKG 20 yo, part of it).

Short PR interval may occur with:

- A non-sinus origin of the P wave
- Pre-excitation, in which the PR interval is cut short by the premature depolarization of the ventricle through an accessory bypass tract, resulting in a slurred upstroke of the QRS complex called a **delta wave** (EKG 20 yo).

Depressed PR segment relative to the TP-segment EKG baseline suggests pericarditis [5, 6] but is not specific for this condition [7] (EKG 67 yo)

	**First degree AV block**
	**Delta Wave, resulting from pre-excitation, and associated with a short PR segment.**
	**PR segment depression in the setting of acute pericarditis. The baseline is a line linking the onset of the P waves**

3. Q WAVE & QRS COMPLEX

Q Wave

Q waves refer to the initial deflection of the QRS complex when the deflection is negative (i.e. below the EKG baseline) [1]. Whether a Q wave is normal depends on the lead and the Q wave's duration, depth, size relative to the R wave, the presence of Q waves in contiguous lead groupings and ST deviations or T wave changes in the same leads [8].

Pathological Q Waves [8]

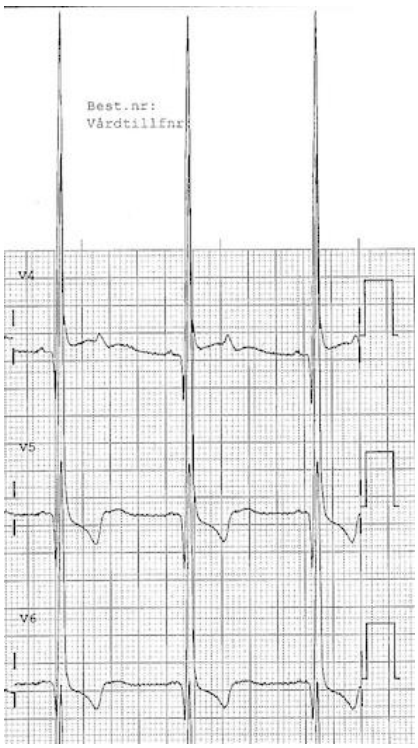
Lead	Pathological Q Wave	Lead	Pathological Q Wave
I, aVL	• Q wave ≥ 0.03 sec and ≥ 0.1 mV deep* • Q wave > 25% of following R wave • QS complex	V1	A QS complex in V1 is normal
II	• Q waves ≥ 0.03 sec and ≥ 0.1 mV deep*	V2, V3	• Q wave ≥ 0.02 sec • QS complex
aVF	• Q wave ≥ 0.03 sec and ≥ 0.1 mV deep* • Q wave > 25% of following R wave • QS complexes	V3	• Q wave ≥ 0.02 sec • QS complex
III	A Q wave < 0.03 sec and < 25% of the R wave amplitude is normal if the frontal QRS axis is between -30° and 0°.	V4-V9	• Q wave ≥ 0.03 sec and ≥ 0.1 mV deep* • Q wave > 25% of following R wave • QS complex

* in any two leads of a contiguous lead grouping (I-aVL; II-III-aVF; V1-V6; V7-V9)

Differential Diagnosis of Pathological Q Waves [8]

Pathophysiology	Examples
Infarction	**Prior myocardial infarction**
Cardiomyopathy	**Obstructive, dilated or stress cardiomyopathy**
Hypertrophy	**Left ventricular hypertrophy**, **right ventricular hypertrophy**
Conduction abnormalities	**Pre-excitation**, **left bundle branch block**, **left anterior hemiblock**
Infiltrative	**Cardiac amyloidosis**
Infectious, inflammatory	**Myocarditis**
Pressure overload	**Acute cor pulmonale**
Electrolytes	**Hyperkalemia**

Narrow (< 0.03 sec), deep Q waves in I, aVL, V5 and/or V6 in a patient with high left ventricular voltage who presents with syncope or presyncope suggests hypertrophic obstructive cardiomyopathy (Amal Mattu http://ekgumem.tumblr.com/post/28409061231/ecg-findings-in-hypertrophic) (EKG 26 yo).



QRS Complex

The QRS complex stretches from the beginning of the Q wave (or the beginning of the R wave in the absence of Q wave) to the J point, i.e. the junction between the QRS complex and the ST-segment. It represents the time required for depolarization to spread throughout the ventricles [1].

- **R wave** refers to the first positive deflection of the QRS complex.
- **S wave** refers to the negative deflection of the QRS complex following an R wave.
- **R' wave** refers to positive QRS complex deflection following an S wave.
- **QS wave** refers to an entirely negative QRS complex [1].

A normal QRS duration in adults is ≤ 100 msec [1]; such 'narrow' QRS complexes indicate that the site of cardiac activation is at or above the bifurcation of the bundle of His [2], that the His-Purkinje system distal to the bifurcation is functioning properly and that the myocytes are depolarizing normally.

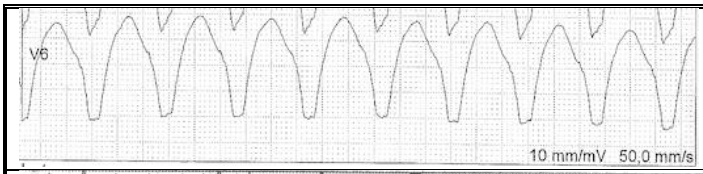
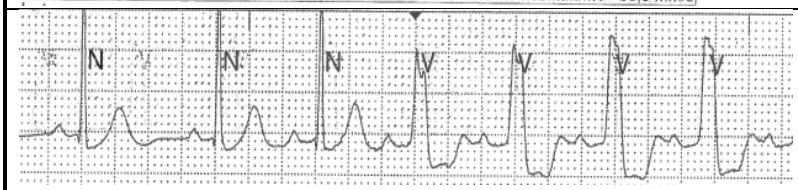
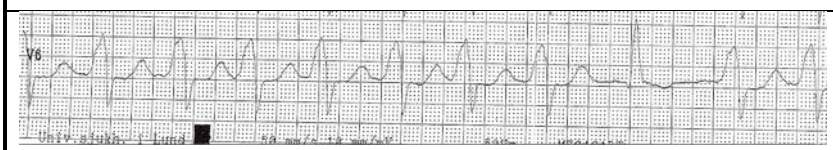
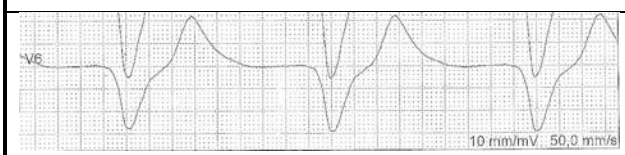
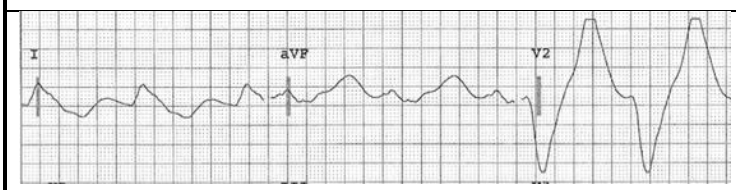
Wide QRS complexes indicate one of the following:

- that the depolarization of the ventricles has not occurred via a healthy HIS-purkinje system [1], e.g. in the presence of a left bundle branch block (LBBB) or right bundle branch block (RBBB)
- abnormally functioning fast sodium channels, e.g. due to hyperkalemia or poisoning

Differential Diagnosis of Wide QRS complexes

Pathophysiology	Examples
Depolarization originates in the ventricle	• **Premature ventricular beat** (EKG 79 yo) • **Ventricular escape rhythm** in AV block III (EKG 45 yo) • **Paced ventricular beats**. In the setting of right ventricular pacing, the EKG shows a LBBB pattern (EKG 95 yo). If a patient with a pacemaker shows a RBBB pattern, it indicates that the pacemaker

	wire is stimulating the left ventricle [9, 10] • **Ventricular tachycardia** (EKG 61 yo)
Bundle branch block	• **Left bundle branch block** (EKG 25 yo) • **Right bundle branch block** +/- left fascicular blocks • **Tachycardia-related bundle branch block** [2] • **Ashman's phenomenon,** whereby a long RR interval is followed by a short RR interval and a wide QRS complex at the end of the short RR interval due to incomplete repolarization of a bundle branch (typically right bundle branch) (EKG 78 yo)
Accessory pathway	• Part of the ventricle is prematurely depolarized through an accessory pathway, such as a with the Wolff-Parkinson-White syndrome (EKG 83 yo, EKG 56 yo) • **Antidromic atrioventricular reentry tachycardia** (AVRT)
Hyperkalemia	• **Hyperkalemia** interferes with the functioning of sodium channels [11], thereby impending phase 0 and resulting in a wide QRS complex (EKG 78 yo)
Membrane stabilization	• Intoxication with **class I antiarrhythmics** and other **sodium channel blocking agents** inhibits the fast cardiac sodium channels, a phenomenon known as 'membrane stabilization' [12] (EKG 54 yo). The compounds that can produce this effect are listed in Chapter 07 Sodium Channel Blockade Toxidrome.

	**Monomorphic Ventricular Tachycardia**
	**Supraventricular tachycardia leading to a rate-related bundle branch block, and erroneously interpreted as a ventricular tachycardia**
	**Irregular wide QRS complex tachycardia with an occasional narrow QRS complex: atrial fibrillation with pre-excitation**
	**Broad QRS complexes resulting from hyperkalemia. The heart rate is around 70 bpm. P waves are not visible.**
	**Mild tachycardia (around 110 bpm; 50 mm/s) with very wide QRS complexes resulting from poisoning with a sodium channel blocking agent**

	(Amitryptiline in this case)

Complete bundle branch block is suggested by QRS complex duration > 120 msec in adults, > 100 msec in children 4 to 16 years of age, and > 90 msec in children less than 4 years of age [13] accompanied by other morphological criteria.

Left Bundle Branch Block (LBBB) (EKG 25 yo) [1, 13]

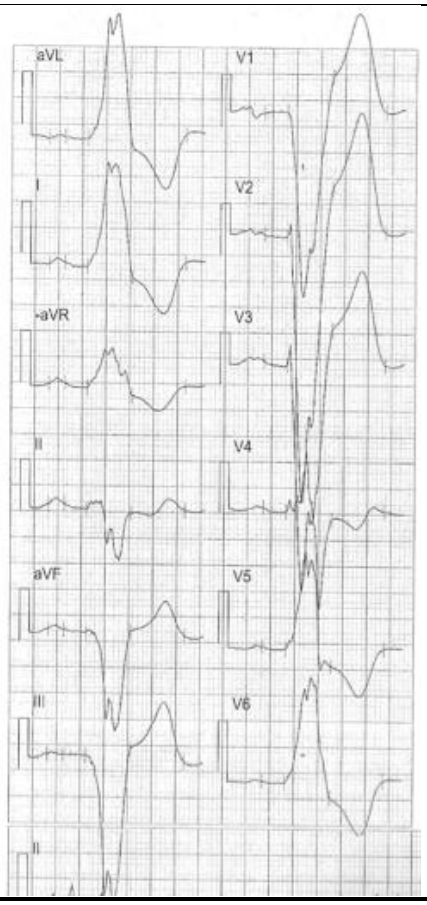
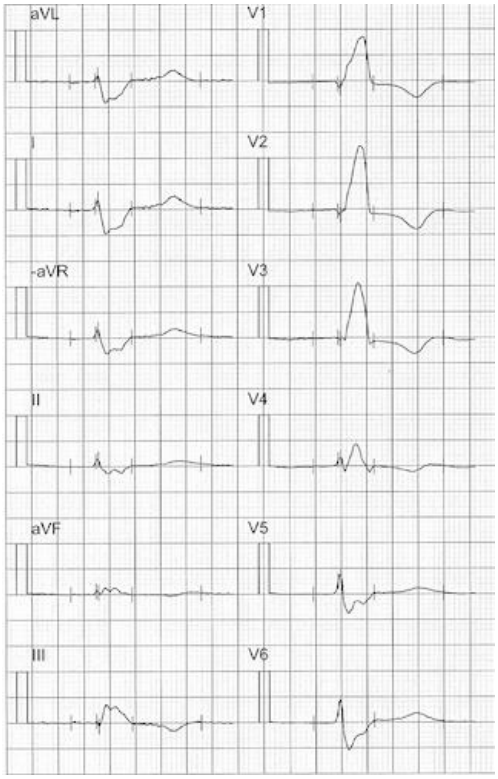
Suggestive Findings	Differential Diagnosis
• Wide, entirely negative QS complex in V1 (rarely, a wide rS complex) • Wide, tall R wave without a Q wave in V6	• Long-standing hypertensive disease • Valvular lesion (e.g. aortic stenosis, aortic regurgitation) • Cardiomyopathies • Coronary artery disease • Degenerative changes

Right Bundle Branch Block (RBBB) (EKG 50 yo RBBB) [1, 13]

Suggestive Findings	Differential Diagnosis
• rSR' appearance in V1 or V2. The R' deflection is usually wider than the initial r wave. • qRS pattern in V6 with a wide S wave of greater duration than the R wave or > 40 ms in leads I and V6 in adults. • When a pure dominant R wave with or without a notch is present in V1, the R peak time in leads V5 and V6 is normal while the R peak time in lead V1 is > 50 ms.	• Atrial septal defect with left-to-right shunt • Chronic pulmonary disease with pulmonary artery hypertension • Pulmonary stenosis • Cardiomyopathies • Coronary artery disease • Chronic degenerative changes

A **right bundle branch block** combined with a **left anterior fascicular block** (EKG 50 yo RBBB) results in
- A wide QRS complex with a wide S wave in V6
- A leftward axis

A **right bundle branch block** combined with a **left posterior fascicular block** (EKG 91 yo) results in
- A wide QRS complex with a wide S wave in V6
- A rightward axis

Left Bundle Branch Block	Right Bundle Branch Block with Left Posterior Fascicular Block
	

If a patient with **pacemaker** who initially has a LBBB pattern on the EKG (due to right ventricular pacing) now presents with a RBBB pattern, it indicates that the pacemaker wire has become dislodged and is now stimulating the left ventricle [9, 10].

The **Ashman phenomenon** refers to a bundle branch block pattern classically seen in patients with atrial fibrillation. A long RR cycle is followed by a short RR cycle ('long-short' rule), and the second beat of that combination shows a bundle branch pattern (usually RBBB) [2] (EKG Ashman).

4. R WAVE: QRS AXIS & VENTRICULAR HYPERTROPHY

QRS Axis

The mean QRS electrical axis (hereafter referred to as "QRS axis") refers to mean direction of the QRS complex as seen on the coronal plane of the body. The EKG leads that map the heart's electrical activity onto the body's coronal plane ar the limb leads. A normal QRS axis lies between -30° and +100° [1]. When the QRS complex is positive in both lead I and lead II, the QRS axis lies between - 30° and + 90° and is thus normal.

QRS axis deviation can be detected by noting the polarity of the QRS complexes in leads I and II [1]:

QRS Axis Deviation

Lead I	Lead II	QRS Axis	Differential Diagnosis
QRS -	QRS +	Rightward shift +90° to + 150° (EKG 67 yo)	• Right ventricular hypertrophy • Left posterior hemiblock • Lateral wall myocardial infarction • Chronic lung disease (e.g. emphysema) • Acute right ventricular overload (e.g. PE)
QRS +	QRS -	Leftward shift -30° to - 90°	• Left ventricular hypertrophy • Left anterior hemiblock • Left bundle branch block • Inferior wall myocardial infarction • Endocardial cushion defects (congenital)
QRS -	QRS -	"Northwest" axis +150° to -90°	• Incorrect lead placement • Situs inversus (EKG 37 yo) • Heart transplant
Isoelectric QRS	Isoelectric QRS	Indeterminate axis	• Normal variant • Intoxication with sodium channel blockers • Hyperkalemia

Ventricular Hypertrophy

Ventricular hypertrophy may be suggested by the height of the R wave in specific leads, by the sum of the R wave and the S wave in specific leads, or by additional findings. The criteria listed in the following tables have varying sensitivies and specificities [14].

Left Ventricular Hypertrophy (LVH) [1]

Suggestive Findings	Differential Diagnosis
• R_{aVL} > 11-13 mm • S_{V1} + R_{V5} or R_{V6} > 35 mm (i.e. > 3.5 mV) • S_{V3} + R_{aVL} > 28 mm in men; > 20 mm in women • Slight ST-segment depression followed by an asymmetrically inverted T wave in V5-V6 • EKG findings of left atrial hypertrophy • Left axis deviation	• Systemic hypertension • Aortic stenosis, aortic regurgitation • Mitral regurgitation • Dilated, hypertrophic cardiomyopathy

Right Ventricular Hypertrophy (RVH) [1] (EKG 19 yo)

Suggestive Findings	Differential Diagnosis
• R wave exceeding the S wave in lead V1 • Right axis deviation • T wave inversions in V1-V3 • EKG findings of right atrial hypertrophy	• Pulmonary hypertension • Pulmonary stenosis

Tall R waves in lead V1, defined as an R/S ratio ≥ 1, are unusual. The QRS complex in lead V1 usually shows as small R wave (due to left-to-right septal depolarization) followed by a large S wave (due to the dominance of left ventricular depolarization). The differential diagnosis of **tall R waves in lead V1** is[15]:

- Normal variant occuring in 1% of the population
- Right bundle branch block
- Left ventricular ectopy
- Right ventricular hypertrophy
- Acute right ventricular dilatation (strain)
- Hypertrophic cardiomyopathy
- Progressive muscular dystrophy
- Dextrocardia
- Misplaced leads
- Posterior myocardial infarction: tall R waves in V1-V2, associated with ST depression and upright T waves, provide a "mirror image" of the Q waves, ST elevation and inverted T waves seen on the posterior leads V7-V9 in the setting of a posterior STEMI [16] (EKG 90 yo)

5. S WAVE & ST SEGMENT

S Waves

- The sum of the S waves and R waves in specific leads may suggest left ventricular hypertrophy (see previous section).
- A wide S wave in V6 of greater duration than the R wave or an S wave > 40 ms in leads I and V6 in adults, combined with a wide QRS complex, suggests a right bundle branch block.

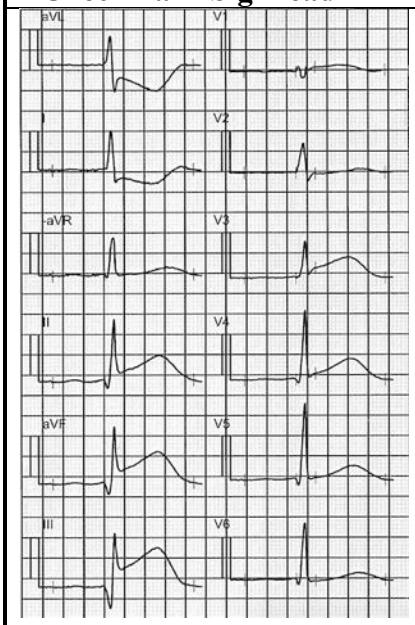
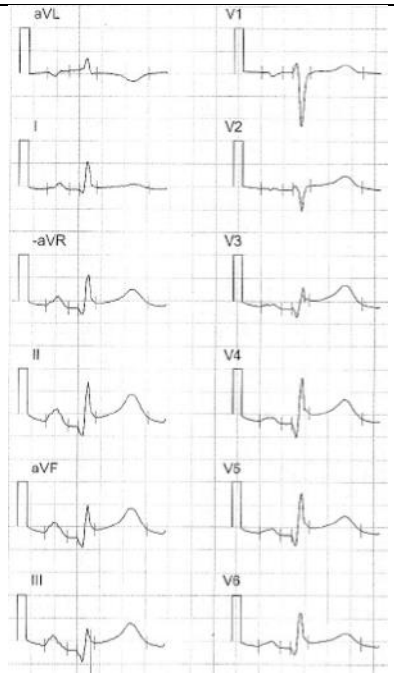
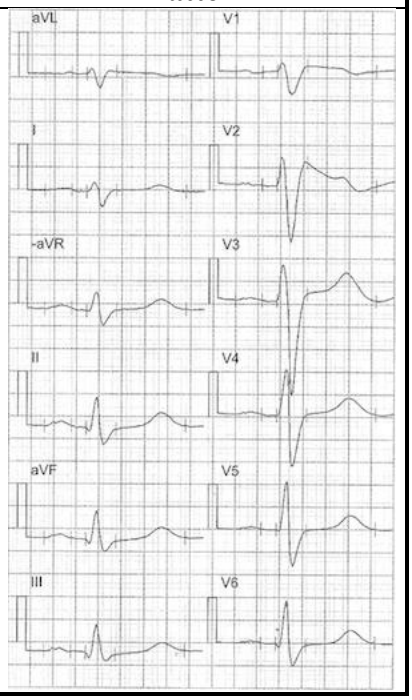
ST Segment

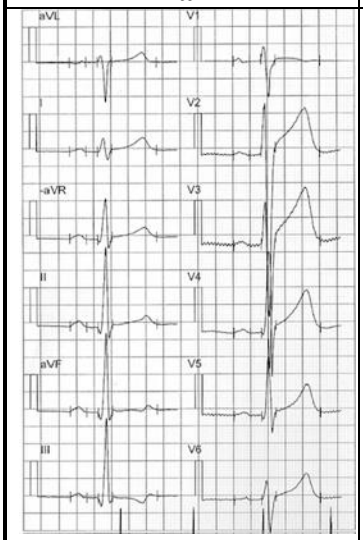
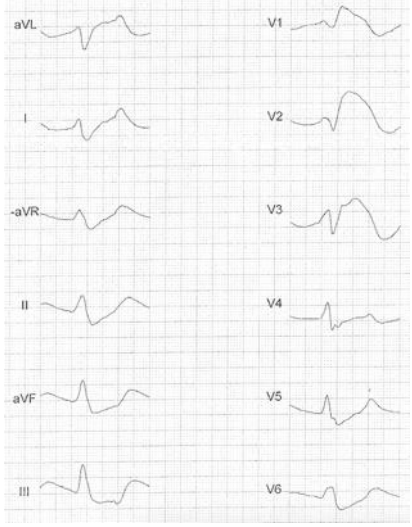
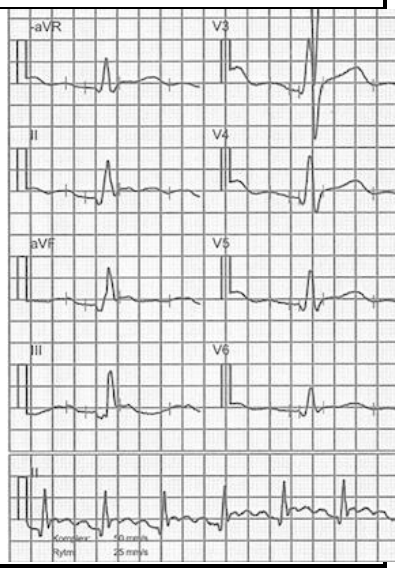
The **ST-segment** streches from the end of the QRS complex to the beginning of the T wave and represents the beginning of ventricular repolarization [1]. The junction between the QRS complex and the ST-segment is referred to as the **J point** [1]. The differential diagnosis of ST-segment elevation and depression is presented in the following tables.

Differential Diagnosis of ST-Segment Elevation (see [17] and [18])

Pathophysiology	Characteristics
STEMI	• **Horizontal or convex (dome-shaped)** ST-segment elevation suggests STEMI. The ST-segment elevation in STEMI may also be concave. • **ST-segment elevation in lead III > ST-segment elevation in lead II** strongly suggests STEMI instead of pericarditis (Mattu https://www.youtube.com/watch?v=cE71p9mfOq8) • **Check-mark sign** refers to a QR-T complex, i.e. a complex where the QR complex seems to merge directly with the T wave without an intervening S wave; this complex suggests STEMI [7] (EKG 54 yo). • **Reciprocal ST-segment depressions** may be present (EKG 46 yo antero-lateral STEMI). • **The location of the ST-segment elevation** corresponds to the culprit lesion (see Chapter 07 STEMI)
Diffuse Ischemia	• **Type 2 myocardial infarctions** (resulting e.g. from decreased perfusion) can lead to ischemic ST-segment elevations that are not limited to a specific coronary territory (EKG 92 yo)
Normal	• **Normal ST-segment elevation** occurs in 90% of healthy young men in the precordial leads [18] (EKG 22 yo). The ST elevations are concave up, and there are no reciprocal ST depressions.
Early Repolarization	• ST-segment elevation associated with a notch at the J point in V4 is referred to as 'early repolarization.' It is common in healthy young people in the anterior leads. The ST-segment is concave up and the T waves are upright in V2 – V6. • Early repolarization occurring in the inferior leads, especially with a J-point elevation of > 0.2 mV, appears to be associated with an increased risk of death from cardiac causes and arrhythmias in middle-aged patients (Tikkanen 2009). Another study showed an association between early repolarization in the inferolateral leads and ventricular fibrillation (Haissaguerre 2008).
Pericarditis	• ST-segment elevations are **concave (saddle-shaped)** and **diffuse**, i.e. not limited to a specific coronary territory • **Reciprocal ST-segment depressions are absent** (EKG 67 yo; EKG 25

	yo-1) • ST-segment elevation to T wave amplitude ratio ≥ 0.25 in lead V6 strongly suggests pericarditis [19]
LVH	• ST-segment elevation in the precordial leads can occur in the context of left ventricular hypertrophy
LBBB	• A LBBB results in ST-segment elevation in the precordial leads. • A pacemaker that stimulates the right ventricle will also result in a LBBB pattern. • A STEMI equivalent in the setting of a LBBB can be detected using the Sgarbossa criteria (Chapter 07 STEMI)
Hyperkalemia	• Elevated ST-segments can occur in the context of hyperkalemia, so-called pseudoinfarct pattern [4] (EKG 66 yo).
Brugada	• The Brugada pattern consists of [20] (EKG 39 yo): o a downward sloping ST-segment elevation in leads V1 + V2 o a complete or incomplete right bundle branch block • The Brugada pattern is due to a heritable defect in sodium channels in the myocytes. It may be associated with life-threatening arrhythmias and/or a family history of sudden cardiac death, in which case the criteria for the so-called Brugada syndrome are fullfilled and an implantable cardiodefibrillator is recommended.
Flutter	• Flutter waves may lead to ST-segment elevation (EKG 52 yo).
Takotsubo Cardiomyopathy	• Takostubo cardiomyopathy is also referred to as apical ballooning syndrome, stress cardiomoypathy and broken heart syndrome [21] • ST-segment elevation on EKG which usually yields to T wave inversions within hours • The condition is characterized by the acute onset of chest pain, dyspnea, shock, the absence of pathological coronary artery obstruction on angiogram, left ventricular systolic dysfunction with ballooning of the apex on angiography in conjunction with normal or increased contraction of the basilar area., Prior to angiography, the condition cannot be clinically distinguised from STEMI.

ST-Elevation from STEMI Checkmark Sign lead III	ST-Elevation from Pericarditis	ST-Elevation from Brugada Pattern
		

ST-Segment Elevation in a healthy 22-year-old man	ST-Segment elevation from hyperkalemia ("Pseudoinfarct Pattern")	ST-Segment elevation from Flutter Waves
		

Differential Diagnosis of ST-Segment Depression (adapted from [1])

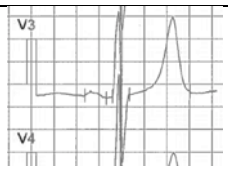
Pathophysiology	Characteristics
Ischemia	• ST-segment depression from subendocardial ischemia (EKG 33 yo; EKG 53 yo) • Reciprocal ST-segment depression from a transmural myocardial infarction
LVH / RVH	• ST-segment depression resulting from ventricular hypertrophy is termed 'strain pattern.'
BBB	• Bundle branch blocks lead to ST-segment depression in certain leads.
Medications	• 'Scooping" or 'coving' ST-segment depression suggests a pharmacological effect, e.g. secondary to **digoxin** [22].
Metabolic	• **Hypokalemia** can result in ST-segment depression

6. T WAVE & QT DURATION

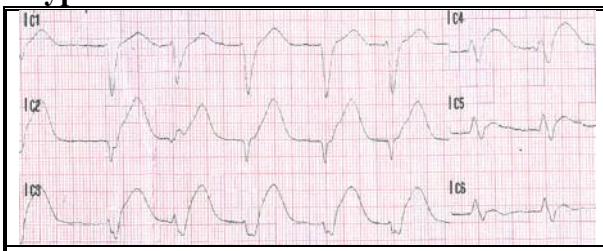
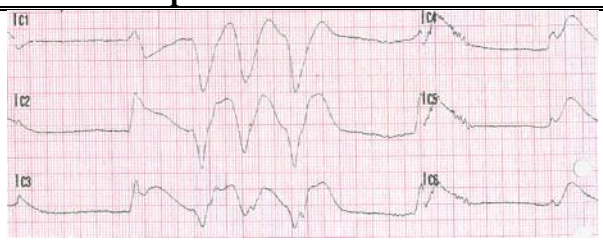
T Wave

The **T wave** is the EKG deflection that follows the QRS complex. Where the ST-segment ends and the T wave beginnings is somewhat arbitrary [1]. The T wave corresponds to part of ventricular repolarization [1]. Normal T waves are asymmetrical, with a slower rise to peak or descent to trough and faster return to baseline [1].

Differential Diagnosis of Large Positive T waves

Pathophysiology	Characteristics	
Myocardial ischemia	• **Hyperacute T waves** refer to tall, symmetrical T waves seen in the acute phase of a transmural infarction [1], possibly resulting from localized extracellular hyperkalemia [23] (EKG 46 yo 1a + 2a; EKG 55 yo; EKG 60 yo?; EKG 67 yo)	
Hyperkalemia	• **'Tenting' and 'peaking' of the T wave** refer to tall, symmetrical T waves generally considered to be the earliest EKG sign of hyperkalemia [4] (EKG 78 yo; EKG 87 yo).	

Hyperacute T Waves in Leads V2-V3 Prior to the Development of ST-Elevation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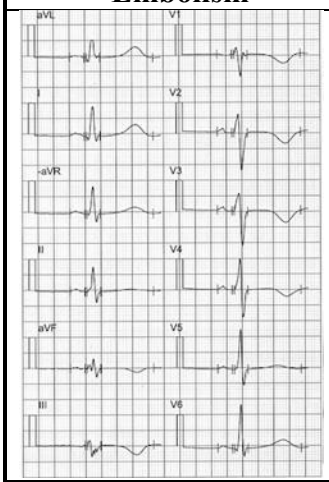
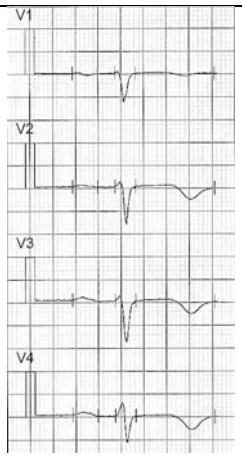
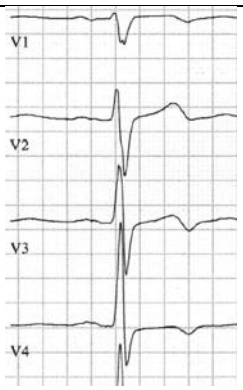
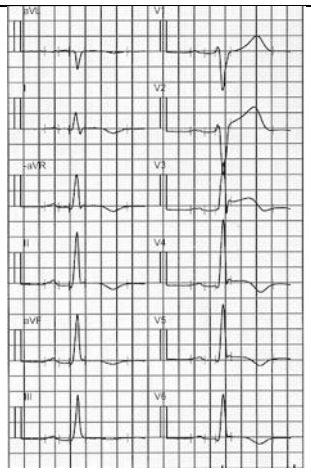
Differential Diagnosis of Negative T waves

Pathophysiology	Characteristics
Normal	• **Normal, negative T waves** can be seen in leads with a negative QRS complex, e.g. in V1 [1]
Left ventricular hypertrophy	• The typical left ventricular strain pattern consists of an initially convex (dome-shaped), gradually downward sloping ST-segment leading to an inverted, asymmetric T wave with an abrupt return to the baseline in the lateral leads (I, aVL, V5, V6) [24]
Pulmonary embolism	• Negative T waves in the precordial leads (V1-V4) are often seen in patients with acute coronary syndrome (ACS) and pulmonary embolism (PE). In a series of 300 patients with negative precordial T waves, the presence of negative T waves in both III and V1 suggested PE as opposed to ACS (SN 90%, SP 97%) [25] (EKG 85 yo, EKG 45 yo, EKG 62 yo). Lead III faces the inferior region of the right ventricle while leads V1 and V2 face its anterior region [25]. Pressure overload may impair coronary flow and the inverted T waves may reflect ischemia. The same findings may be expected in other conditions of RV pressure overload, e.g. pulmonary hypertension.

Myocardial infarction	• Negative T waves occur during the evolving phase of a Q wave myocardial infarction and sometimes with a non-Q wave myocardial infarction. The negative T wave results from a delay in regional repolarization produced by the ischemic injury [1].
Myocardial ischemia	• Deep symmetrical T wave inversions (type 1) (EKG 76 yo; EKG 64 yo; EKG 84 yo) or biphasic T wave changes (type 2) (EKG 47 yo) in V2 and V3, in a patient with a history of angina pain who is pain free, suggest tight LAD stenosis. This pattern is referred to as '**Wellens' syndrome**' or '**LAD coronary-T wave syndrome**' and suggests left anterior descending artery stenosis [26-29]. Cardiac enzymes may be negative. These patients do not require immediate percutaneous intervention but should be admitted for coronary angiography.
Takotsubo	• Takotsubo (stress) cardiomyopathy is a cardiac syndrome characterized by ST-segment elevation, negative T waves, elevated cardiac enzymes and transient left ventricular apical ballooning without obstructive coronary disease. In a series of 300 patients with negative T waves in the precordial leads, negative T waves in leads -aVR and no negative T waves in lead V1 identified Takotsubo cardiomyopathy with SN 95% and SP 97% [25].
CVA-T waves	• Very deep, widely splayed negative T waves may occur in the setting of cerebrovascular accidents such as subarachnoid hemorrhage, and are referred to as 'CVA-T waves' [1, 30]
Pericarditis	• Diffusely inverted T waves may be seen weeks following acute pericarditis [1, 5] (EKG 25 yo-2)

T-wave Inversions from Pulmonary Embolism	**Wellens type 1 T-Wave Inversions**	**Wellens type 2 Biphasic T waves**	**T-wave Inversions from Subacute Pericarditis**
			

Abnormal T Wave Morphology

Pathophysiology	Characteristics
Pseudo-normalization	• Pseudonormalization of the T waves refers to a normal T wave replacing a negative T wave in a patient with acute chest pain or angina equivalent. Such a phenomenon suggests acute coronary syndrome [26].
Biphasic, notched T wave	• The T waves of patients with hereditary long QT syndromes are frequently abnormal with a biphasic contour or a prominent notched component [31].

QT Interval

The **QT interval** is measured from the Q wave until the end of the T wave. It represents ventricular depolarization and repolarization. The QT interval varies with the heart rate, and the Bazett formula is used to correct for the heart rate: QTc = QT / square root of the RR interval expressed in seconds (Seslar Congenital Long QT Syndrome). The lower limit of a normal QTc interval is around 330 msec but has not been well defined [1].

A **prolonged QTc interval** (upper one percent) is > 470 msec in adult men, > 480 msec in adult women and > 460 msec in 1 – 15 year-olds [31]. QTc prolongation is associated with certain arrhythmias, predominantly the polymorphic ventricular tachycardia called torsade de pointes.

Differential Diagnosis of Prolonged QTc Interval [1]

Pathophysiology	Examples
Electrolytes	• **Hypokalemia**, **hypomagnesemia**, **hypocalcemia** (less commonly)
Medications	• **Antiarrhythmics**, especially Class IA (Quinidine, pronainamide) and Class III (Ibutilide, Sotalol, Amiodarone) • **Antidepressants**, e.g. tricyclic antidepressants. • **Antipsychotics**, e.g. phenothiazines • **Antihistamines**, e.g. • **Miscellaneous**, see http://www.azcert.org for a complete list
Hereditary	• **Congenital Long QT Syndrome** is caused by 'channelopathies,' i.e. abnormal ion channel function in the heart that result in prolonged repolarization [1].
Ischemia	• **Myocardial ischemia** [1]
Other	• **Cerebrovascular accidents** [1] • **Hypothermia** prolongs the QT interval by slowing the repolarization of myocardial cells [1]

Differential Diagnosis of Short QTc Interval

Pathophysiology	Examples
Electrolytes	• **Hypercalcemia**, **hyperkalemia**
Medications	• **Digitalis**

7. ADDITIONAL FINDINGS

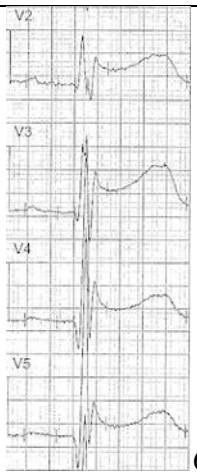
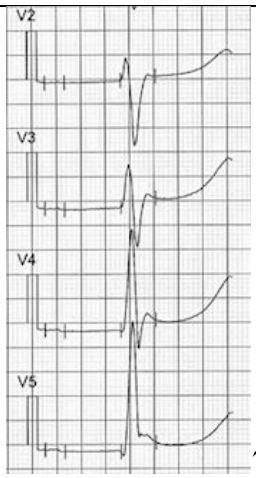
U Waves

U waves are positive deflections following the T waves that are sometimes seen in leads V4-6. They represent the last phase of ventricular repolarization [1]. U waves are usually low voltage (< 0.2 mV) and have the same polarity as the T wave [23]. Negative U waves may appear after positive T waves in the setting of left ventricular hypertrophy and myocardial ischemia [1].

Differential Diagnosis of U Waves

Pathophysiology	Examples
Electrolytes	• **Hypokalemia**, **hypercalcemia**
Metabolic	• **Thyrotoxicosis**
Medications	• **Sotalol**, **phenothiazines**, **digitalis** and other medications [1]
Other	• **Cerebrovascular accidents** can lead to prominent U waves in conjunction with CVA T waves [1]

Osborn Waves

Osborn waves, also known as **prominent J waves**, are found in hypothermia [32] (EKG 60 yo EKG 74 yo). The mechanism appears to be related to the differential effects of systemic cooling on the repolarization of different layers of the ventricles [1].	 60-year-old	 74 year-old

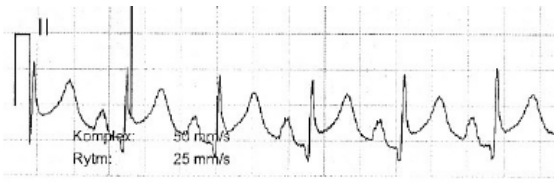
Epsilon Waves

Episolon waves are low amplitude notches found right after the QRS in the right precordial leads (V1-V3). They suggest arrhythmogenic right ventricular dysplasia (ARVD), a genetic disorder leading to fibro-fatty changes that can cause sudden cardiac death in young people [33, 34]. Other EKG findings that may be present in patients with ARVD include [35]:

- QRS duration ≥ 110 msec in V1-V3
- S wave upstroke (from the nadir of the S wave to the isoelectric line) ≥ 55 msec in V1-V3 (95% of patients); the interval between the nadir of the S wave and the end of all depolarization deflections is referred to as the Terminal Activation Ducation (TAD).
- T wave inversions in V1-V3 (85% of patients)
- QRS duration > 110 msec in I [33]

Spodick Sign

Spodick sign refers to downsloping of the TP-segment and suggests acute pericarditis [7] (EKG 67 yo).



CHAPTER 06–ULTRASOUND

Point-of-care ultrasound is a powerful adjunct to the ABCDE during the initial assessment of potentially critically ill patients. Ultrasound may provide key information that allows for the identification and management of many resuscitation syndromes. As an example, one study showed that point-of-care ultrasound improved the initial diagnostic accuracy among patients with non-traumatic shock in the ED from 50% to 80% [1].

Point-of-care ultrasound may be used to answer specific questions, e.g. whether pleural fluid is present. Ultrasound may also be used as a screening examination during the initial assessment of a critically ill patient, in the same way that the ABCDE, bedside blood tests and the electrocardiogram may be considered screening instruments that can provide unexpected pivotal findings. The ultrasound findings may then be best interpreted in conjunction with other information to recognize resuscitation syndromes (Chapter 07).

There are several protocols that are tailored to specific situations, e.g.
- RUSH (**R**apid **U**ltrasound in **S**hock and **H**ypotension) in the setting of hypotension and/or shock [2]
- EFAST (**E**xtended **F**ocused **A**ssessment with **S**onography in **T**rauma) in the setting of trauma [3]
- BLUE (**B**edside **L**ung **U**ltrasound in **E**mergency) in the setting of dyspnea [4]
- CAUSE (**C**ardiac **A**rrest **U**ltra-**S**ound **E**xam) in the setting of cardiac arrest [5]

This chapter presents a **generic** point-of-care ultrasound screening examination tailored to the initial management of a critical patient. The examination consists of 5 steps incorporating eight views and is organized according the mnemonic **HIJKL**:

1. Heart: Pericardial fluid? Right-ventricular distension? Contractility?
2. IVC: Inferior vena cava size? Decrease during inspiration?
3. Juice: Free intraperitoneal fluid? Pleural fluid? Hydronephrosis? Gastric/bladder retention?
4. Krack: Abdominal aortic aneurysm?
5. Lung: Lung-sliding? A lines versus B lines?

Ultrasound images (US xx yo) are provided in Appendix 3.

1. HEART

Attempting to visualize the heart first through **subxiphoidal four-chamber view** is easiest and most practical.

Subxiphoidal Four-Chamber View

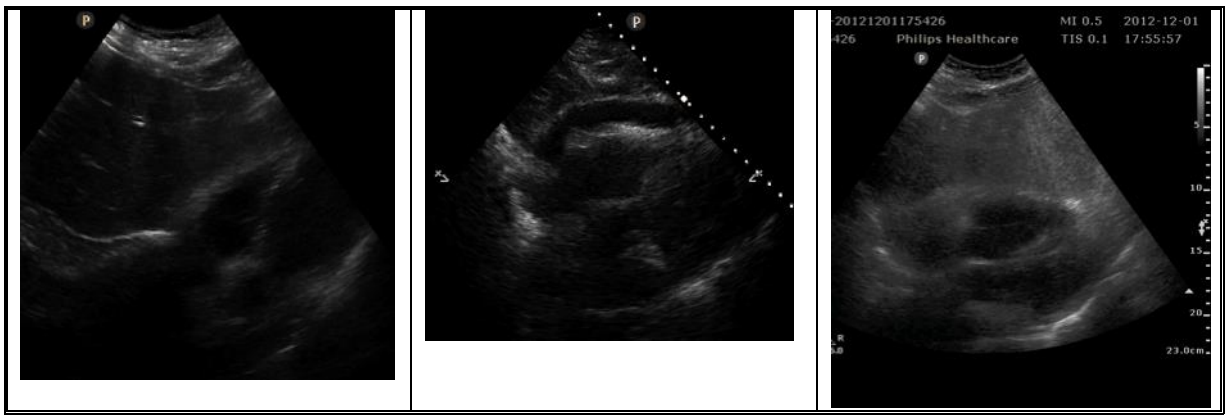
TECHNIQUE

- **Patient**: supine. Having the patient take and hold a deep breath may improve visualization of the heart (EFAST).
- **Probe**: attempt to visualize the heart using the curvilinear probe. If the heart cannot be visualized, switch to the phased array probe with the smaller footprint. Depth is initially set at 20 cm of penetration (EFAST).
- **Placement**: the probe is placed 2-3 cm below the xiphoid process with the orientation marker pointing towards the patient's right when the image preset is in the abdominal mode or towards to the patient's left when the image preset is in the cardiac mode. The transducer is directed towards the patient's chin or left shoulder. Positioning the probe slightly to the right of the xiphoid may allow for better visualization of the heart through the liver, which acts as a sonographic window (SonoSpot Subxiphoidal). The examiner holds the transducer palm down in order to be able to 'flatten' the transducer onto the abdomen.
- **Procedure**: the transducer may initially be aimed posteriorly to visualize the aorta and inferior vena cava (IVC). The transducer is then aimed cephalad towards the patient's left shoulder and the IVC is followed as it merges with the right atrium. Both the inferior and superior pericardial borders should be visualized (SonoSpot Subxiphoidal).

POTENTIAL FINDINGS

- **Pericardial fluid** manifests as an anechoic or echogenic layer surrounding the heart (US 65 yo). Clotted blood results in an echogenic fluid collection; internal movement of the echogenic components (swirling) suggests clotted blood as opposed to an epicardial fat pad (EFAST).
- **Pericardial tamponade** is suggested by collapse of the right atrium in systole (sensitive) [6] and collapse of the right ventricle in diastole (specific) [7].
- **Epicardial fat pad** manifests as a hypoechoic space around the heart whereby the echogenic components appear fixed (no swirling pattern) (EFAST).
- **Intraabdominal fluid** on the caudal side of the diaphragm suggests hemoperitoneum in the trauma patient and ascites in the medical patient (EFAST)
- **Pleural fluid** manifests as fluid to the side of the heart extending laterally (EFAST).
- **Dilated right ventricle** suggests right ventricular pressure overload, e.g. secondary to a large pulmonary embolism.
- **Decreased left ventricular contractility** in the setting of shock suggests a cardiogenic cause.

Normal	Pericardial Fluid	Dilated Right Ventricle



If the heart cannot be visualized subxiphoidally, switch to the **apical four-chamber view**.

Apical Four-Chamber View

TECHNIQUE

- **Patient**: supine or lying in the left lateral decubitus position (this will bring the heart closer to the chest wall) (Philips TTE). The patient can be supported by placing pillows under the right shoulder (Philips TTE). Abducting the left arm will open the intercostal spaces (Philips TTE).
- **Probe**: Phased array (1-5 MHz) (Philips TTE) or curvilinear array with small foot print (2-5 MHz) (EFAST). Depth is initially set at 14-18 cm (Philips TTE).
- **Placement**: on the apical impulse with the orientation marker at 3 o'clock.
- **Procedure**: the transducer is tilted upwards until all four chambers are visualized. The transducer is moved medially-laterally until the long axis of the heart is vertical (Philips TTE). From the apical four chamber view, the face of the transducer is further tilted upward until the aortic valve appears to obtain a five chamber view (Philips TTE).

POTENTIAL FINDINGS

- **Pericardial fluid** may be seen.
- **Pericardial tamponade** is suggested by RV collapse during diastole (Philips TTE).
- **Decreased LV contractility** is suggested by decreased left ventricular wall thickening and reduction in LV size during systole at the papillary muscle level (Philips TTE). Large regional wall motion abnormalities may also be identified.
- **LV hypertrophy** is suggested by thickened LV walls (Philips TTE).
- **RV dilatation** is suggested by an RV size > 2/3rd of the LV size (Philips TTE).

If the heart cannot be visualized apically, switch to the **parasternal long-axis view**.

Parasternal Long-Axis View

TECHNIQUE

- **Patient**: supine or lying in the left lateral decubitus position (this will bring the heart closer to the chest wall) (Philips TTE). The patient can be supported by placing pillows under the right shoulder (Philips TTE). Abducting the left arm will open the intercostal spaces (Philips TTE).

- **Probe**: phased array (1-5 MHz) (Philips TTE) or curvilinear array with small foot print (2-5 MHz) (EFAST). The depth is initially set at 12-16 cm. A depth of 20-24 cm is used to assess for pericardial or pleural effusions (Philips TTE).
- **Placement**: in the 3rd-4th intercostal space with the orientation marker pointing towards the patient's right shoulder (10 o'clock) (Philips TTE). Alternatively, the probe is placed just under the clavicle and just next to the sternal border and then moved caudally from one rib space to another until the heart is found (SonoSpot Cardiac)
- **Procedure**: the following tips are recommended to optimize the image (SonoSpot Cardiac; Philips TTE):
  - slowly changing the angle of the probe (pointing cephalad-caudal) to find the intercostal space that allows for the best view
  - moving up an intercostal space if the interventicular septum and left ventricular wall are angled as opposed to horizontal
  - slowly rotating the probe if the left ventricle appears "closed" in order to visualize the longitudinal view of the heart
  - tilting the transducer away from the septum or sliding the probe medially-laterally in order to place the aortic and mitral valves in the center of the image
  - adjusting the depth in order to visualize the descending aorta

POTENTIAL FINDINGS

- **Pericardial fluid** extends between the posterior section of the left ventricle and the descending aorta (EFAST) (US 79 yo)
- **Pleural fluid** does not pass between the heart and the descending aorta (EFAST)
- **Epicardial fat pad** manifests as a hypoechoic space usually present along the right border of the heart whereby the echogenic components appear fixed (no swirling pattern) (EFAST)
- **Left ventricular hypertrophy** is suggested by thickened LV walls (Philips TTE).
- **Decreased left ventricular contractility** in the setting of shock suggests a cardiogenic cause.
- **Large aortic root** (> 4 cm) in a patient with acute chest pain suggests type A aortic dissection (Stone aorta).
- **Intimal flap** in the aortic root or in the portion of the descending thoracic aorta that can be visualized suggests aortic dissection. Color flow doppler may reveal two lumens with distinct blood flow [2].
- **Heart-point sign** refers to intermittent, flickering visualization of the heart in the parasternal view, whereby the heart is visible during diastole but disappears during systole. It suggests a pneumothorax extending to the precardiac space [8].

If the heart can be visualized using the parasternal long-axis view, it is expeditious to visualize the heart using the **parasternal short-axis view** as well.

Parasternal Short-Axis View

TECHNIQUE

- **Patient**: supine or lying in the left lateral decubitus position (this will bring the heart closer to the chest wall) (Philips TTE). The patient can be supported by placing pillows under the right shoulder (Philips TTE). Abducting the left arm will open the intercostal spaces (Philips TTE).

- **Probe**: phased array (1-5 MHz) (Philips TTE) or curvilinear array with small foot print (2-5 MHz) (EFAST). The depth is initially set at 12-16 cm. A depth of 20-24 cm is used to assess for pericardial or pleural effusions (Philips TTE).
- **Placement**: in the 3rd-4th intercostal space with the orientation marker pointing towards the patient's left shoulder (2 o'clock) (Philips TTE).
- **Procedure**:
  - tilt the transducer's face slightly upward towards the patient's right shoulder to visualize the aortic valve (Philips TTE).
  - tilt the transducer perpendicular to the chest wall to visualize the mitral valve (Philips TTE).
  - tilt the tranducer's face slightly downward towards the patient's left flank to visualize the papillary muscle level (Philips TTE). The LV should be round and in the middle of the screen. If the LV is pear-shaped or asymmetric, move up one intercostal space or rotate the transducer (Philips TTE).

POTENTIAL FINDINGS

- **Pericardial fluid** may be seen surrounding the heart (US 28 yo)
- **Decreased LV contractility** is suggested by decreased left ventricular wall thickening and reduction in LV size during systole at the papillary muscle level (Philips TTE).
- **Hyperdynamic LV** is suggested when the LV chamber, at the papillary muscle level, is almost completely obliterated by wall thickening and motion during systole (Philips TTE).
- **Left ventricular hypertrophy** is suggested by thickened LV walls (Philips TTE).
- **Interventricular septal flattening** during diastole, known as the **"D" sign**, suggests increased right ventricular pressure [9] (Philips TTE).
- The **right ventricle is dilated** if its size is > 2/3rd of the size of the LV (Philips TTE).

2. INFERIOR VENA CAVA

If the subxiphoidal view could be acquired, the intrahepatic inferior vena cava (IVC) can be visualized by positioning the right atrium in the center of the screen and rotating the probe. If the subxiphoidal view was unobtainable, or if the intrahepatic IVC cannot be visualized, the intraabdominal IVC can be visualized during step 4.

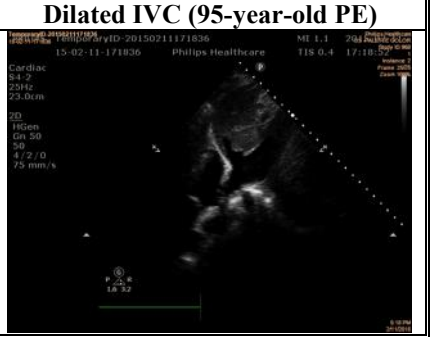
Intrahepatic Inferior Vena Cava

TECHNIQUE

- **Patient**: supine.
- **Probe**: phased array (1-5 MHz) (Philips DVT) or curvilinear array
- **Placement**: 2-3 cm below the xiphoid process. The orientation marker is placed as 12 o'clock. Depth of 16-24 cm (Philips TTE).
- **Procedure**: from visualizing the heart in the subxiphoidal four chamber view, the transducer is rotated 90° counter-clockwise while visualization of the right atrium is maintained, until the IVC, draining into the right atrium, can be visualized. IVC size should be measured caudal to the hepatic vein inlet [10]. M-mode can be used to graphically demonstrate the decrease in size upon inspiration [2].

POTENTIAL FINDINGS

- **Caval index** refers to the relative decrease in IVC diameter during one respiratory cycle.
- **IVC size > 2 cm and caval index < 50%** suggests that the CVP is > 10 cm H2O [2]. In the setting of shock, these findings suggest obstructive (e.g. pericardial tamponade) or cardiogenic shock.
- **IVC size < 2 cm and caval index > 50%** suggests that the CVP is < 10 cm H2O [2] (US 91 yo). One study showed that a caval index ≥ 50% was associated with a central venous pressure (CVP) < 8 mm Hg with SN 91% (71-99) and SP 94% (84-99) [11]. In the setting of shock, these findings suggest hypovolemic or distributive shock [2].
- **The sniff test** refers to an augmentation of respiratory variation in size by having the patient sniff or inspire forcefully [2].

		Dilated IVC (95-year-old PE)
		

3. JUICE

This step consists in three view (perihepatic, perisplenic and suprapubic) allowing for the identification of fluid in various locations.

Perihepatic Window

TECHNIQUE

- **Patient**: supine. Placing the patient in Trendelenburg may improve the sensitivity of identifying intraperitoneal fluid by one-third [12]. Conversely, rolling the patient to examine the back prior to the ultrasound examination will decrease its sensitivity to detect intraperitoneal fluid [13].
- **Probe**: phased array (1-5 MHz) or curvilinear array (2-5 MHz) (EFAST).
- **Placement**: Midaxillary line between the 8th and 11th rib with the orientation marker directed towards the right axilla or towards the right scapula to obtain an oblique view and minimize rib shadows. Depth is initially set at 20 cm (EFAST).
- **Procedure**: The following cephalad-to-caudal examination sequence is recommended (SonoSpot RUQ):
  - above the diaphragm, with a depth of 16-19 cm, having the patient take a deep breath
  - between the diaphragm and the liver
  - between the liver and the entire superior pole of the right kidney, i.e. Morison's pouch, with a depth to 13-16 cm; the whole kidney should be "fanned" through
  - between the left liver edge and entire inferior pole of the kidney, with a further decrease in depth. A common area of fluid accumulation is around the tip of the liver. Fluid may reach this area by coming up from the right pericolic gutter or from the left upper quadrant across the epiploic foramen.
  - Fluid may collect in various locations and therefore it is important to sweep both anteriorly-posteriorly as well as cephalad-caudal direction to detect small amounts of fluid (EFAST).

POTENTIAL FINDINGS

- **Pleural fluid** manifests as anechoic or echogenic area cephalad to the diaphragm (EFAST). The normal "mirror image" of the liver cephalad to the diaphragm is lost. The posterior thoracic cage (vertebral bodies and posterior ribs) will be seen cephalad to the diaphragm due to transmission of the ultrasound waves through the pleural fluid, so-called "**V-line sign**" [14] or "**spine sign**" (SonoSpot Spine Sign) (US V-line sign x 2). In the trauma setting, pleural fluid suggests hemothorax.
- **Tissue-like sign** refers to a liver-appearance of the lung. It indicates translobar consolidation [15]. This finding is also referred to as **hepatization of the lung** [2] (US 38 yo).
- **Shred sign**, also known as **fractal sign,** refers to a shredded, or fractal-like boundary between an area of lung consolidation and surrounding aerated lung. It indicates non-translobar consolidation [15]
- **Morison's pouch** (hepatorenal recess) refers to the interface between **Glisson's capsule** (the capsule surrounding the liver) and **Gerota's fascia**, a layer of connective tissue encapsulating the kidney, adrenal gland and perinephric fat (EFAST).
- **Intraabdominal fluid** manifests as anechoic or echogenic fluid present between Glisson's capsule and Gerota's fascia. The free fluid may extend around the tip of the liver. Free fluid will be linear, curvilinear or triangular when the fluid abuts bowel (EFAST). Free

fluid suggests hemoperitoneum in the setting of trauma and ascites or gastrointestinal perforation in the non-traumatic setting.

- **Retroperitoneal fluid** manifests as anechoic or echogenic fluid between Gerota's fascia and the true capsule of the kidney (EFAST). Ultrasound is insensitive for detecting retroperitoneal bleeding [13, 16].
- **Perinephric fat** manifests as an area of medium-level echogenicity between Gerota's fascia and the true capsule of the kidney. It may be mistaken as echogenic free fluid. The echos within clotted blood move during respiration, while lack of echo movement suggests fat (EFAST). The presence of a **double line sign** (one bright line on the edge of the kidney, and one bright line on the outer edge of the fat) also helps differentiate perinephric fat from fluid (SonoSpot RUQ).
- **Hydronephrosis** manifests in several ways depending on its grade [17]. When the hydronephrosis is mild, the pelvis is open and filled with hypoechoic urine. With moderate hydronephrosis, the calyces are open with blunting (US ho2). With severe hydronephrosis, the calyces are 'ballooned' out, the pyramids/medulla obliterated, while the cortex remains (US 430635).
- **Renal cyst fluid** has a an circular shape with lack of triangular corners (EFAST).
- **Parenchymal injury** to the liver or right kidney in the setting of trauma generally results in hyperechoic areas (EFAST). Ultrasound is insensitive for detecting parenchymal injury [13, 16].
- **Bowel fluid** in the duodenum or hepatic flexure of the colon has round or oval borders since it is contained with the bowel (EFAST). Peristaltic motion may be present.
- **Gallbladder fluid** is contained within an oval structure. The lack of triangular corners argues against intraabdominal fluid (EFAST).
- **Hepatic vein** manifests as an anechoic wedge with liver seen on both sides (EFAST).

Perisplenic Window

TECHNIQUE

- **Patient**: supine.
- **Probe**: phased array (1-5 MHz) or curvilinear array (2-5 MHz) (EFAST).
- **Placement**: posterior axillary line between the 8th and 11th rib, corresponding to the level of the xiphoid process (EFAST), with the orientation marker directed towards to the left axilla or towards the left scapula to obtain an oblique view and minimize rib shadows. Depth is initially set at 20 cm (EFAST).
- **Procedure**: the most important place to look for fluid, between the diaphragm and the spleen, may be masked by air in the left lower lobe as the patient takes an inspiration (**curtain effect**). The patient may be asked to avoid taking deep breaths. The following cephalad-to-caudal examination sequence is recommended (SonoSpot LUQ):
  - above the diaphragm, with a depth of 16 cm, having the patient take a deep breath
  - between the diaphragm and the spleen, while the patient avoids taking deep breaths
  - between the spleen and the entire superior pole of the left kidney
  - between the left edge of the spleen and the entire inferior pole of the kidney (the left paracolic gutter)

POTENTIAL FINDINGS

Many of the potential findings in this view (e.g. pleural fluid) are identical to those found with the perihepatic view. Only the findings specific to the perisplenic view are covered below.

- **Thoracic aorta** may be visualized in the presence of pleural fluid (US 78 yo).

- **Intraabdominal fluid** will first accumulate at the diaphragm-spleen interface. Fluid will also accumulate around the inferior pole of the spleen. The splenorenal fossa is somewhat inaccessible to fluid accumulation due to the splenorenal ligaments and is often the last place where free fluid will accumulate (EFAST). Free fluid will be linear, curvilinear or triangular as the fluid abuts bowel (EFAST).
- **Splenic injury** usually results in a diffuse heterogeneous echogenic pattern. (EFAST). Subcapsular hematoma results when splenic hemorrhage is contained by an intact splenic capsule. Clotting rapidly occurs, resulting in an echogenic appearance. The ultrasound is insensitive for parenchymal injuries.
- **Bowel fluid** in the splenic flexure of the colon has round or oval borders since it is contained with the bowel (EFAST). Peristaltic motion may be present.
- **Stomach fluid** is found just deep to the spleen on ultrasound. The fluid is surrounded by a visible wall and usually contains multiple small echoes with or without ring-down artifact from gas bubbles or air (EFAST). A large amount of fluid in the stomach is consistent with a proximal intestinal obstruction.

Pelvic Window

TECHNIQUE

- **Patient**: supine. The pelvic window uses the bladder as a sonographic window. If a Foley catheter is placed, the catheter should be clamped temporarily, or it may be used for retrograde filling of the urinary bladder if the patient has an empty bladder (EFAST). However, an overdistended bladder may mask small amounts of fluid in the pouch of Douglas.
- **Probe**: phased array (1-5 MHz) or curvilinear array (2-5 MHz) (EFAST).
- **Placement**: just cephalad to the pubic symphysis in the midline (EFAST), with the orientation marker directed to the right to obtain a transverse view and cephalad to obtain a sagittal view. EFAST recommends only performing the sagittal view. Depth is initially set at 20 cm.
- **Procedure**: The probe can be rocked caudally with the beam aimed into the pelvis. Decreasing the gain to avoid post-fluid acoustic enhancement will decrease the likelihood of overcalling free fluid when visualizing the seminal vesicles and the prostate (Stone Pelvic View).

POTENTIAL FINDINGS

- The most dependent area in the pelvis is the **retro-vesicular space** in the male and the **rectouterine pouch** (also referred to as the **pouch of Douglas** and the **posterior cul-de-sac**) in the female patient [13]. The **anterior cul-de-sac** refers to the space between the bladder and uterus.
- **Intraabdominal fluid** manifests as anechoic or echogenic fluid in the retro-vesicular or rectouterine pouch on the transverse view or cephalad to the urinary bladder on the sagittal view (EFAST). The fluid has triangular corners as it interfaces the bowel. The absence of peristalsis can help distinguish between clotted, echogenic blood and bowel (EFAST) (US 30 yo)
- **Physiologic fluid** manifests as small amounts of fluid in the pouch of Douglas in premenopausal women.
- **Urinary bladder** manifests as an oval-shaped anechoic area, without triangular angles, completely surrounded by an echogenic border (the urinary bladder wall) (EFAST). The examination may reveal a large bladder suggesting obstruction.

- **Seminal vesicles** are paired, hypoechoic or anechoid structures located under the urinary bladder that taper in a cephalad direction and do not extend beyond the bladder (EFAST). On the transverse view, the seminal vesicles have a "bow-tie" appearance (EFAST).

4. KOILS

This step consists in placing the probe over the abdominal midsagittal line. The view allows for the identification of enlarged round structures ("coils"), i.e. an abdominal aortic aneurysm, a large well-filled IVC, and dilated loops of small bowel.

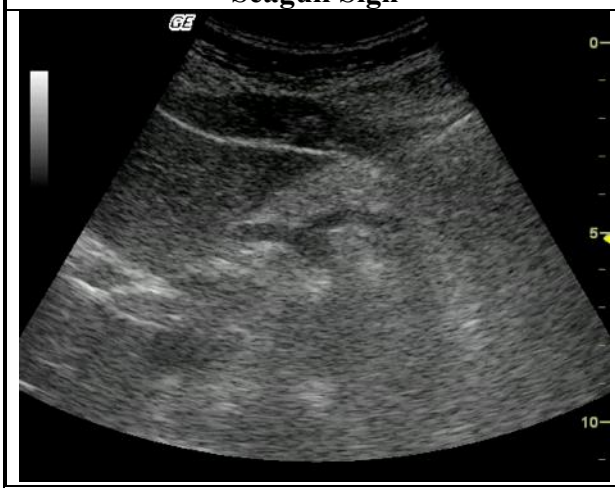
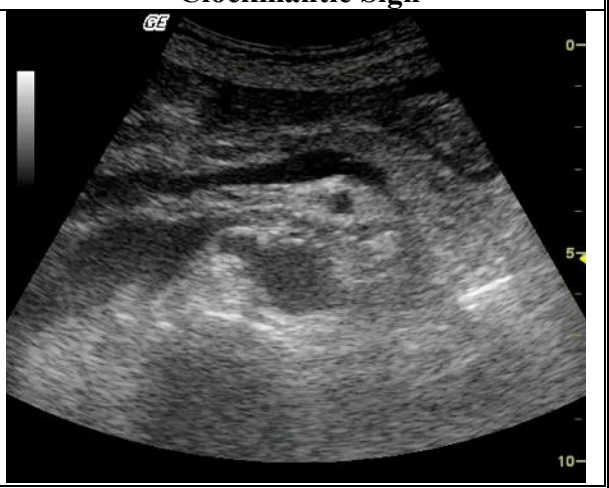
Abdominal Aorta

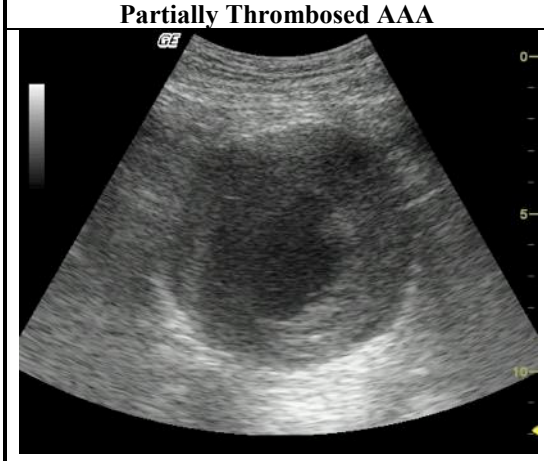
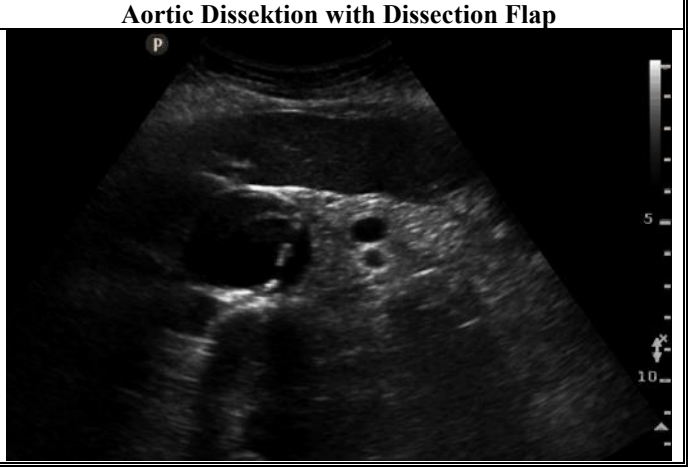
TECHNIQUE

- **Patient**: supine.
- **Probe**: phased array (1-5 MHz) or curvilinear array (2-5 MHz).
- **Placement**: In the midline between the xiphoid process and the umbilicus, with the orientation marker directed to the right. Depth is initially set at > 20 cm.
- **Procedure**: the abdominal aorta is first visualized in transverse section, from the portion under the xiphoid process to beyond the bifurcation. The examination ends with a sagittal view of the aorta. The following techniques may be used if abdominal gas impairs visualization (Stone aorta, Sonoguide Aorta):
  - applying gentle pressure, jiggling the probe up and down to get the bowel gas out of the way
  - rotating the patient in the lateral decubitus position to get the bowel gas out of the way
  - scanning from the RUQ, increasing the depth, asking the patient to "take a deep breath and hold" to lower the liver margin and using the liver as an acoustic window
  - scanning from the right mid axillary line, at or below the costal margin, with the probe directed slightly anterior, to visualize the aorta deep to the IVC.

POTENTIAL FINDINGS

- **Seagull sign** refers to the configuration of the celiac artery branching into the hepatic and splenic arteries.
- **Clockmantle sign** refers to the appearance of the SMA surrounded by bright echogenic tissue.
- **Abdominal aortic aneurysm** is present if the abdominal aorta is > 3 cm in diameter (measurement is from from outer wall to outer wall (Sonoguide Aorta)); the aortic aneurysm may be partially thrombosed;
- **Intimal flap** rules in an aortic dissection (Stone aorta).
- **Common iliac artery aneurysm** is present when its diameter exceeds 1.5 cm (Stone aorta).

Seagull Sign	Clockmantle Sign
	

Partially Thrombosed AAA	Aortic Dissektion with Dissection Flap
	

In addition:

- **The intraabdominal IVC** can be visualized to the left of the aorta on the screen. The IVC can be visualized in the transverse and sagittal planes.
- **Dilated loops of small bowel** may be identified superficial to the aorta and IVC. Dilated small bowel loops in three segments suggests small bowel obstruction SN 94% SP 94% [18].

5. LUNGS

The final step consists in an anteroposterior examination of the lungs.

Anteroposterior Lung

TECHNIQUE

- **Patient**: supine.
- **Probe**: 2.5-5 MHz probe (Chapter 4 Mike & Matt), curvilinear low-frequency transducer can be used first; it is usually sufficient to identify lung-sliding and allows for a determination of A-line or B-line pattern. A high-frequency linear transduced can be used if the presence or absence of lung-sliding is uncertain [19].
- **Placement**: the lung examination should at a minimum include two points on each side of the chest wall, with the transducer oriented sagitally and the orientation marker directed towards to the patient's clavicle:
  - a point in the midclavicular line in the 2nd or 3rd intercostal space
  - a point in the 4th intercostal space medial to the anterior axillary line (Philips Lung, [15])
- **Procedure**: the transducer is moved until a view is obtained that includes two adjacent ribs. The transducer is held perpendicular to the pleural surface. Note is made of whether lung-sliding is present and whether the predominant artifact pattern consists of A-lines or B-lines (see below).

POTENTIAL FINDINGS

- **Bat sign** refers to the constellation of a horizontal hyperechoic line (representing the parietal pleura) between two rib shadows[15]. The sign is obtained by placing the ultrasound probe in the intercostal space perpendicular to the ribs (US)
- **Lung-sliding** refers to a shimmering of the visceral on the parietal pleura. Lung-sliding indicates that the pleural line includes the visceral pleura [15]. The presence of lung-sliding rules out pneumothorax with near 100% sensitivity. The absence of lung sliding, i.e. a motionless pleural line, may result from (Philips Lung):
  - Pneumothorax
  - Absence of ventilation, e.g. apnea, phrenic nerve palsy, jet ventilation, esophageal intubation, intubation of the opposite main-stem bronchus, pneumectomy
  - Dense lobar consolidation, e.g. pneumonia, lung contusion, atelectasis (B-lines may be present, ruling-out pneumothorax)
  - Pleural adhesions, pleurodesis, bullae (A-lines or B-lines may be present)
- **Comet tails** refer to short, vertical, bright lines that originate from the pleura and fade rapidly (as opposed to B lines that extend the full length of the screen). Comet-tails also indicate the absence of air between the viscera and parietal pleura and rule out pneumothorax [20].
- **Sandy beach sign,** also known as **seashore sign**, refers to a granular or sandy appearance deep to the pleural line seen using M-mode ultrasonography. It corresponds to the present of lung-sliding in B-mode ultrasonography.
- **Barcode sign**, also known as **stratosphere sign,** refers to the presence of horizontal lines deep to the pleural line seen using M-mode ultrasonography. It corresponds to the absence of lung-sliding in B-mode ultrasonography.
- **Lung-point** refers to the point on the chest wall where lung-sliding appears intermittently with respiration. It results from the inspiratory increase of parietal contact of the collapsed lung and corresponds to the edge of the pneumothorax. It is pathognomonic for

pneumothorax [15]. The lung-point may be used to map out the pneumothorax and estimate its size. Lateral lung-points are associated with a 90% need for drainage [15]. If the pneumothorax is large and there is no lung tissue in contact with the pleura, no lung-point will be seen [19]. Complex pneumothoraces with extensive adherences will not generated a lung-point either [15].

- **Lung-Pulse** refers to a slight movement of the pleural line with each heart beat as movement from the heart is transferred to the pleural line [19]. The presence of a lung-pulse excludes pneumothorax [19].
- **A Lines** are horizontal lines that are separated from each other by the same distance separating the skin from the pleural line. They represent a reverberation artifact resulting from air (pneumothorax) or tissue almost completely composed of air (a well-aerated lung) underneath the pleural line (Philips Lung; Chapter 4 Mike & Matt).
- **B Lines** are bright, vertical, laser-like lines that originate from the pleura, are transmitted the full depth of the screen (> 18 cm) without fading (as opposed to the comet-tail artifacts), and move in concert with lung-sliding [15]. The presence of B-lines rules out pneumothorax [19]. Conditions where interstitial fluid or cellularity are diffusely increased and conditions where alveolar air is partially lost results in B-lines [21]. They indicate that the interstitium is thickened, most often by fluid. They indicate a mixture of air and water deep to the pleural (US 95 yo).
- **Diffuse Bilateral B lines** suggest [22]
  - Pulmonary edema
  - Interstitial pneumonia / pneumonitis
  - Pulmonary fibrosis
  - Acute respiratory distress syndrome (ARDS)
- **Focal B lines**, i.e. discrete areas with multiple B-lines, suggest [19, 22]:
  - Pneumonia and pneumonitis
  - Atelectasis
  - Pulmonary infarction
  - Pulmonary contusion
  - Pleural disease
  - Malignancy
  - Focal posterolateral B-line may be found in a normal lung, due to gravity alone [15].
- **Lung-rockets** refer to 3 or more B lines between two ribs [15]. Greater than three B lines in a longitudinal plane at a single intercostal space is considered a "positive" exam for B-line pattern [19]. Two or more positive regions bilaterally constitutes the "interstitial syndrome" [19].
- **Tissue-like sign** refers to a liver-appearance of the lung. It indicates translobar consolidation [15]. This finding is also referred to as **"hepatization of the lung"** [2] (US 38 yo).
- **Shred sign**, also known as **fractal sign,** refers to a shredded, or fractal-like boundary between an area of lung consolidation and surrounding aerated lung. It indicates non-translobar consolidation [15].

CHAPTER 08–PROBLEMS

"You got to be very careful if you don't know where you're going, because you might not get there." Lawrence Peter ("Yogi") Berra

This chapter deals with the information that should be acquired from patients presenting with specific problems, and the 'don't miss' diagnoses that should be considered. The concepts underlying problem-driven information acquisition are presented in Chapter 01. The generic approach to the individual patient is present in Chapter 02. The following paragraphs provide a brief summary of the approach to the individual patient and the rational underlying problem-driven information-acquisition.

The **first step** in patient assessment is determining whether the patient is stable. If the patient if unstable, the ABCDE (Chapter 03) should be carried out, augmented if available by point-of-care tests such as bedside blood tests (Chapter 04), the electrocardiogram (Chapter 05) and ultrasound examination (Chapter 06). Identified resuscitation syndromes should then be managed (Chapter 07).

The **second step** consists in the acquisition of problem-driven information. Patients enter the realm of EM because of:

- subjective problems, e.g. chest pain, shortness of breath, paresthesias
- objective problems, e.g. rash, fever, an abnormal test result (e.g. anemia, pleural effusion)
- potential problems, e.g. suspected poisoning, allergic reaction, post-traumatic fracture or bleeding

Some patients may be referred to the ED because of concern for a specific diagnosis. However, focussing on a putative diagnosis may lead to cognitive biases such as diagnostic momentum and premature closure. Rooting patient assessment instead in the patient's problem may prevent diagnostic errors.

Problems such as chest pain may be caused by a multitude of diagnoses. However, the list of 'don't miss' diagnoses--diagnoses where therapy within days decreases morbidity and mortality--is limited. The main diagnostic goal of the assessment in the ED is to rule-in or rule-out these diagnoses. Bayes' theorem provides a framework for doing so. The patient's age, gender and additional background information allow for an estimation of the pretest probabilities for these conditions. MAPLES is a mnemonic for the background information necessary for these estimations and for decision-making:

- M stands for medications
- A stands for allergies
- P stands for past medical history
- L stands for life circumstances
- E stands for ethanol
- S stand for smoking

Further information is required to fine-tune the likelihood of 'don't miss' diagnoses. Given the interdependency of the likelihoods of competing diagnoses, the same information can help fine-tune the likelihoods of several 'don't miss' diagnoses. One can therefore argue that, given a certain problem, some information ought to be routinely acquired. Formalizing this body of problem-driven information as a checklist may prevent diagnostic errors stemming from faulty or incomplete information acquisition. The onus during this step is to resist the

temptation to prematurely abrogate information-acquisition and jump to diagnostic conclusions. In a sense, this step is unintellectual and may be refer to as 'System-0' thinking.

OPQRST+ is a mnemonic for a problem-driven history that suits most problems:
- O stands for onset: time of onset of the problem, activity at the time, rapidity of onset
- P stands for position: location, size and radiation of the pain
- Q stands for quality: a subjective description of the problem
- R stands for relieving and aggravating factors
- S stands for severity, e.g. intensity of the pain, how the problem limits activities of daily living
- T stands for temporal factors: whether the problem has been constant, intermittent, increasing
- + stands for associated manifestation, e.g. the presence of nausea when the problem is abdominal pain

One can also argue for routine, problem-driven acquisition of information from the physical examination and point-of-care tests (bedside blood tests, EKG, ultrasound).

The **third step** consists in using the acquired information to consciously estimate the likelihood that the patient is suffering from potential 'don't miss' diagnoses. System-1 will already have suggested one or several diagnostic hypotheses through its pattern-recognition function. Consciously considering 'don't miss' diagnoses using System-2 may decrease the risk of premature closure. Clinical decision rules can guide the likelihood assessment for a specific diagnosis, and the physician needs to take into consideration the fact that the likelihoods of competing diagnoses are interrelated. Additional, hypothesis-driven investigations may be acquired during this step (these diagnosis-specific investigations are presented in Chapter 09).

The **fourth step** deals with decision-making regarding further investigations and treatments, and whether these investigations and treatments require hospital admission. This step involves assessing the risks-benefits of various investigational and treatment strategies for the individual patient, the ultimate goal being to maximize patient well-being.

This chapter presents:
- differential diagnoses for problems that help guide hypothesis generation
- checklists for problem-driven information acquisition and how this information guides diagnostic reasoning
- a checklist of 'don't miss' diagnoses. The list does not include diagnoses that become obvious during information acquisition, such as a glucose of 0.9 mmol/L in a patient with a decreased level of consciousness, but rather those that may be overlooked by a System-1 blinded by another potential diagnosis.
- the management of specific diagnoses when there is a 1-to-1 correlation between the problem (e.g. vision loss) and the diagnosis (e.g. retinal artery occlusion). The management of diagnoses (e.g. aortic dissection) that may result in several problems (chest pain, back pain, syncope, neurological deficit) is covered in Chapter 09.

PAIN

ABDOMINAL/FLANK PAIN

INTRODUCTION

The term 'abdominal/flank pain' refers here to pain or discomfort located in the abdomen and/or flank, i.e. pain located between the lower border of the rib case and the pelvis. Pain located to or under the chest wall is covered under the section 'chest/thoracic pain.' Pain localized to the midline of the back is covered under ‘back pain.'

DIFFERENTIAL DIAGNOSIS

Anatomy	Examples
Gastrointestinal	• Gastritis, peptic ulcer disease • Acute appendicitis, diverticulitis, ileus, mesenteric ischemia • Hernia • Epiploic appendagitis
Hepatobiliary	• Cholecystitis, cholangitis • Pancreatitis
Genitourinary	• Ectopic pregnancy (early pregnancy) • Abruptio placenta (late pregnancy) • Salpingitis, ovarial torsion • Testicular torsion • Renal colic, pyelonephritis, urinary retention
Cardiovascular	• Ruptured (expanding) abdominal aortic aneurysm, aortic dissection • Myocardial infarction
Pulmonary	• Pneumonia • Pulmonary embolism
Musculoskelettal	• Herniated thoracic disc • Muscle spasm, hematoma
Systemic	• Adrenal crisis • Diabetic ketoacidosis • Familial Mediterranean Fever • Mononucleosis • Porphyria

EPIDEMIOLOGY

A • **Age** influences the prevalence of the causes of abdominal pain [4]:

Final Diagnosis	< 50 years	≥ 50 years
Abdominal pain NOS	40%	16%
Appendicitis	32%	15%
Biliary disease	6%	21%
Bowel obstruction	2%	12%
Pancreatitis	2%	7%
Diverticulitis	< .1%	6%
Cancer	< .1%	4%
Hernia	< .1%	3%
Vascular	< .1%	2%
Gynecological	4%	< .1%

	Elderly patients are more likely to have life-threatening causes of abdominal pain, e.g. ruptured abdominal aneurysm, perforated ulcus, mesenteric ischemia [5].
G	**Women** may suffer from gender-specific conditions e.g. salpingitis, ectopic pregnancy, ovarial torsion. **Men** may suffer from gender-specific conditions e.g. prostatitis, testicular torsion.
H	**Family history** of recurrent bouts of abdominal pain suggests hereditary angioedema, familial mediterranean fever.

BACKGROUND

M	☐ **What medications do you take?** • **Corticosteroids** increase the risk for peptic ulcer when taken in conjunction with NSAIDs RR 4.4 (2.0-9.7) but not among patients not taking NSAIDs [6]. Corticosteroids may mask clinical signs of infection / inflammation [5]. • **Immunosuppressive medications** and **chemotherapy** lead to atypical physical findings and laboratory findings, and an increased risk of infectious causes for the abdominal pain [5]. • **SSRIs** in conjunction with NSAIDs increase the risk of peptic ulcer disease complications ☐ **Do you take NSAIDs?** • **NSAIDs** increase the risk for peptic ulcer disease (OR 5) [7] and for perforated peptic ulcer (OR 3.6) [8]
A	☐ **Are you allergic to medications or contrast?**
P	☐ **What are your past medical conditions?** • **Prior myocardial infarction**, **stroke**, **intermittent claudication** increase the risk for mesenteric ischemia, ruptured abdominal aortic aneurysm, myocardial infarction. • **Atrial fibrillation** increases the risk for mesenteric ischemia [5]. • **Gastric bypass** increases the risk for internal hernia [9]. The risk is highest roughly 1 year after the operation (check). • **Recent operation** increases the risk for post-operative complications such as abscess. • **Colonoscopy**, **gastroscopy** within the past hours/days suggests perforation. • **Immunocompromised states** (e.g. from cancer, chronic liver disease) increase the risk of infectious causes and atypical clinical presentations [5]. ☐ **Have you previously had abdominal surgery?** • **Prior abdominal surgery** increases the risk for bowel obstruction [5].
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Early pregnancy** and abdominal pain may result from ectopic pregnancy. • **Late pregnancy** and abdominal pain may be caused by abruptio placenta with concealed hemorrhage.
E	☐ **How much alcohol do you drink and how often?** • **Alcohol** abuse increases the risk of pancreatitis, hepatitis and gastritis [5].
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • Smoking > 15 cigarettes per day was associated with **perforated peptic ulcer** RR 3.5 (1.7-7.1) [10] • Smoking increases the risk of abdominal pain related to atherosclerosis, e.g. **ischemic colitis**, **ruptured abdominal aortic aneurysm**.

HISTORY

O	☐ **When did the pain start?** • Pain that has **lasted for over two weeks** can as a rule be investigated outside of the ED (ref?) ☐ **How long did it take for the pain to reach its maximal intensity: seconds, minutes, hours?** • **Sudden** onset (peak within seconds) suggests **rupture** (e.g. ruptured abdominal aortic aneurysm, ectopic pregnancy, peptic ulcer, esophagus, spleen, ovarian cyst, aortic dissection) or **ischemia** (e.g. acute coronary syndrome, mesenteric ischemia, testicular torsion, ovarian torsion, splenic infarction, kidney infarction) [11] • **Rapid** onset (peak within minutes) suggests obstruction (gallstone, kidney stone) or pancreatitis [11] • **Gradual** onset (peak within hours) suggests inflammatory conditions (appendicitis, diverticulitis, pyelonephritis, cystitis, prostatitis, salpingitis) [11]
P	☐ **Where is the pain located? How large is the painful area?** • **Generalised**, panabdominal pain suggests intestinal obstruction, pancreatitis, early appendicitis, mesenteric thrombosis, peritonitis (e.g. perforerated appendicitis, ulcus, diverticulum, ectopic pregnancy) or systemic causes of abdominal pain (e.g. diabetic ketoacidosis, adrenal crisis) [5]. • **Visceral** pain is poorly localized [5] and not limited to one side of the abdomen (e.g. diffuse periumbilical in early appendicitis) • **Epigastric visceral** pain suggests pathology in an organ proximal to the ligament of Treitz, e.g. the stomach, duodenum, liver, bile duct, pancreas, spleen [5]. • **Periumbilical visceral** pain suggests pathology in an organ located between the ligament of Treitz and the hepatic flexure: jujenum, ileus, appendix, proximal colon [5]. • **Lower abdominal visceral** pain suggests pathology from hindgut structures: distal colon and genitourinary tract [5]. • **Parietal** pain is more localized [5] and often unilateral (e.g. pain in the lower quadrant once the inflamed appendix as led to parietal inflammation) • **Right upper quadrant** pain suggests pathology of the stomach, duodenum, hepatobiliary organs, heart, lung; it may also be caused by a retrocecal appendix or appendicitis in pregnancy [5]. • **Left upper quadrant** pain suggests pathology of the stomach, spleen, pancreas, heart, lung [5] • **Flank** pain suggests renal or pleural origin (e.g. "flank pain" may be caused by a pulmonary embolism that has resulted in a lower lobe infarction) • **Right lower quadrant** pain suggests appendicitis, cecal diverticulitis, incarcerated hernia, pathology in the genitourinary organs [5]. • **Left lower quadrant** pain suggests sigmoid diverticulitis, incarcerated hernia, aortic aneurysm, pathology in the genitourinary organs [5]. • **Pelvic / groin** pain suggests pathology of the genitourinary organs. Pelvic pain may also be caused by hip pathology, especially in the very young or elderly [5]. ☐ **Does the pain radiate anywhere?** • **Radiation to shoulder or supraclavicular** region suggests irritation of the diaphragm, due to e.g. lower lobe pneumonia, pulmonary embolism, acute cholecystitis, intraperitoneal free fluid (e.g. subsequent to a ruptured ectopic pregnancy) [5]. • **Radiation to the right scapula** region suggests hepatobiliary pathology [5].

	• **Radiation to the left scapula** suggests splenic pathology or diaphragmatic irritation [5]. • **Radiation to neck, jaw, arm** suggests myocardial ischemia • **Radiation to back** suggests ruptured abdominal aortic aneurysm, aortic dissection, pancreatitis • Radiation to lower back or proximal leg suggests gynecologic pathology • **Radiation to the groin or testis** suggests testicular torsion, renal colic; aortic dissection may even manifest as testicular pain [12]. ☐ **Has the pain migrated?** • Migration **from the epigastrium to the right lower quadrant** suggests acute appendicitis • Migration **from the right/lef lower quadrants to the epigastrium** suggests a local process (e.g. acute appendicitis, diverticulitis, ovarian cyst) that has led to generalized peritonitis (e.g. through rupture, abscess with free pus)
Q	☐ **How would you describe the pain?** • **Aching** is the adjective sometimes used to describe visceral, poorly characterized pain [5]. • **Sharp** is the adjective sometimes used to describe the parietal pain resulting from irritation of the parietal peritoneum [5]. • **Crampy, colicky** pain suggests pain from an organ affected by peristalsis (urethra, biliary duct, bowel) [5].
R	☐ **Is the pain worsened by deep inspiration?** • Deep inspiration exacerbates pain caused by pathology in the **organs adjacent to the diaphragm**, e.g. gallbladder, hepatitis, pancreatitis, lower lobe pneumonia, pulmonary embolism; the diaphragm may also be irritated by intraperitonael bleeding, e.g. from a ruptured ectopic pregnancy. ☐ **Is the pain worsened by movement?** • Movement exacerbates pain associated with **peritonitis**.
S	☐ **How severe is the pain on a scale of 1-10?** • **Severe** abdominal pain that does not respond to opioid analgesia suggests a surgical cause of the abdominal pain, e.g. mesenteric ischemia, ovarialtorsion. Cope wrote that the "majority of severe abdominal pains which ensue in patients who have been previously fairly well, and which last as long as six hours, are caused by conditions of surgical import." [13]
T	☐ **Has the pain been constant, intermittent, increasing?** • **Intermittent** pain suggests small bowel obstruction (typical interval of 2-5 minutes), large bowel obstruction (typical interval of 6-10 minutes) [11], biliary colic or ureteral colic. ☐ **Have you had prior similar episodes?** • **Absence of prior episodes** increases the risk of significant pathology [5]
+	☐ **PO: have you had any nausea or vomiting?** • **Pain preceding vomiting** is more likely to be caused by surgical disease [5]. In contrast, vomiting usually precedes pain in cases of acute gastroenteritis; however, the sequence may be reversed in the elderly [5]. • **Anorexia** suggests acute appendicitis as opposed to salpingitis in the female patient with lower abdominal pain [14] • **Biliary vomitus** in a newborn suggests intestinal malrotation ☐ **PR: have you had any diarrhea or constipation?**

	• **Decreased bowel movements** / obstipation suggests constipation or bowel obstruction ☐ **PU: have you had any dysuria, urgency, frequency, hematuria, polyuria?** • **Dysuria** suggests urinary tract infection, but may also occur with appendicitis (appendix irritating the bladder) • **Polyuria** may suggest new-onset diabetes and diabetic ketoacidosis as the cause of abdominal pain. ☐ **PV: when was your last menstruation (fertile women)? Have you had any vaginal discharge?** • **Vaginal discharge** suggests salpingitis • **Absence of menstruation** suggests ectopic pregnancy • **Concurrent menstruation** suggests endometriosis or a ruptured ovarian cyst

PHYSICAL EXAMINATION

VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?**
	• **Tachypnea** may result from metabolic acidosis e.g. from a gangrenous viscera or sepsis [5]
	• **Hypoxia** suggests pneumonia, pulmonary embolism, pulmonary edema
	• **Shock** in conjunction with abdominal pain suggests [5, 15]:
	  ○ Ruptured abdominal aortic aneurysm (hemorrhagic shock)
	  ○ Ruptured ectopic pregnancy (hemorrhagic shock)
	  ○ Bowel obstruction (hypovolemic shock)
	  ○ Myocardial infartion (cardiogenic shock)
	  ○ Acute pancreatitis (distributive shock)
	  ○ Perforated viscus, e.g. perforated ulcer, colonic diverticula (distributive shock)
	  ○ Mesenteric ischemia (distributive shock)
	  ○ Acute adrenal insufficiency (distributive shock)
	• **Fever** suggests intraabdominal infection [5].
	• **Hypothermia** may occur with sepsis in the elderly [5].

CV	☐ **Auscultation: regular heart rate? Heart sounds?** • **Irregularly irregular** heart rhythm suggests atrial fibrillation and increases the risk for mesenteric embolism.
Lung	☐ **Auscultation?** • **Ronchi** suggest pneumonia, pulmonary effusion, pulmonary embolism
Abdo	☐ **Inspection** • **Surgical scars** suggests prior abdominal surgery and an increased risk of bowel obstruction from adherences • **Distended abdomen** suggests bowel obstruction or ascites with spontaneous bacterial peritonitis • Localized bulging may suggest a **hernia** ☐ **Auscultation** • The diagnostic value of the presence / absence and nature of **bowel sounds** is controversial [4] ☐ **Palpation** • **Rebound tenderness**, **guarding** (aka défence, voluntary) and **rigidity** (involuntary) are manifestations of increasing peritonitis • **Central, lower abdomal mass** may represent a distended bladder from urinary retention.

	• **Pain out of proportion to the examination** may suggest mesenteric ischemia [5] • **Inguinal areas** should be examined to rule out an incarcerated inguinal / femoral hernia [5]. An incarcerated femoral hernia in an elderly patient may present with diffuse, non-localized abdominal pain. • During **late pregnancy**, the uterus becomes intraabdominal and adds complexity to the physical examination [5]. • **Carnett Sign:** with the physician pushing on the abdomen at the point of maximal tenderness, ask the patient to lift his or her neck from the bed and then his or her shoulders; if this maneuver increases the pain, it suggests a musculoskeletal etiology rather than an intra-abdominal source [16].
GU	☐ **Testicular examination in male patients < 25 years** • **Testicular torsion** can present with abdominal or inguinal pain in the absence of testicular pain in 5-12.5% of cases [17]. Most cases of testicular torsion occur in men between the ages of 10 and 24 years [18].

There is no good evidence that a routine **per rectal** examination in all patients with abdominal pain [19], nor that a routine **gynecological** examination in all women with abdominal pain, are of value.

BEDSIDE TESTS

☐ CRP +/- WBC

- WBC and CRP are markers of inflammation with different kinetics. They contribute diagnostic information over and beyond that provided by the physical examination, e.g. in acute appendicitis [20].
- The WBC in itself is neither sufficiently sensitive nor sufficiently specific to help rule-in or rule-out a serious cause of abdominal pain [5].

☐ EKG in patients > 50 years

- Myocardial ischemia may presents as upper abdominal pain.
- The stress of abdominal pain may precipitate cardiac ischemia in elderly patients.
- The EKG may reveal atrial fibrillation, which increases the risk of mesenteric ischemia.

☐ Ultrasound of the abdominal aorta in patients > 60 years

- **Ruptured abdominal aortic aneurysm** may present is a variety of different ways and is often misdiagnosed [21]. In one review, chock was only present in 29% of patients with ruptured abdominal aortic aneurysm [21]. The consequences of missing the diagnosis are catastrophic for the patient. The diagnosis of RAAA should therefore be considered in every older patient with abdominal or flank pain [22]. A systemic review showed that emergency department bedside ultrasound had SN 99% (96-100) and SP 98% (97-99) for the diagnosis of an AAA > 3 cm [23]. Ultrasound is fast and noninvasive.

☐ Urine dipstick

- A **positive leucocyte esterase test** and a **positive nitrite test** suggest a urinary tract infection (cystitis, pyelonephritis). However, as many as 40% of patients with acute appendicitis have pyuria, bacteriuria or hematuria [24]
- **Hematuria** is present in 90% of cases of renal colic [25]. However, microscopic hematuria may occur with other conditions, e.g. a ruptured abdominal aortic aneurysm [22].

☐ Urine pregnancy test in fertile women

- **Pregnancy testing** is indicated in all fertile women with abdominal pain [5]. Ectopic pregnancy should be suspected in all women with acute abdominal pain and a positive pregnancy test [5].

MANAGEMENT

1. Analgesia?

- **Opioid** administration to patients with abdominal pain may alter physical examination findings but does not increase the risk of management errors [26]. Opioids do not need to be withheld for diagnostic reasons, yet an argument can be made for not administering opioids to patients with abdominal pain until they have been assessed:
  - some patients presenting with abdominal pain have an opioid addiction
  - treating patients with non-specific abdominal pain with opioids is of dubious value, regardless of whether the treatment occurs inside or outside of the ED
  - patients with severe, ischemic abdominal pain require prompt management and not simply prompt analgesia
  - other pain medications are available
- **NSAIDs administered IM** (e.g. Diclofenac 75 mg IM) is first line therapy for renal colic.

2. Hypothesis-driven investigations?

- Consider hypothesis-driven investigations (blood tests, radiological investigations) to rule-in diagnostic hypotheses (see respective sections in Chapter 09).
- **Abdominal ultrasound** is recommended as the first-line diagnostic imaging modality in general [27, 28].
- **CT abdomen** is recommended if the ultrasound is negative or inconclusive, given its high sensitivity and specificity [28]. Need for contrast? Value of non-contrast CT [29].

3. Admission/urgent work-up?

- Abdominal pain is one of the few problems associated with an extensive list of "don't miss" diagnoses. If System-1 does not suggest specific diagnoses that can be ruled-in through additional tests, admission for inpatient investigation or abdominal CT should be considered for patients with one of the following "high-risk"syndromes:

Syndrome	Findings	Differential diagnosis
1. Abdominal pain + shock	• Tachycardia and/or hypotension • Elevated lactate, decreased BE	• Ruptured aortic aneurysm • Ruptured ectopic pregnancy • Perforation and sepsis • Severe pancreatitis • Cholangitis
2. Severe and/or sudden pain	• Sudden onset of diffuse pain • Severe pain unresponsive to analgesics • Peritoneal findings are absent	• Mesenteric ischemia • Aortic dissection • Perforated peptic ulcer • Ovarian / testicular torsion
3. Generalized peritonitis	• Pain worsens with movement • Diffuse tenderness • Rigidity or rebound tenderness	• Perforated peptic ulcer • Perforated diverticulitis • Perforated appendicitis • Cholecystitis, pancreatitis
4. Bowel	• Prior abdominal surgery	• Adhesions

obstruction	• Diffuse, crampy pain with intermittent intensification • Vomiting, decreased bowel movements, absent flatus • Swollen abdomen • Constant, hyperactive, "metallic" abdominal sounds • Diffusely tender abdomen	• Bowel cancer • Volvulus • Small Bowel Obstruction • Large Bowel Obstruction
5. Inflammed right lower quadrant	• Pain in the right lower quadrant • Peritoneal findings in the right lower quadrant OR elevated WBC/CRP	• Acute appendicitis • Salpingitis • Ovarial pathology • Mesenteric adenitis • Sigmoiditis
6. Impaired activites of daily living	• Patients, often elderly ones, who are sufficiently affected by their abdominal pain that they no longer can take care of their activities of daily living (ADLs)	

4. Non-specific abdominal pain?

- Reassurance that no severe, urgent cause can be identified
- Avoid opioids.

BACK PAIN

INTRODUCTION

The term 'Back Pain' refers here to pain over or adjacent to the spine, i.e. pain in the midline of the back extending from the cervical spine down to the lumbar spine. Pain that is not located in the midline of the back is covered under the sections 'Chest / Thoracic Pain' and 'Abdominal / Flank Pain.'

DIFFERENTIAL DIAGNOSIS

Anatomy	Examples
Muscles	• Acute muscle strain
Ligaments	• Acute ligamentous injury
Vertebral bodies	• Fracture or subluxation • Ostemyelitis • Metastases • Spinal stenosis, spondylolisthesis
Joints	• Degenerative joint disease • Seropositive arthritis, ankylosing spondylitis
Vertebral disk	• Disk herniation, diskitis
Epidural space	• Spinal epidural abscess • Hematoma • Metastases
Spinal cord	• Transverse myelitis
Vascular	• Rupture abdominal aortic aneurysm • Aortic dissection
Pulmonary	• Pleural effusion, pneumonia, pulmonary embolism
Renal	• Nephrolithias, pyelonephritis
Biliary	• Cholecystitis, pancreatitis
Ovarian	• Ovarian torsion, mass or tumor

EPIDEMIOLOGY

A
- **Older age** (defined as age > 65 years in men and age > 75 years in women) was associated with a 9% (3-25%) risk of fracture among patients with low back pain assessed within primary, secondary or tertiary care as reported in a systematic review [1].
- **Advanced age** is a risk factor for lumbar spinal stenosis: > 70 years LR+ 2.0 (1.6-2.5); < 60 years LR 0.40 (0.29-0.57) [2] as well as a risk factor for serious causes of back pain such as ruptured abdominal aortic aneurysm, malignancy [3].
- **Age < 20 years** suggests congenital or developmental disorders such as spondylolisthesis or spondylolysis [3]. It was not found to be associated with fracture or malignancy according to a systematic review [1].

BACKGROUND

M
- ☐ **What medications do you take?**
- **Immunosuppression** (e.g. anti-rejection medications in patients with organ transplants) increases the risk of infectious etiology [3].
- **Prolonged corticosteroid use** was associated with a 33% (10-67%); LR+ 48.5 (11.5-

	205) risk of fracture among patients with low back pain assessed within primary, secondary or tertiary care according to a systematic review [1]. Corticosteroid use may also increase the risk for infectious etiologies [4]. • **Anticoagulants** increase the risk of epidural hematomas [4]. ☐ **What pain medications have you been taking and how often?**
A	☐ **Are you allergic to medications or to contrast?**
P	☐ **What are your past medical conditions?** • **Poorly controlled hypertension** is a risk factor for aortic dissection and ruptured abdominal aortic aneurysm [3]. • **Trauma** prior to pain onset suggests vertebral fracture. Even minimal trauma can result in a fracture in elderlly patients with osteoporosis [3]. In one systematic review, severe trauma was associated with a 11% (8-16%) risk of fracture among patients with low back pain assessed within primary, secondary or tertiary care [1]. • **Intravenous drug use** increases the risk for spinal epidural abscess [3] and diskitis [4]. ☐ **Any recent procedures or investigations?** • **Recent procedures** such as those involving the genitourinary or gastrointestinal system increase the risk of bactermia and hematogenous seeding of the spine [3]. ☐ **Have you had cancer previously?** • **Current or previous history of cancer** suggests metastases. Back pain is often the initial presenting symptom of metastatic disease[3]. The cancers that often metastasize to bone are breast, lung, prostate, kidney and thyroid carcinomas [4], as well as multiple myeloma. In one systematic review, history of malignancy was associated with a 33% (22-46%) risk of spinal malignancy among patients with low back pain assessed in the emergency setting [1].
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Work history** [4].
E	☐ **How much alcohol do you drink and how often?**
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • Smoking is a risk factor for **abdominal aortic aneurysm** [3].

HISTORY

O	☐ **When did the pain start? What were you doing when the pain started?** • Pain following a **specific physical activity** suggests muscular strain or ligamentous injury [4]. • Pain following **trauma** suggests contusion, strain or fracture [4]. • Pain following **sudden deceleration** suggests aortic dissection [4]. ☐ **How long did it take for the pain to reach its maximal intensity: seconds, minutes, hours?** • **Sudden onset, severe back pain** suggests aortic dissection [4]. • **Slow onset** suggests a non-mechanical cause (e.g. tumor) [4].
P	☐ **Where is the pain located? How large is the painful area?** • Benign causes of back pain occur generally in the **lumbar or cervical spine** [3]. • **Isolated thoracic back pain** has traditionally been associated with an increased risk for serious pathology, e.g. aortic dissection (AD), spinal epidural abscess (SEA), vertebral osteomyelitis, malignancy, and perforated gastric ulcer [3]. However, a systematic review showed no association between thoracic pain and malignancy [1].

	• **Absence of paraspinal discomfort** and localization of pain to the midline argues against lumbar strain as suggests more serious pathology e.g. malignancy, vertebral osteomyelitis, fracture, and SEA [3]. ☐ **Does the pain radiate anywhere?** • **Bilateral buttock or leg pain** suggests lumbar spinal stenosis LR 6.3 (3.1-13) [2]. • **Associated chest or abdominal pain** suggests a visceral cause [4]. • **Flank pain** suggests renal or pleural origin [4]. • **Pain radiating down the leg** in a dermatomal distribution, particularly pain extending below the knee, suggests nerve root involvement [4]. 95% of herniations occur at the L4-5 and L5-S1 disk spaces, resulting in radicular pain in the L5 and S1 dermatomes [5].
Q	☐ **How would you describe the pain?** • **Change in character**
R	☐ **Is the pain relieved by analgesia?** • Pain **unrelieved by rest and analgesics** suggests malignancy and infectious causes [4]. ☐ **Is the pain relieved by lying down?** • Pain **aggravated by lying down** suggests malignancy or infection [3]. • Pain that **worsens at night** argues against musculoskeletal etiologies [3] and suggests malignancy and infectious causes [4]. ☐ **Is the pain aggravated by flexion, extension, ambulation?** • Pain that worsens with **bending, sitting, coughing, sneezing, and straining** (Valsalva) suggests disk herniation. • Pain that **improves when bending forward** suggests lumbar spinal stenosis LR 6.4 (4.1-9.9) [2]. • The **absence of pain when seated** suggests lumbar spinal stenosis LR 7.4 (1.9-30) [2]. • **Neurogenic claudication** (pain or other discomfort with walking or prolonged standing that radiates into one or both lower extremities and is typically relieved by rest or lumbar flexion) suggests lumbar spinal stenosis LR+ 3.7 (2.9-4.8); LR- 0.23 (0.17-0.31) [2]; the pain worsens especially with "downhill" ambulation [4].
S	☐ **How severe is the pain on a scale of 1-10? How does the pain affect daily function?** • **Severe pain** of sudden onset suggests aortic dissection.
T	☐ **Has the pain been constant or intermittent? Increasing?** • Pain that progresses over the course of **weeks to months** suggests malignancy or infection [3]. • Pain persisting **for over 6 weeks** suggests malignancy or infection [3]. ☐ **Have you had prior similar episodes?**
+	☐ **Do you have any leg weakness?** • **Leg weakness** and **gait abnormalities** in association with back pain suggest spinal cord or nerve root pathology. Weakness confined to a myotome suggests nerve root compression. ☐ **Do you have decreased sensation in the legs or perineum?** • **Leg paresthesias** suggest spinal cord or nerve root pathology. Paresthesia confined to a dermatome suggests nerve root compression. Numbness and tingling in one of both legs is consistent with spinal stenosis [4]. • **Saddle anesthesia** suggest cauda equina syndrome. ☐ **Do you have any difficulty urinating or defecting?**

	• **Urinary or fecal abnormalities** suggests cauda equina or conus medullaris. ☐ **Have you had any fever or chills?** • **Fever, chills** suggest malignancy or infection [3].

PHYSICAL EXAMINATION

VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?** • **Hypotension** combined with back pain of recent onset suggests RAAA [3]. • **Hypertension** combined with acute onset of severe back pain is consistent with aortic dissection. • **Fever** combined with severe, localized back pain suggests spinal epidural abscess [3], osteomyelitis, diskitis [4]. Fever is not present in most cases of musculoskeletal pain (e.g. herniated disk) [3]. • **Normothermia** does not rule out an infectious cause of back pain [3].
Back	☐ **Inspection** • **Cutaneous findings** may suggest infection or trauma [3]. In one systematic review, the presence of contusion or abrasion was associated with a 62% (49-74%) risk of fracture among patients with low back pain assessed within primary, secondary or tertiary care [1]. ☐ **Palpation** • **Point tenderness to percussion** of the spinous processes suggests fracture, osteomyelitis, SEA, or malignancy [3].
NS	☐ **Leg strength and gait** • Distal (e.g. heel-walking, toe-walking) and proximal (partial knee bend while bearing weight on one leg) strength. • **Wide-based gait** is consistent with lumbar spinal stenosis LR 13 (1.9-95) [2]. ☐ **Leg sensation** ☐ **Leg reflexes & Babinski** ☐ **Romberg** • **Abnormal Romberg** is consistent with lumbar spinal stenosis LR 4.2 (1.4-13) [2].

BEDSIDE TESTS

☐ **CRP**

• An elevated CRP suggests an infectious or inflammatory cause.

☐ **Ultrasound of the abdominal aorta in patients > 60 years**

• To rule out abdominal aortic aneurysm, which can present with back pain.

MANAGEMENT

97% of patients presenting with acute back pain have a mechanical or non-specific cause [5]. Imaging and other diagnostic investigations are only warranted when key findings within the history and physical examination ("red flags") suggest the possibility of serious pathology [3]. A plain film of the back is in general of dubious value, even though it reportedly improved patient satisfation [6]. Decision-making is guided by the suspected diagnosis / syndrome.

1. Ruptured abdominal aortic aneurysm?

• See section in Chapter 09 for likelihood assessment and management.

2. Aortic dissection?

- See section in Chapter 09 for likelihood assessment and management.

3. Focal neurological deficits and progressive or disabling symptoms?

- Conditions of concern: spinal cord compression,
- MRI of the lumbar spine without contrast (and with contrast in some cases), myelography and postmyelography CT of the lumbar spine, lumbar spine CT with or without intravenous contrast, and/or electromyography/nerve conduction velocity [7].

4. Malignancy, osteomyelitis, diskitis or fracture?

- Presence of red flags e.g. age > 50 years, cancer, osteoporosis, immunosuppression, use of steroids or intravenous drugs, trauma, unintentional weight loss, progression of symptoms, focal neurologic deficit
- MRI without and with contrast is the preferred imaging workup [7]. CT without contrast if MRI is unavailable or contraindicated [7]. Other tests to consider: plain radiograph, technetium 99m bone scanning.

6. Disk hernia or spinal stenosis?

- The **straight leg raise** (SLR) is the classic test for sciatic nerve root irritation. With the knee extended, the leg is passively raised until pain is elicited. The test is positive if pain radiates down the leg below the knee in a dermatomal distribution when the leg is elevated to less than 90° [4] In surgical populations, characterized by a high prevalence of disk herniation (58% to 98%), the SLR showed SN 92% and SP 28% [8].
- The **crossed SLR** test is done by passively raising the patient's asymptomatic leg, while keeping the knee straight. The presence of pain radiating from the back to the opposite affected leg is a positive test. In surgical populations, the crossed SLR showed SN 28% and SP 90% [8].
- The following clinical decision rule for lumbar spinal stenosis may be of value [9]:

Risk Factors	Points
History	
• Age 60-70 years	1
• Age > 70 years	2
• Absence of diabetes	1
• Neurogenic claudication	3
• Exacerbation of symptoms when standing up	2
• Symptom improvement when bending forward	3
Physical Examination	
• Symptoms induced by having patients bend forward	-1
• Symptoms induced by having patients bend backward	1
• Good peripheral artery circulation	3
• Abnormal Achilles tendon reflex	1
• Straight Leg Raise test positive for reproducing pain	-2

≥ 7 points: SN 93%, SP 72%, LR+ 3.3 (2.7-4.0), LR- 0.1 (0.06-0.16)

- Two-thirds of herniated disks regress or resolve over 6 months [5]. At the same time, disk bulging (52-81%) and anular tears with focal disk protrusion (32-67%) are commonly found in asymptomatic patients [4]. Consequently, early imaging is not warranted. See [10].
- Pharmacotherapy may include acetaminophen, nonsteroidal antiinflammatory drugs, and/or skeletal muscle relaxants. In some cases, tramadol, opioids, and/or benzodiazepines may be appropriate. Gabapentin can be considered [7].
- Activity level could be normal or with specific restrictions. Consider referral for physical or occupational therapy consult and a follow-up in 4 weeks [7].

7. Non-specific back pain?

- Absence of red flags, back pain < 4 weeks.
- Pharmacotherapy may include acetaminophen, nonsteroidal antiinflammatory drugs, and/or skeletal muscle relaxants. In some cases, tramadol, opioids, and/or benzodiazepines may be appropriate [7]. One randomized controlled trial among patient with acute, nontraumatic, non-radicular lower back pain did not show that adding Cyclobenzprine or oxycodone to naproxen improved functional outcomes or pain at 1 week compared with naproxen alone [11]. Diazepam no better than placebo when added to naproxen for lower back pain [12].
- Activity level could be normal or with specific restrictions. Consider referral for physical or occupational therapy consult and a follow-up in 4 weeks [7].
- Manage expectations: many patients with continue to have pain after 6 weeks.
- One study showed no advantage of early imaging among patients > 65 years following a new primary care visit for back pain in regards to function and pain at a 12 month follow-up visit [13].

Indikation för utredning med MRT-översikt [14]:

- Smärttillstånd med duration > 3-4 veckor och ≥ 1 röd flagga
- Radikulära smärtor som inte kan behandlas, alternativt om ingen förbättring har inträtt efter 6 veckor trots aktiv behandling
- Smärttillstånd med duration > 8 veckor i kombination med gula flaggor

Röda Flaggor

- Ryggsmärta hos barn < 18 år
- Avsevärda smärtor eller smärtdebut efter 55 års ålder
- Väldsamt trauma bakom smärtan
- Konstant eller progredierande smärta under natten
- Tidigare cancersjukdom
- Systemisk steroidbehandling
- Drogmissbruk, HIV
- Viktförlust
- Allmänt nedkommen
- Bestående svår rörelseinskränkning
- Intensifierad smärta vid minsta rörelse
- Strukturell deformitet, skolios
- Svårighet att urinera
- Förlust av tonus i analskinkter eller avföringsinkontinens
- Sadelanestesi

- Utbredd progredierande motorisk svaghet eller gångstörningar
- Misstänkt inflammatorisk sjukdoma (Mb Bechterew)
- Gradvis insättande sjukdom före 40 års ålder
- Markant morgonstelhet
- Ihållande rörelseinskränkning
- Perifera leder angripna
- Irit, hudutslag, kolit, utsöndring från urinröret
- Ärflighet

Gula Flaggor
Gula flaggor är psykosociala faktorer som hindrar återhamtningen efter en akut episod av muskuloskeletal smärta. Psykosociala faktorer är väsentliga, särskilt i utvecklingen av ett långvarigt smärtproblem. Vanligtvis är dessa faktorer viktigare än biomedicinska eller biomekaniska faktorer. Riskfaktorerna kan i stort sett uppdelas i tre områden:
- Emotionella faktorer, t ex:
  - rädsla för ökad smärta vid aktivitet
  - ökat fokus på somatiska symtom
- Kognitiva faktorer, t ex:
  - katastroftankar eller övertygelse om att smärta betyder skada
  - övertygelse om att smärtan helt måste försvinna innan normala aktiviteter eller arbete kan återupptas
- Beteendefaktorer, t ex:
  - oproportionellt undvikande av aktiviteter och rörelser
  - överkonsumtion av smärtstillande

Exempel på akuta indikationer för bilddiagnostik vid smärtor i ländryggen:
- cauda equina-syndrom
- radikulära smärtor med snabb progress
- ryggtrauma
- misstanke om spondylit

CHEST/THORACIC PAIN

"One must be a professional Ulysses in craft and wisdom not to sometimes err in estimating the nature of an attack of severe chest pain. There is no group of cases so calculated to keep one in a condition of wholesome humility." William Osler

INTRODUCTION

The term 'chest/thoracic pain' refers here to pain or discomfort localized to the part of the body enclosed by the ribcage but excluding the middle of the back. Pain localized to the abdomen or flank is covered under the section 'Abdominal / Flank Pain' while pain over or adjacent to the spine, i.e. pain in the midline of the back extending from the cervical spine down to the lumbar spine, is covered under the section 'Back Pain.'

DIFFERENTIAL DIAGNOSIS

Anatomy	Examples
Heart	• Acute coronary syndromes (ACS), including acute myocardial infarction (AMI) • Perimyocarditis, Dressler's syndrome
Aorta	• Aortic dissection (AD) • Takayasus arteritis
Lung	• Pulmonary embolism (PE) • Pleuropneumonia, pleuritis, pneumothorax
Gastrointestinal	• Esophagitis, esophageal spasm, esophageal rupture (Boerhaave syndrome) • Gastritis, gastric ulcer • Biliary colic, cholecystitis, cholangitis
Musculoskelettal	• Muscle rupture, myositis • Costochondritis, Tietze's syndrome • Rib fracture
Other	• Herpes zoster • Mediastinitis, pneumomediastinum • Psychogenic

EPIDEMIOLOGY

A	• **Increasing age** is a risk factor for ACS [1], PE [2] and AD [3] but argues against spontaneous pneumothorax, which affects mainly patients in their 20's and rarely occurs in patients > 40 years [4].
G	• **Spontaneous pneumothorax** affects preferentially men (M:W 12:5) [4]. • **Cardiovascular disease**: its clinical manifestations develop 7-10 years later in women than in men [5] • **Aortic dissection** M:F 2:1 [6]

BACKGROUND

M	☐ **What medications do you take?** ☐ **Do you take oral contraceptives / exogenous hormones?** • **Oral contraceptives** containing estrogen increase the risk for venous thromboembolism [7].
A	☐ **Are you allergic to medications or to contrast?**

P	☐ **What are your past medical conditions?** • **Diabetes, hypertension, hypercholesterolemia** are weakly associated with an increased risk for ACS [8, 9]; hypertension is a risk factor for AD [10]. • **Cancer** (active or metastatic) is a risk factor for PE [2]. • **Recent surgery** is a risk factor for PE [2]. • **Immobilisation** is a risk factor for PE [2]. • **Marfan's syndrome** and **Ehlers Danlos** are risk factors for AD [10]. • **Recent angiography** and **aortic valve operation** are risk factors for AD. ☐ **Do you have any known heart disease?** • **Prior myocardial infarction** increases the risk for ACS LR 1.3 (1.0-1.8) [1]; pleuritic chest pain occurring weeks to months after a myocardial infarction may be due to an autoimmune reaction (**Dressler's syndrome**). ☐ **Have you ever had clots in our legs or clots in your lungs?** • **Prior DVT or PE** increase the risk for PE [2].
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Pregnancy** increases the risk of AMI 3-4 fold [11]. The main risk factors for AMI in pregnancy are age > 35 years, hypertension and diabetes mellitus. The main cause of AMI in the peri- and postpartum period is **coronary artery dissection** [11, 12]. • **Pregnancy** is a risk factor for **PE** and **AD** [13].
E	☐ **How much alcohol do you drink and how often?** • **Heavy alcohol consumption** increases the risk of **pancreatitis.**
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • Smoking is at best weakly associated with an increased risk of **ACS** [8]. • Smoking in itself is not a risk factor for **PE** [2].

HISTORY

O	☐ **When did the pain start? What were you doing when the pain started?** • **Pain brought on by exertion** suggests ACS LR+ 1.5-1.8, LR- 0.66-0.83 [14]. ☐ **How long did it take for the pain to reach its maximal intensity: seconds, minutes, hours?** • **Sudden onset** suggests AD[15] (SN 85%; LR+ 1.6; LR- 0.3) and spontaneous pneumothorax. • **Pain that increases over seconds** is consistent with PE (SN 46%) (Thompson 2005 UTD). • **Pain that increases over minutes** suggests ACS [15] and PE (SN 26%) (Thompson 2005 UTD).
P	☐ **Where is the pain located? How large is the painful area?** • **Focal pain** (e.g. coin-sized area) suggests a musculoskeletal origin and argues weakly against ACS (LR 0.6) [15]. • **Diffuse pain** (visceral pain) suggests ACS, PE, AD. In one study of 1212 consecutive patients > 35 years with chest pain evaluated in the primary care setting, pain location did not help distinguish acute coronary syndrome from patients with chest wall syndrome, gastro-esophageal reflux disease or psychogenic chest pain [16]. • **Retrosternal pain** is consistent with ACS, perimyocarditis [17], AD, esophageal pain. Retrosternal pain argues against PE (OR 0.58) [2]. • **Chest and abdominal pain** is consistent with AD [10]. • **Dermatomal pain** suggests herpes zoster.

	• **Pain migration** suggests AD (LR+ 1.1-7.6) [10]. ☐ **Does the pain radiate anywhere?** • **Radiation to the neck** suggests ACS [15], perimyocarditis [17], AD. • **Radition to the arms** suggests ACS [15], perimyocarditis [17], AD, cervical radiculopathies [18]. • **Radiation to the trapezius muscle ridges** suggests perimyocarditis [17]. • **Radiation to the back** suggests AD [10], acute cholecystitis, acute pancreatitis.
Q	☐ **How would you describe the pain?** • "**Pressure**" is weakly suggestive of ACS (LR 1.3) [15] and consistent with perimyocarditis [17]. • **"Sharp, stabbing**" is consistent with perimyocarditis [17] and argues against ACS (LR 0.3 [15]. • **"Ripping, tearing"** is suggestive of AD (SN 39%) [10].
R	☐ **Is the pain worsened by deep inspiration?** • **Pleuritic pain** suggests a musculoskeletal disorder (costochondritis, Tietze's syndrome, rib fracture), a pleuropulmonary disorder (peripheral PE, pneumothorax, pneumonia engaging the pleura, pleuritis) or perimyocarditis. Pleuritic pain argues against ACS (LR 0.2) [15] and AD unless blood has entered the pleural space. • **Pain that worsens with palpation** suggests musculoskeletal disorder but does not help decrease the likelihood of a peripheral pulmonary embolism [19]. Pain that worsens with palpation argues against ACS (LR 0.3) [15]. ☐ **Is the pain worsened by certain body positions?** • **Positional pain** argues against ACS (LR 0.3) [15]. • **Pain that worsens when supine and improves when upright** is typical of perimyocarditis [17].
S	☐ **How severe is the pain on a scale of 1-10?** • **"Worse ever" pain** is suggestive of AD (SN 90%) [15]. • **Severe pain (9-10/10)** does not increase the risk of AMI [20]; the pain from AMI may be mild to severe (or non-existent).
T	☐ **Has the pain been constant, intermittent, increasing?** • **Pain which lasts seconds or days** argue against ACS [15]. • **Pain which resolves spontaneously within minutes to hours** argues for ACS and esophageal spasm and against PE and AD. ☐ **Have you had prior similar episodes?** • **Recent prior similar episodes** suggest ACS and argues against PE and AD.
+	☐ **Warm: "Have you had fever or chills?"** • **Fever** suggests pneumonia, PE, perimyocarditis, and argues against ACS. • **Fever, chills and/or cough** were the initial symptoms in 80% of pneumonias vs 13% of PE while **dyspnea and/or pleuritic chest pain** were the initial symptoms in 80% of PE vs 9% of pneumonias in a retrospective study[21]. ☐ **Wind: "Have you been short of breath?"** • **Shortness of breath** suggests PE and ACS. ☐ **Walk: "Have you had leg pain or swelling?"** • **Unilateral leg pain or swelling** suggests DVT and PE.

PHYSICAL EXAMINATION

GA	• **Diaphoresis** suggests ACS (LR 2.9) [1].

VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?** • **Tachypnea** and **tachycardia** are consistent with ACS, AD, PE, perimyocarditis. • **Hypotension** is consistent with ACS, PE, AD (SBP < 100 mm Hg in 25% of cases [22]) and perimyocarditis in the presence of a significant effusion [17]. • **BP difference > 20 mm Hg** suggests AD (LR 5.7) [10]. • **Temperature > 38.5°C** argues against ACS, PE (SN 2%) [23], AD. • **Fever** may occur in the setting of purulent pericarditis [17].
CV	☐ **Auscultation: S3? Murmur?** • **S3** suggests ACS (LR 3.2) [1]. • **Pericardial friction rub** suggests perimyocarditis [17]. • **Crunching sound** (Hamman's sign) can sometimes be heard in cases of esophageal perforation. ☐ **Jugular venous pressure: elevated?** • **Jugular venous distension** suggests ACS (LR 2.4) [1], tamponade secondary to a large pericardial effusion [17] or AD, or a massive PE.
Lung	☐ **Auscultation: crackles? diminished breath sounds?** • **Crackles** are consistent with pneumonia, ACS (LR 2.1) [1], PE (SN 21%) [23].
Abdo	☐ **Palpation: upper abdominal tenderness?** • **Epigastric** pain upon palpation or pain under the right costal margin suggests cholecystitis.
Leg	☐ **Inspection: swelling? Edema?** • **Unilateral swelling** suggests deep venous thrombosis and concomittent PE. • **Bilateral edema** suggests right-sided heart failure.
CW	☐ **Inspection: rash?** • Rash following a **dermatome** suggests zoster. ☐ **Tenderness upon palpation?** • Pain localized to the **costochondral joint** suggests costochondritis; signs of inflammation suggests Tietze's syndrome. • **Reproduction of chest pain upon palpation** of the chest wall does not help distinguish between PE and musculoskeletal causes [19].

BEDSIDE TESTS

☐ **CRP and Troponin if > 40 years old**

• WBC and CRP may be elevated with pneumonia, PE, ACS, perimyocarditis.
• Troponin may be elevated with ACS, PE, perimyocarditis.

☐ **EKG**

PR	• **PR depression** suggests pericarditis and is rare in ACS [17].
Q	• **Q waves** may be present with myocardial ischemia/infarction but are absent in acute pericarditis [17].
QRS	• **New onset bundle branch block** suggests myocardial ischemia. • New onset **right bundle blanch block** is consistent with a large PE.
R	• **Loss of R wave voltage** often occurs with myocardial ischemia but does not occur with acute pericarditis [17].
ST	• **ST elevation** can occur in healthy individuals and in conditions other than myocardial infarction [24].

	• **Localized convex ST elevation** with reciprocal **ST-segment depression** suggests ACS. • **Diffuse concave ST elevation** in the limb and precordial leads suggests acute pericarditis [17]. • **ST elevation in II > ST elevation in III** strongly favors acute pericarditis [25]. • **ST elevation in III > ST elevation in II** very strongly favors acute MI [25]. • **ST-segment elevation / T wave amplitude in V6 ≥ 0.25** strongly suggests acute pericarditis [26]. • An **upsloping, 1- to 3-mm ST-segment depression** at the J point in leads V1-V6 that continued into a tall, positive symmetrical T wave is associated with occlusion of the proximal left anterior descending coronary artery [27]. • AD may occlude the coronary ostia resulting in ST elevation. • In the presence of ST elevation in II, III and aVF, EKG with V3R and V4R is recommended to detect **right ventricular infarction** caused by a proximal right coronary artery occlusion [28, 29]. • In the presence of isolated ST-depression ≥ 0.05 mV in leads V1 through V3, isolated **posterior myocardial infarction** may be present and confirmed by posterior chest leads V7-V9 [29].
T	• **T wave inversion** while the ST-segments are still elevated suggests myocardial ischemia, while T wave inversion after ST-segments have normalized suggests pericarditis [17]. • **Negative T waves in the precordial leads** can occur in ACS and PE; the presence of negative T waves in both V1 and III suggests PE (SN 90%, SP 97%) [30].

☐ Ultrasound

- **Pericardial fluid** may suggest an effusion from a perimyocarditis or hemopericardium from an AD.
- **Right ventricular dilation** suggests massive PE.
- **Dilated aortic root** suggests AD; the intimal flap in the descending aorta may occasionally be visualized.
- **Absence of lung sliding** is consistent with pneumothorax, while a **lung point** is diagnostic for pneumothorax.

MANAGEMENT

This section deals with the management of patients for whom the cause of the chest/thorax pain is not obvious following data acquisition. One study randomized physicians to the provision of the pretest probabilities for ACS (http://pretestconsult.com/v21/acs) and PE (http://pretestconsult.com/v21/pe), as well as a recommended investigations. The physicians who had access to this information ordered significantly fewer radiological investigations. The proportion of patients with > 5 mSv to the chest and no significant cardiopulmonary diagnosis within 90 days was reduced from 33% to 25% (p = 0.038) [31].

1. Cardiac monitoring?

According to the Ottawa Chest Pain Cardiac Monitoring Rule, a patient being worked up for chest pain in the ED does not need to be on cardiac monitoring if the following criteria are met: [32]

- Patient is currently chest pain free
- EKG is normal or nonspecific, i.e. no signs of:

- acute ischemia
- infarction
- bundle branch block
- prolonged QRS, QT or PR interval
- left ventricular hypertrophy with strain
- arrhythmia
- paced rhythm

2. Aortic dissection?

- See section in Chapter 09 for likelihood assessment and management.

3. Pulmonary embolism?

- See section in Chapter 09 for likelihood assessment and management.

4. Acute coronary syndrome?

- See section in Chapter 09 for likelihood assessment and management.

5. Acute pericarditis?

- See section in Chapter 09 for likelihood assessment and management.

6. Chest X-ray?

- A chest X-ray may help rule-in conditions such as pneumonia, pneumthorax and rare conditions such as pneumomediastinum.

HEADACHE/FACIAL PAIN

INTRODUCTION

This section covers headaches and facial pain that do not follow recent head trauma. Post-traumatic headache is covered under the section Trauma to the Head or Neck. Throat pain & neck pain are covered in another section. Headache accounts for approx 1% of visits to the ED.

DIFFERENTIAL DIAGNOSIS

The causes of "primary" headaches are:

- Tension headache (50% of headaches among patients visiting the ED) [1]
- Migraine headache (10% of headaches among patients visiting the ED) [1]
- Cluster headache

Approximaly 4% of ED patients with headache have a **serious or secondary cause** for their headache [2].

Pathophysiology	Examples
Vascular Cardiac	• Intracranial hemorrhage, subarachnoid hemorrhage • Cavernous sinus thrombosis, cerebral sinus thrombosis • Arterial dissection
Infectious Infiltrative	• Meningitis, encephalitis, cerebral abscess, sinusitis • Iritis, optic neuritis
Neoplastic Neurological	• Brain tumor • Trigeminal neuralgia
Intoxication Withdrawal	• Medications overuse, carbon monoxide poisoning • Withdrawal (e.g. abstinence from alcohol/caffein, medications)
Collagen vascular	• Lupus cerebritis
Autoimmune	• Temporal arteritis
Trauma Mechanical	• Concussion, post-lumbar puncture, pseudotumor cerebri • Acute closed-angle glaucoma • Cervical spondylosis, disc herniation, temporo-mandibular joint syndrome
Endocrine Metabolic	• Hypoxia, hypercapnia, hypoglycemia • Pheochromocytoma, hypertensive crisis, preeclampsia

EPIDEMIOLOGY

A	• **Age > 50/55** years is associated with intracranial pathology: SN 61%; SP 78%; LR 2.72 [2]; SN 52%; SP 78%; LR 2.34 (1.73-3.17) [3]. • The **elderly** are at risk for subdural hematoma, even in the absence of a clear history of trauma [4].
G	• **Female** gender is associated with increased prevalence of **migraine** (17% for women vs 5% for men) [4] and 3-fold increased prevalance of **temporal arteritis** [5]. • 90% of **cluster headaches** occur in **men** [6].
H	• A family history of **migraine** headaches is present in 70% of patients with migraine [6]. • **Subarachnoid hemorrhage** (SAH) in a first- or second-degree relative is a risk factor for ruptured aneurysm OR 4.0 [7].

BACKGROUND

M	☐ **What medications do you take?** • Medications that commonly cause headaches include **nitroglycerin**, **calcium channel blockers**, **digitalis**, **estrogen** [6]. • **Anticoagulant** use is a risk factor for subdural hematoma [1]. • **Oral contraceptive** use is a risk factor for venous sinus thrombosis [4]. • Intake of **vasoactive substances** (e.g. cocaine, ecstasy, amphetamine, cannabis, serotonin reuptake inhibitors, migraine medications, alpha sympathomimetics) suggests reversible cerebral vasoconstriction syndrome [8]. Headache following cocaine use may be caused by an intracranial bleed [6]. ☐ **How often do you take pain medications, e.g. NSAIDs, paracetamol?** • Long-term use of **analgesics** suggests medication overuse [4].
A	☐ **Are you allergic to medications or to contrast?**
P	☐ **What are your past medical conditions?** • **Current or prior cancer** suggests metastases, carcinomatous meningitis. • **Immunosuppression** increases the risk for unusual infectious causes of headache (toxoplasmosis, cryptococcal meningitis, brain abscess) and unusual non-infectious causes (e.g. central nervous system lymphoma) and may blunt signs of infection (e.g. fever, meningismus) [1]. • **Sinus or ear infection** or **recent surgical procedure** increases the risk of meningitis [1]. • **Cerebrospinal shunt** increases the risk of increased intracranial pressure [1]. • **Adult-onset polycystic kidney disease** increases the risk for SAH.
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Crowded living conditions** is a risk factor for meningitis [1]. • **Pregnancy** is associated with o preeclampsia (> 20 weeks gestation + BP > 140/90) o a worsening of muscle contraction headaches o brain tumors enlarge during pregnancy and most become symptomatic during the second half of pregnancy; pituitary gland and prolactin-secreting adenomas swell during pregnancy o on the other hand, 18-86% of classic migraine sufferers experience remission during pregnancy (Rosen's 8th Chapter 177) o See [9] regarding approach to headache in pregnancy in the ED • **Post-partum period** is associated with cerebral venous thrombosis, eclampsia, reversible cerebral vasoconstriction syndrome [8].
E	☐ **How much alcohol do you drink and how often?** • **Alcohol abuse** is a risk factor for subdural hematoma. • **Alcohol withdrawal** can cause headache [4].
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?**

HISTORY

O	☐ **When did the pain start? What were you doing when the pain started?** • **Onset during exertion** is suggestive of SAH OR 2.7 [10], SN 23% [11]. • **Onset during or following sexual activity** suggests coital headache [6] or SAH (6% of 131 SAH) [12]. • Frontal or occipital headache that begins 24-48 hours after **lumbar puncture** suggest

	persistent cerebrospinal fluid leak [6]. • **Onset following a fire** or headache that recurs whenever the patient is a **particular environment** (e.g. basement) is consistent with carbon monoxide poisoning [1, 6]. ☐ **How long did it take for the pain to reach its maximal intensity: seconds, minutes, hours?** • **Sudden onset** is associated with intracranial pathology SN 78%, SP 65%, LR+ 2.24 [2]; OR 2.44, LR+ 1.74 [3]. **"Thunderclap" headache** defined as a severe headache (VAS ≥ 7) reaching maximal intensity within one minute of onset [8]. SAH accounts for 11-25% of thunderclap headaches [8]. Roughly 10% of neurologically intact patients with a "thunderclap headache" have a SAH [13]. Other causes of thunderclap headaches include cerebral ischemia or bleeding, cervical artery dissection, cerebral venous thrombosis, reversible cerebral vasoconstriction syndrome, pituitary apoplexy [14].
P	☐ **Where is the pain located? How large is the painful area (diffuse or focal)?** • **Occipitalnuchal** location is an independent predictor of intracranial pathology in one study: SN 78%, SP 84%, LR 4.74 [2] but may also be caused by muscle spasm and cervical radiculopathy [6]. • **Unilateral** headache is suggestive of migraine; unilateral facial pain is suggestive of sinusitis, trigeminal neuralgia [6]. • Tension-type headaches are most commonly **bilateral** [4]. • **Highly localized** pain area suggests temporal arteritis, temporomandibular joint (TMJ) disease, dental infections, or sinus infections (e.g. pain over the maxillary sinus), whereas the location of pain of migraine, SAH and meningoencephalitis is more diffuse [1]. • **Orbital** headaches suggest glaucoma, optic neuritis, cluster headache, cavernous sinus thrombosis [6]. • **Anterior neck pain** in association with headache may suggest internal carotid artery dissection • **Posterior neck pain** in association with headache may suggest verterbral artery dissection [4]. ☐ **Does the pain radiate anywhere?** • **Radiation down the cervical spine** may result from the tracking of subarachnoid blood down the spinal canal.
Q	☐ **How would you describe the pain? New type of headache? Pulsating?** • **New type** of headache is traditionally regarded as a risk factor for intracranial pathology [6]; e.g., a new type of headache in patients with HIV is associated with an increased risk of intracranial pathology [15]. New headache in patients > 50 years should raise concern for glaucoma, intracranial lesions, temporal arteritis [6]. • **Pulsatile pain** that correlates with the patient's pulse is usually vascular in origin, while a pulsative pain that does not correlate with the patient's pulse is nonspecific [6].
R	☐ **Worse with valsava, bending forward?** • **Aggravation by exertion or a valsalva-like maneuver** is associated with serious intracranial abnormality LR+ 2.3 (1.4-3.8), LR- 0.70 (0.56-0.88) [16]. ☐ **Worse when lying down or standing up?** • **Headache worsened by the upright position** suggests intracranial hypotension and cerebellar stroke [8]; in particular, headache **relieved by recumbency** is typical for post-lumbar puncture headache [4]. • **Headache worsened by the recumbent position** suggests SAH, intracranial

	hypertension syndrome, cerebral venous thrombosis, acute sinusitis [8].
S	☐ **Pain intensity on a 1-10 scale?** • **Subjective severity** does not help predict serious intracranial pathology [3]; however, subjective severity may be useful to monitor response to therapy [1]. • **Increasing severity** is not associated with intracranial pathology [16]. • **Response to analgesia** has limited diagnostic utility [17]; rapid resolution of pain in the ED does not rule-out serious causes of headache [1]. ☐ **Awaking at night because of headache? Functional impairment?**
T	☐ **Duration? Has the pain been constant, intermittent, increasing?** • **Paroxysms of pain** in the trigeminal nerve distribution lasting only seconds suggests trigeminal neuralgia [4]. ☐ **Worse in the morning? Worse in the evening?** • **Worse headache in the morning** (e.g. patient awakening with headache) suggests increased intracranial pressure (e.g. secondary to a brain tumor), hypertension, cluster headache [6]. • **Worse headache in the evening** is consistent with tension-type headache. ☐ **Have you had prior similar episodes?** • Patients with migraine, cluster, and tension headaches tend to have a **stereotypical recurrent pattern** [1]. • **First ever, new onset headache** has traditionally been considered to be a risk factor for serious pathology, but evidence is lacking [16]. • **Increasing frequency** has traditionally been considered suggestive of intracranial pathology [16].
+	☐ **Neck pain or stiffness?** • **Neck stiffness** is suggestive of meningitis or SAH [8]; neck stiffness occurs in 70% of adults with meningitis [18] and 83% of adults with community-acquired bacterial meningitis [19]. ☐ **Fever?** • **Fever** suggests a current infection (e.g. meningitis) but may also occur with SAH and temporal arteritis. ☐ **Visual phenomena or eye pain?** • **Scintillating scotomas** (dark spots) or **flashing lights** that develop over minutes and usually last 60 minutes before reversing completely suggests migraine with aura [4]. The presence of a classic visual aura followed by headache does not warrant neuroimaging [16]. On the other hand, imaging is recommended if the aura is sensory, motor, or has changed in character, since such an aura is associated with serious intracranial abnormality LR 3.2 (1.6-6.6) [16]. • **Visual changes** and eye pain may suggest glaucoma and iritis [4]. • **Photophobia** may occur with meningeal irritation (e.g. secondary to meningitis, SAH), migraine, eye pathology (iritis, uveitis, acute angle closure glaucoma) [6]. ☐ **Recent trauma to the head?** • **Preceding, even remote head trauma,** suggests epidural or subdural hematoma, traumatic SAH, skull fracture and concussion [1]; the trauma can be minor (e.g. subduralhematom efter "headbanging"). • **Vomiting** is only weakly associated with serious intracranial abnormality in the context of a chronic, non-migrainous headache LR 1.8 (1.2-2.6) [16]. • **Ear, nose and throat symptoms** suggest complicated sinusitis [8].

PHYSICAL EXAMINATION

VS	☐ **RR, O2%, HR, BP, Temp?** • **Fever** suggests infectious causes (meningitis, brain abscess, sinusitis) but may also occur with temporal arteritis or SAH. • **Hypertension** may cause headache, be a sign of secondary causes of headache (e.g. acute hypertensive crisis, pheochromocytoma, stroke, preeclampsia), or result from pain and anxiety [4].
Head	☐ **Focal Tenderness to Palpation?** • **Sinus tenderness** upon palpation suggests sinusitis [4]. • **Temporal artery** tenderness, swelling, nodularity, decreased or absent pulsation suggests temporal arteritis [4, 5]. ☐ **Meningismus?** • **Resistance to passive flexion of the neck** suggests meningitis or SAH, but may also be due to arthritis or neck injury [6]**.**
Eye	☐ **Conjunctivitis?** • **Conjunctival injection** may occur with cluster headaches [8] and acute closed-angle glaucoma [6]. • **Eyelid edema** on the same side as the headache suggests cluster headache [8]. • **Decreased visual acuity** occurs with acute closed-angle glaucoma [6]. ☐ **Fundoscopy: papilledema? Subhyaloid hemorrhage?** • **Papilledema** on fundoscopy is suggestive of raised intracranial pressure [4]. • **Subhyaloid (pre-retinal) hemorrhage** on fundoscopy is highly suggestive of SAH [4] whereas **retinal hemorrhages and exudates** may be secondary to hypertensive encephalopathy [6].
NS	☐ **Cortical function** • **Altered mental status** in a patient with new-onset headache suggests intracranial pathology [16]. ☐ **Cranial nerve function** • **Unilateral pupillary dilation** suggests SAH from a posterior cerebral artery aneurysm compressing the third cranial nerve [8]. • **Unilateral Horner's syndrome** suggests dissection of the ipsilateral carotid artery [8] or cluster headache. • **Mid-dilated pupil that is poorly reactive to light** suggests acute closed-angle glaucoma [6] ☐ **Motor function** ☐ **Sensation** ☐ **Reflexes** ☐ **Coordination** • **Abnormal neurological findings** are associated with serious intracranial abnormality LR 5.3 (2.4-12) [16]

BEDSIDE TESTS

☐ **CRP in patients > 50 years**

- The CRP is usually very high with **temporal arteritis** [20]. One source recommends checking the erythrocyte sedimentation rate (ESR) in every patient > 50 years old with new-onset headache of unknown origin [21]. A CRP is recommended here instead the ESR out of convenience.

☐ EKG in patients > 50 years

- The EKG may reveal signs of ischemia which can be secondary to pain-induced catecholamine release [22] or even primary in the case of cardiac cephalagia (acute myocardial infarction with headache as the sole symptom). Routinely taking an EKG in patients over 50 years with thunderclap headache is recommended [14].

MANAGEMENT

1. Subarachnoid hemorrhage?

- See section in Chapter 09 for likelihood assessment and management.

2. Meningitis?

- See section in Chapter 09 for likelihood assessment and management.

3. Temporal arteritis?

- See section in Chapter 09 for likelihood assessment and management.

4. Migraine?

- See section in Chapter 09 for likelihood assessment and management.

5. Does the patient have a serious underlying cause?

A prospective study was carried out on 589 patients > 15 years who presented to the ED with nontraumatic headache and were fully alert (GCS 15) [3]. 13% of these patients were found to have a serious underlying cause for their headache. The presence of ≥ 1 of the following had a SN 98.6%, SP 34.4%, LR+ 1.50 (1.39–1.63), LR- 0.04 (0.01–0.29) for predicting a serious intracranial pathology:

- Age > 50 years (LR 2.34)
- Sudden onset of the headache (LR 1.74)
- Abnormal findings on neurological examination (LR 3.56)

Non-contrast CT head is the initial mode of investigation for such patients.

6. Non-specific headache?

- Symptomatic treatment
- Avoid opioids (ref?)

NEUROLOGICAL SYMPTOMS

VERTIGO/DIZZINESS

INTRODUCTION

Patients use the word "dizziness" to refer to variety of experiences [1, 2]:

- an illusion of motion (vertigo)
- unsteadiness when walking (disequilibrium)
- malaise (light-headedness)
- a feeling of impending faint (presyncope)

This section focuses on the approach to the patient with an illusion of motion and/or disequilibrium, i.e. the sensation that arises when the signals from the eyes, inner ears and the body's proprioception do not concord with each other or are falsely interpreted by the brain [3]. The approach to the patient with presyncope is covered in the section Syncope/Seizure.

The term **acute vestibular syndrome** (AVS) refers to the rapid onset (over seconds to hours) of dizziness lasting for a day or more and accompanied by nystagmus, gait unsteadiness, nausea/vomiting and intolerance to head motion [2, 4]. **Isolated AVS** refers to AVS symptoms and signs in the absence of other neurological deficits. The cause of an AVS is said to be

- **peripheral** when the lesion is located in the semicircular canals of the inner ear or the vestibular nerve
- **central** when the lesion is located in the brainstem, cerebellum or spinal cord

DIFFERENTIAL DIAGNOSIS

Adapted from [1, 2]

Pathophysiology	Examples
Vascular Cardiac	• Stroke or TIA affecting the brainstem, cerebellum or laryrinthine artery • Vertebrobasilar dissection or insufficiency • Subclavian steal syndrome • Vestibular migraine • Brainstem hypertensive encephalopathy
Infectious Infiltrative	• Vestibular neuritis • Herpes zoster oticus (Ramsay Hunt syndrome) • Bacterial labyrinthitis (acute suppurative labyrinthitis) • Acute otitis media • Brainstem encephalitis (e.g. listeria, paraneoplastic) • CNS inflammation (e.g. sarcoidosis)
Neoplastic Neurological	• Cerebro-pontine angle neoplasm • Multiple sclerosis, Miller Fischer syndrome • Temporal lobe epilepsy
Deficiency	• Wernicke syndrome (B1 deficiency)
Intoxication Withdrawal	• Medication ototoxicity (e.g. post aminoglycoside therapy) • Antiepileptic medications • Drug intoxication (alcohol, illicit drugs)
Trauma Mechanical	• Benign paroxysmal positional vertigo • Ménière's disease • Traumatic vestibulopathy (labyrinth concussion)

	• Hydrocephalus

EPIDEMIOLOGY

P	• Roughly half of patients seeking care in the ED because of dizziness suffer from neither an AVS not benign paroxysmal positional vertigo (BPPV) but rather from cardiovascular, metabolic, toxicologic, psychiatric och infectious conditions [5]. • 10-20% of patients who present with acute dizziness to the ED have an AVS [2]. • 25% +/- 15% of AVS are caused by stroke [2].
A	• **Age < 50 years** in patients with AVS suggests vestibular neuritis. However, in one prospective study of patients with AVS and 1 stroke risk factor, 25% of patients with ischemic stroke and 3 of 4 patients with vertebral artery dissection were < 50 years old [4]. • **Age > 50 years** suggests stroke. However, isolated AVS in patients > 50 years is more likely neuritis than stroke [2].

BACKGROUND

M	☐ **What medications do you take?** • **Aminoglycosides**, **anticonvulsants**, **quinine**, **quinidine** and **minocycline** are vestibulotoxic [1].
A	☐ **Are you allergic to medications or to contrast?**
P	☐ **What are your past medical conditions?** • **Atrial fibrillation**, previous **stroke**, **coronary artery disease** increase the risk for stroke and TIA [1] • **≥ 1 vascular risk factor** (hypertension, diabetes, hypercholesterolemia) appears to confer an increased risk for stroke [2]. • **Migraine** headaches, current or past, increase the risk for vestibular migraine.
L	☐ **Life circumstances: occupation? social support? activities of daily living?**
E	☐ **How much alcohol do you drink and how often?** • **Alcohol** is vestibulotoxic [1].
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • **Smoking**, a vascular risk factor, appears to confer an increased risk for stroke [2].

HISTORY

O	☐ **When did the dizziness start?** • Patients who have had dizziness for **months** are unlikely to have an AVS [6]. ☐ **How long did it take for the dizziness to reach its maximal intensity: seconds, minutes, hours?** • **Sudden onset** over seconds-minutes suggests stroke [2] • **Gradual onset** over hour-days suggests vestibular neuritis, although some strokes also have a gradual onset [2]. Onset is unhelpful when the patient wakes up with the symptom [2].
P	☐ **Is the dizziness brought on by changing your body position?** • Transient dizziness triggered by **standing** suggests orthostatic hypotension or BPPV [7]. • Transient dizziness triggered by **turning over in bed** is associated with Dix-Hallpike positive BPPV OR 10.17 (2.49-41.63) [8]. • Transient dizziness triggered by **bending the head** forwards or backwards suggests

	BPPV [7]. • **Positional vertigo**, i.e. vertigo that persists as long as the head is in a specific position, suggests vestibular migraine[9].
Q	☐ **How would you describe your "dizziness"? Illusion of motion? Feeling of faintness?** • The feeling of **impending loss of consciousness** suggests presyncope (see section Syncope/Seizure). • In one study, half of patients with dizziness were unable to report which symptom type described their experience [10]. • How the patient describes his/her experience (vertigo, disequilibirum, light-headedness) has little correlation with the cause of the symptom [2].
R	☐ **Is the dizziness worsened by head motion?** • **Head motion intolerance** during the acute stage (i.e. that the vertigo is worsened by head motion) does not increase the likelihood of a benign cause [11]. ☐ **Does anything lessen the symptoms?** • Patients with vestibular neuritis tend to lie on their side with the healthy ear down [12]. • Presumably, the absence of symptoms when lying completely still argues against AVS.
S	☐ **How severe is the dizziness? How does it impair your ability to function?** • **Gait/postural imbalance** or **nausea/vomiting** out of proportion with the subjective severity of the dizziness suggests a central cause [2].
T	☐ **How long did the dizziness last: seconds, minutes, hours, days?** • **≤ 15 seconds** duration was associated with Dix-Hallpike positive BPPV OR 4.36 (1.18-16.19) [8]. Patients may report a duration of "**minutes**" even if the episode lasted seconds and may report prolonged unsteadiness following the acute episode [13]. • **5-10 minutes** duration is consistent with a transient ischemic attack (TIA) [14]. • **Minutes-hours** duration suggests Ménière's disease, TIA • **Hours-days** duration suggests vestibular migraine [15] and Ménière's disease [16] • **Several days - weeks** duration suggests vestibular neuritis or stroke. • **Several months** duration is not consistent with a "peripheral" or "central" cause of vertigo [6]. • **Repetitive episodes** occur with TIA, vestibular migraine and Ménière's disease [2]. ☐ **Have you had prior similar episodes?** • **Recurrent episodes** of transient dizziness lasting seconds to minutes over the preceding weeks or months suggests a vascular episode [2]. • A **single episode** a few days prior to presentation is non-specific [2].
+	☐ **D's: double vision, dysarthria, dysphagia, deafness, dysmetria, decreased strength / sensation?** • **Presence of ≥ 1 D** (double vision, dysarthria, dysphagia, dysmetria, decreased strength, decreased sensation) suggests stroke [2]. ☐ **Decreased hearing?** • **Auditory symptoms** (decreased hearing, tinnitus, sensation of ear fullness) in association with dizziness points to a peripheral cause (e.g. labyrinthitis or Ménière's disease) according to many experts. However, hearing loss in association with dizziness may also result from stroke, since the vascular supply to the inner ear derives from the anterior inferior cerebellar artery (AICA) [2, 17]. • **Fullness in one ear** (aural pressure) is an initial feature of a typical Ménière's attack, leading to progressive **tinnitus** and ipsilateral fluctuating **hearing loss** [13]. Both Ménière's disease and vestibular migraine may manifest as repeated episodes with

	vertigo, decreased hearing, tinnitus, ear fullness and headache with migraine features [9, 16]. • **Absence of permanent hearing** loss despite repeated vertigo episodes with hearing loss suggests vertibular migraine [18]. ☐ **Pain: Ear pain? Headache? Neck pain?** • **Ear pain** and vertigo occur with Ménière's disease [15], bacterial labyrinthitis (due to spreading of the infection to the inner ear), and the Ramsay Hunt syndrome (vertigo, facial palsy and vesicles in the external acoustic meatus caused by varicella zoster virus)[19]. • **Mild headache of gradual onset over hours** in association with dizziness and disappearance of pain within 24–48 hours suggests vestibular migraine [2, 9]. The patient has usually had similar episodes in the past. Dysarthria, ataxia and visual disturbances may also precede the headache [1]. Vertigo caused by vestibular migraine can occur without headache, and a migraine-like headache can also occur in patients with Meniere's disease [20]. • **Severe headache and neck pain of sudden onset** that is sustained (> 72 hrs in one series, 2-35 days in another) suggests dissection of the vertebral artery when associated with dizziness [2]. However, the absence of head or neck pain does not rule out vertebral dissection (pain is absent in 1 in 4 dissections of the vertebral artery) [2]. ☐ **Recent head or neck trauma?** • **Recent head or neck trauma** increases the risk of dissection of the vertebral artery OR 3.8 [21], even if pain is absent and the trauma was minor [2]. However, half of symptomatic cases with dissection of the vertebral artery have no preceding trauma [22]. Head trauma is a frequent antecedent of BPPV, presumably leading to the dislocation of otoliths from the utriculus [23]. Trauma to the ear or barotrauma can lead to perilymphatic fistula between the middle and inner ear, leading to fluctuating hearing loss and vertigo.

PHYSICAL EXAMINATION

VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?** • **Abnormal heart rate and blood pressure** suggest presyncope. • **Fluctuating or decreased level of consciousness** in association with vertigo suggests pons pathology due to basilar occlusion or compression from edema secondary to a cerebellar stroke [24]. • **Fever** suggests an infectious etiology, e.g. acute bacterial (suppurative) labyrinthitis.
NS	☐ **Cranial Nerves** • **Horizontal nystagmus** may be caused by peripheral lesions (in which case the slow phase is in the direction of the diseased hypoactive ear) [1] or by central lesions (in which case the fast phase is towards the side of the lesion) [25]. • **Suppression of horizontal nystagmus with visual fixation** and exacerbation of horizontal nystagmus with loss of visual fixation (e.g. with the use of Frenzel's glasses or by covering one eye and shining a light in the other [26]) suggests, according to traditional teaching, a peripheral lesion [27] but evidence is lacking [2]. • **Vertical nystamus** suggests a central lesion (brainstem or cerebellum) [1], in which case downbeat nystagmus is associated with craniocervical junction or cerebellar lesions while upbeat nystagmus is associated with medullar lesions [25]. • **Gaze-dependent change in nystagmus direction** in a patient with AVS speaks for

	stroke: SN 38% (32-44); SP 92% (86-98); LR- 0.68 (0.60-0.76); LR+ 4.51 (2.18-9.34) [2]. • **Alexander's law** refers to the observation that the nystgamus is more severe when the patient is looking in the direction of the nystagmus [28]. • **Ophthalmoplegia** suggests stroke. • **Horner's syndrome** (unilateral ptosis and miosis) in the presence of vertigo suggests a lateral medullary infarct which may result from thrombosis of the posterior inferior cerebellar artery (PICA). PICA is a mnemonic for several of the findings that may be associated with this lesion and that constitute the Wallenberg syndrome [29]: o **P**haryngeal dysmotility, hiccups, hoarseness o **I**psilateral Horner's syndrome o **C**erebellar findings such as ataxia, nystagmus o **A**lternating hemianesthesia: decreased pain sensation ipsilateral face, contralateral body • **Unilateral facial paresis** in combination with vertigo may result from stroke in the AICA distribution [30] or from facial nerve palsy as part of the Ramsay Hunt syndrome. ☐ **Motor Function** • **Arm or leg weakness** in association with vertigo suggests contralateral brainstem pathology. ☐ **Sensory Function** • **Arm or leg paresthesia** in association with vertigo suggests contralateral brainstem pathology. ☐ **Coordination** • **Dysmetria** suggests ipsilateral brainstem or cerebellar pathology. • **Truncal ataxia**, i.e. inability to sit unaided with arms crossed, suggests stroke [2, 31]. • **Disproportionate gait unsteadiness** in relation to the degree of vertigo suggests stroke [2, 31]. A retrospective study of patients with cerebellar stroke and isolated AVS reported that 80% had gaze-dependent change in nystagmus direction and/or could not walk without assistance [32]. The main features of a "cerebellar gait" are a wide base, unsteadiness, irregularly of steps, tremor of the trunk, and lurching from side to side [1].

BEDSIDE TESTS

☐ EKG if patient > 50 years

Routinely taking an electrocardiogram among patients > 50 years with vertigo may be justified:

- Atrial fibrillation is a risk factor for embolic stroke
- Tachy- or bradyarrhythmias suggest presyncope as opposed to a nervous system problem.

MANAGEMENT

1. Stroke?

If the patient has an AVS (i.e. rapid onset of sustained dizziness accompanied by nystagmus, gait unsteadiness, nausea/vomiting and intolerance to head motion), stroke should be suspected when:

- the neurological examination reveals other abnormalities suggestive of brainstem or cerebellar stroke (e.g. ataxia, motor or sensory deficits, severe gait or truncal ataxia) [33].
- the nystagmus is vertical, purely rotatory, or changes directions according to gaze direction

For example, infarction of the lateral medulla leads to a cluster of neurological deficits refered to as the **Wallenberg's syndrome**. Infarction of the lateral medulla may result from ischemia due to occlusion of the Posterior Inferior Cerebellar Artery (PICA). PICA is a mnemonic for several of the findings that may be present:

- **P**haryngeal dysmotility, hiccups, hoarseness
- **I**psilateral Horner's syndrome
- **C**erebellar findings such as ataxia, nystagmus
- **A**lternating hemianesthesia: decreased pain sensation ipsilateral face, contralateral body

The management of stroke is covered under Chapter 09-Stroke. Specific points in regards to stroke patients with vertigo are as follows:

- CT has a sensitivity approaching 0% for the detection of acute ischemia in the posterior circulation [34, 35]. CT has a sensitivity of 89% to detect acute intracranial bleeding [36], yet a retrospective study of 595 cases of intracranial bleeding found that only 2.2% had vertigo as their chief complaint, and that among those patients all had either headache, an episode of loss of consciousness or an abnormal neurological examination.
- CT angiography should be carried out in the setting of suspected posterior circulation dissection, basilar thrombosis, and in young patients (in one series, the average age of patients with vertebral artery dissection was 43 years [37]). MRA (Magnetic Resonance Angiography) is for some the diagnostic modality of choice in the setting of rapidly changing neurologic signs and symptoms suggesting impending posterior circulation occlusion [1].
- Intravenous thrombolysis can be considered in patients with symptoms < 3-4.5 hrs without contraindications. Intraarterial thrombolysis, thrombectomy and stent insertion are treatment alternatives in severe cases such as basilar artery occlusion, but studies have so far not shown any better outcomes than with intravenous thrombolysis [38-41].
- Edema or the mass effect of bleeding from a cerebellar stroke can lead to brainstem compression and obstructive hydrocephalus in 10-20% of infarctions [42] and 50% of hemorrhages [43]. Compression occurs during the first week (median 3 days) after symptom onset [44]. Ophthalmoplegia and decreasing level of consciousness occur. Patients should therefore be carefully monitored and the neurosurgeon informed of the patient. The intervention of choice (endoscopic evacuation, stereotactic surgery, decompressive craniotomy, external ventricular drainage) is debated but the value of neurosurgery is well established [44].

2. Vestibular neuritis?

Patients with an acute vesitubal neuritis (AVS) who lack other neurological deficits have a so-called **isolated AVS**. The absence of neurological signs excludes about 2 of 3 strokes causing AVS (LR 0.36) but does not rule-out stroke [2]. Roughly 20-50% of patients with a central cause of vertigo present with isolated AVS. HINTS (Head-Impulse, Nygstagmus, Test-of-Skew) is a clinical decision rule to help identify these patients. The presence of **any of the following** suggests stroke (mnemonic INFARCT):

- **I**mpulse test **N**egative. The horizontal head impulse or head thrust test is carried out by asking the patient to fixate a central target (e.g. the examiner's nose) and by then rapidly rotating to the head in one direction. Both directions are tested. The test is positive if rotation in one direction results in a delayed horizontal refixation saccade. A normal impulse test in a patient with AVS speaks for stroke: SN 85% (79-91); SP 95% (90-100); LR- 0.16 (0.11-0.23); LR+ 18.39 (6.08-55.64) [2].
- Nystagmus changes direction according to gaze (**F**ast phase **A**lternating).

- Positive Test-of-Skew (**R**efixation on **C**over **T**est). The test-of-skew identifies the patients with a lateral pontine lesion who have a positive impulse test, yet have a central lesion. The patient is asked to fixate a central target and the eyes are alternately covered. A vertical refixation saccade indicates skew deviation. Skew deviation speaks for stroke: SN 30% (22-39); SP 98% (95-100); LR- 0.71 (0.63-0.80); LR+ 19.66 (2.76-140.15) [2].

Three studies have evaluated the HINTS clinical decision rule among patients with AVS and risk factors for stroke [4, 45, 46]. These studie report SN 97-100% and SP 84-96%. The HINTS tool is more sensitive than acute MRI in the setting of isolated AVS; MR has a sensitivity of only 40% for the detection of acute ischemia in patients with isolated AVS.

Patients with an isolated AVS and **all of the following** have a peripheral cause of vertigo:
- Positive impulse test (when the head is turned in the opposite direction to that of the nystagmus)
- No change in direction of the nystagmus regardless of gaze direction
- No skew deviation

In the absence of symptoms suggesting ear pathology, these patients most likely have vestibular neuritis, a condition which is thought to be caused by a viral inflammation of the vestibular part of cranial nerve VIII [47]. Treatment for vestibular neuritis consists of the following:
- **Prednisolone** 60 mg daily for 5 days followed by tapering over 5 days; a metaanalysis concluded that the evidence for this therapy is weak [48].
- **Antihistamines** (e.g. Prometazin) or **antiemetics** (e.g. Metoclopramide) for a couple of days only, in order to not interfere with the brain's ability to compensate for the loss of vestibular input [49, 50].
- **Balance exercises** accelerate recovery [51, 52].
- **Admission** is indicated if the patient is highly symptomatic.

3. Benign paroxysmal positional vertigo?

Discrete episodes of vertigo that are triggered by a change in head position and that last for ≤ 15 seconds are highly suggestive of BPPV. According to one study, having both **dizziness duration ≤ 15 seconds** and **onset when turning over in bed** was associated with LR 6.81 (5.11-9.10) for Dix-Hallpike test positive BPPV, while having neither was associated with LR 0.19 (0.08-0.47) for Dix-Hallpike test positive BPPV [8].

The vertigo in BPPV is triggered by **otolithic debris** in the semicircular canals that move when the head changes position and create a false sense of rotation. The posterior semicircular canal is affected in 60-90% of cases [23] and the lateral canal is 10-20% of cases [53].

The **Dix-Hallpike** maneuver starts with the patient in the sitting position and the head rotated 45° to one side and slightly extended; this places the posterior semicircular canal of the side to which the head is rotated in the sagittal plane. The patient is then moved from sitting to supine and the eyes observed for nystagmus. If the maneuver provokes a mixed torsional and vertical nystagmus, Epley's maneuver can be carried out directly. Otherwise, the patient is moved from supine to sitting and the test is repeated with the head turned towards the other side. The test might be more sensitive when carried out with Frenzel's glasses.

The diagnostic criteria for BPPV affecting the posterior semicircular canal of the side to which the head is turned are [23]:

- the Dix-Hallpike maneuver provokes a mixed torsional and vertical nystagmus with the upper pole of the eye beating toward the dependent ear and the vertical nystagmus beating toward the forehead.
- the nystagmus typically begins after a 1-to-2-second latency, lasts for 10 to 20 seconds, and is associated with a sensation of rotational vertigo.
- paroxysmal nature of the provoked vertigo and nystagmus (i.e. an increase and then decline over a period of 10-20 seconds)
- fatigability (i.e. a reduction in vertigo and nystagmus if the Dix-Hallpike test is repeated)

According to these criteria, the Dix-Hallpike examination is by definition 100% sensitive and specific for BPPV affecting the posterior semicircular canal. However, some patients have a history that is highly suggestive of BPPV, yet a negative Dix-Hallpike examination, while some patients with conditions other than BPPV may have a positive Dix-Hallpike test. A structured critical appraisal of the litterature suggests that the Dix-Hallpike has the following test characteristics: SN 79% (65-94); SP 75% (33-100); LR+ 3.17 (0.58-17.50); LR- 0.28 (0.11-0.69) [54].

Epley's canalith-repositioning maneuver is designed to flush otolithic debris out of the posterior semicircular canal and into the vestibule. The Dix-Hallpike maneuver is the first step of the Epley's maneuver. A randomized controlled trial reported that patient-performed Epley's maneuver was 95% effective in treating posterior canal BPPV [55] and effective in 80% of cases after the first performance [56]. The majority of patients who experience vertigo when the Dix-Hallpike test is carried out, yet who lack nystagmus, can also be treated successfully with the Epley's maneuver [57]. One study showed that 90% of patients with posterior BPPV had long-term symptom resoluation (on the order of months) from the Epley's maneuver compared to a sham maneuver [58]. The Epley's maneuver can be carried out once in the ED and patients then set home with written/visual instructions.

The **Head-Roll Test** (Pagnini McClure Test) can be carried out if the history is suggestive of BPPV and the Dix-Hallpike test is negative. The Head-Roll test examines the patient for otoliths in the lateral semicircular canals. The patient is placed in the straight supine position to bring the the lateral semicircular canals into a vertical position. The head is turned to one side and the examiner observes for nystagmus and note direction (geotropic = beating towards the ground; apogeotric = beating towards the ceiling) and degree. The head is then placed in the neutral position and then turned towards the other side.

Gufoni's maneuver is a repositioning maneuver for otolithic debris in the lateral semicircular canals. How the maneuver is carried out depends on the affected side and whether the nystagmus is geotropic or apogeotropic. Randomized controlled trials report that this maneuver is 61% effective for geotropic nystagmus [59] and 73% effective for apogeotropic nystagmus [60].

Barbecue roll (Lempert maneuver) is another maneuver for repositioning otolithic debris in the lateral semicircular canals giving rise to geotrophic nystamus [61]. The starting position is with the patient lying supine with the head turned towards the side where the nystagmus amplitude was greatest on head-roll test examination. The head is first turned to the neutral position, then towards the opposite side. The patient is then rolled into the prone position and carries out a 360º rotation ending up supine again.

4. Ear pathology?

Ear pathology (e.g. acute bacterial labyrinthitis, Meniere's disease, Ramsay Hunt syndrome, perilymphatic fistula) should be suspected in the setting of ear pain. An examination may reveal:

- a red bulging ear drum or pus in the external acoustic meatus suggesting bacterial labyrinthitis
- vesicles in the external acoustic meatus suggesting herpes zoster oticus (Ramsay Hunt syndrome).
- If acute bacterial labyrinthitis, herpes zoster oticus or perilymphatic fistula are suspected, an otorhinolaryngologist should be contacted for antibiotic/antiviral therapy and/or surgical therapy.
- If Ménière's disease is suspected, the patient should be referred to an otorhinolaryngologist for further investigations.

5. Non-specific dizziness

The remaining patients suffer from nonspecific dizziness. The differential diagnosis includes metabolic, infectious, toxicologic and psychiatric conditions [5]. Measuring glucose, electrolytes, hemoglobin, white blood cell count and CRP is reasonable. Further management depends on the diagnostic hypothesis.

WEAKNESS & PARESTHESIA

INTRODUCTION

This section focuses on the approach to the patient with objective or subjective **weakness** (defined as decreased strength) and/or **paresthesia** (defined as abnormal sensation). Visual disturbances (with or without associated weakness/paresthesia) are covered in Chapter 07-Visual Disturbances. Weakness/paresthesia in the setting of vertigo is covered in Chapter 07-Vertigo.

Motor information is conveyed as follows:

- The motor impulse originates in the primary motor cortex contralaterally to the corresponding body part. The primary cortex is organized somatotopically (homunculus) in the following lateral to medial pattern: tongue, face, hand, arm, trunk, leg.
- The impulse descends through the corona radiata and the fibers from the face, arm and leg converge in the capsula interna.
- The motor impulse courses downward through the brainstem and decussates at the level of the medulla.
- The motor impulse then courses down the spinal cord in the corticospinal tract, which is located postero-laterally in the spinal cord.
- The axon synapses with a motor neuron in the anterior horn of the spinal cord at the level where the motor signal exits the spinal cord through the anterior nerve root.
- The impulse reaches the muscle through nerves, of which some are initially bunched together into a brachial or lumbosacral plexus.
- The nerve activates the muscle through the neuromuscular junction (NMJ).

Fine touch, vibration and proprioception information is conveyed as follows:

- The impulse originates when mechanoreceptors in the skin are activated.
- The impulse courses towards the spinal cord in a nerve which nucleus is located in a dorsal root ganglion.
- This neuron's axon enters the spinal cord through the posterior nerve root and ascends to the brain in the posterior (dorsal) column.
- The axon synapses with a neuron located in the lower medulla, and the axon from this neuron decussates and ascends along the other side of the brainstem in the medial lemniscus to the thalamus.
- After another synpase in the thalamus, the information courses through the internal capsule and corona radiata to reach the somatosensory cortex in the postcentral gyrus. This cortex is also somatotopically organized in a distribution that resembles that of the primary motor cortex.

Pain and temperature information is conveyed as follows:

- The impulse originates when receptors in the skin are activated.
- The impulse courses towards the spinal cord in a nerve which nucleus is located in a dorsal root ganglion.
- This neuron's axon enters the spinal cord through the posterior nerve root and synapses with another neuron located in the dorsal horn of the spinal cord one or two vertebral levels above or below the entry level.
- The axon of this secondary neuron decussates and ascends along the other side of the spinal cord in the lateral spinothalamic tract, which is located antero-laterally in the spinal cord.
- The impulse ascends through the brainstem to the thalamus.

- After another synpase in the thalamus, the information courses through the internal capsule and corona radiata to reach the somatosensory cortex in the postcentral gyrus.

DIFFERENTIAL DIAGNOSIS

Adapted from [1]

Anatomy	Examples
Brain and brainstem	• Vascular, e.g. ischemic stroke (thrombotic, embolic, systemic hypoperfusion), hemorrhage • Infectious, e.g. brain abscess • Neurologic, e.g. seizure, post-ictal state • Neoplastic, e.g. primary tumors, metastases, carcinomatous meningitis • Autoimmune, e.g. multiple sclerosis • Mechanical, e.g. Arnold-Chiari malformation • Electrolytes, e.g. osmotic demyelinolysis
Spinal cord	• Vascular, e.g. ischemia • Infectious, e.g. spinal epidural abscess, poliomyelitis, West nile virus, enterovirus D68 • Neoplastic, e.g. epidural tumor • Autoimmune, e.g. amyotrophic lateral sclerosis; demyelination (transverse myelitis) • Mechanical, e.g. compression from a disc, abscess, hematom; trauma; syringomyelia
Cauda Equina [2]	• Vascular, e.g. epidural hematoma • Infectious, e.g. herpes simplex virus II • Neoplastic, e.g. meningeal carcinomatosis, lymphoma • Mechanical, e.g. trauma, spinal lumbar canal stenosis, disc herniation
Nerve Root	• Mechanical, e.g. disc hernication, degenerative spine disease [2]
Plexus	• Neoplastic, e.g. Pancoast tumor [2] • Mechanical, e.g. following a motorcycle accident [2]
Nerve	• Vascular, e.g. vasculitis, diabetic neuropathy, critical illness polyneuropathy • Infectious, e.g. Borrelia (Bannwarth's syndrome), tick paralysis (which also inhibits NMJ function) [3]. • Drugs/toxins (toxic neuropathies: examples?) • Mechanical, e.g. trauma, compression neuropathy, nerve entrapment • Autoimmune, e.g. Guillain-Barré syndrome
Neuromuscular junction	• Autoimmune, e.g. Myasthenic crisis • Neoplastic, e.g. Lambert-Eaton syndrome • Drugs/toxins, e.g. acetylcholinesterase inhibitors (cholinergic crisis), organophosphates, succinylcholine, tetrodotoxin from the puffer fish, saxitoxin from shellfish, snake or scorpion envenomation [4] • Infectious, e.g. botulism, tick paralysis (which also inhibits nerve conduction) [3].
Muscle	• Idiopathic inflammatory myopathies, e.g. polymyosis, dermatomyosis, inclusion-body myositis • Drugs, e.g. glucocorticoids, statins
Systemic	• Vascular, e.g myocardial infarction

	• Infectious, e.g. sepsis • Degenerative/Deficiency, e.g. anemia • Intoxication • Withdrawal, e.g. sedatives, stimulant withdrawal • Endocrine, e.g. hypothyroidism • Electrolyte, e.g. hyperkalemia • Metabolic, e.g. uremia

EPIDEMIOLOGY

A	• **Age < 45 years:** among patients < 45 years with stroke, SAH (20%) and ICH (20%) are relatively more common than in elderly patients [5]. Young age argues against thrombotic or embolic stroke due to atherosclerosis [6].

BACKGROUND

M	☐ **What medications do you take?** • **Anticoagulants** increase the risk of hemorrhagic stroke [6]. • **Oral contraceptive** use that includes ethinyl estradiol at a dose of 30 to 40 µg increased the risk of thrombotic stroke among nonpregnant, 15-49 year old women with no history of cardiovascular disease by a factor of 1.3-2.3. The relative risk of stroke with ethinyl estradiol at a dose of 20 µg was 0.9 to 1.7 [7]. • **Statins** may cause myopathic injuries ranging from asymptomatic elevations of creatine kinase levels to rhabdomyolysis [8]. • **Corticosteroids** can cause myopathies [2]. • **Amiodarone**, **cisplatin**, **nitrofurantoin** and **isoniazid** can give rise to ascending sensorimotor symptoms developing over the course of weeks or months [2]. • **Metronidazole** can cause encephalopathy resulting in weakness, dysarthria, ataxia [9] [10]
A	☐ **Are you allergic to medications or to contrast?**
P	☐ **What are your past medical conditions?** • **Transient ischemic attack (TIA) & stroke** are risk factors for a subsequent stroke but also for post-apoplectic seizures. • **Heart disease** including valvular disease, atrial fibrillation, recent myocardial infarction and endocarditis, increases the risk of embolic stroke [6]. • **Hypertension**: severe hypertension is associated with acute onset of focal deficits suggests ICH, whereas chronic hypertension is a risk factor for thrombotic stroke [6]. • **Diabetes** is associated with thrombotic stroke [6]. Diabetes is also associated with polyneuropathy [2]. • **Elevated total cholesterol** and **low HDL** are associated with ischemic stroke [6]. • **Puerperium** is associated with cerebral sinus thrombosis. • **Myasthenia gravis** raises the possibility of either a myasthenic crisis due to too little acetylcholine or a cholinergic crisis due to too much acetylcholine. • **Migraine** raises the possibility of a migraine aura. • **Cancer** raises the possibility of metastatic disease to the brain or spinal cord [3], but also of peripheral neuropathies (e.g. obturator nerve palsy due to pelvic tumor) or paraneoplastic syndrome. • **Seizure** disorder raises the possibility of on-going seizure or post-ictal weakness. • **Gastric bypass surgery of the Roux-en-Y type** raises the possibilty of neurological

	disorders due to vitamin and mineral deficiencies; neurological disorders occur as a complication of bariatric surgery in 5-16% of patients [11, 12].
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Amphetamine** use increases the likelihood of ICH and SAH [6] • **Cocaine** use increases the likelihood of ICH, SAH and ischemic stroke due to vasoconstriction [6]
E	☐ **How much alcohol do you drink and how often?**
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • **Smoking** is a risk factor for extracranial occlusive vascular disease [6].

HISTORY

O	☐ **When did the weakness/paresthesia start? What were you doing at the time?** • **Exertion** just before or upon onset suggests ICH or SAH [6]. • **Trauma** just before or upon onset suggests dissection or ICH [6]. ☐ **How long did it take for the problem to reach its maximal intensity: seconds, minutes, hours?** • **Maximal intensity within seconds** suggests embolism or SAH [6]. • **Maximal intensity over minutes** or a few hours is consistent with ICH [6]. • **Gradual onset** of weakness is consistent with demyelination or neoplasm [1].
P	☐ **Where is the weakness/paresthesia located? Which movements are affected?** • **Isolated whole body part deficits** (e.g. hand, leg) suggests a lesion in the forebrain or brainstem. • **Cranial nerve deficits** associated with contralateral arm/leg symptoms suggests brainstem lesion. • **Sensory/motor level** suggests a spinal cord lesion. • **Symmetrical leg weakness without arm weakness** suggests a spinal cord lesion. • **Segmental weakness** in a specific myotome suggests anterior horn cell / nerve root pathology. • **Isolated deficit limited to the side of a body part** (e.g. foot dorsiflexion but not plantarflexion, paresthesia affecting the fourth and fifth fingers but not the rest of the hand) suggests a mononeuropathy. • **Symmetrical distal arm and leg weakness** suggests a motor-neuron disorder (e.g. amyotrophic lateral sclerosis), a peripheral nerve disorder or a muscular disorder (e.g. myotonic dystrophy) [13]. Primary muscle disorders typical begin with proximal weakness, and proximal weakness that is more severe than distal weakness, however several muscular dystrophies or inherited or acquired myopathies can be manifested by progressive distal weakness [13]. • **Symmetrical proximal arm and leg weakness** (e.g. climbing steps, rising from a sitting position, or lifting the arms over the head) suggests an inflammatory myopathy [14] (or myopathies in general? Probably myopathies in general according to [2]) or NMJ pathology [2]. • **Trouble swallowing** can result from oropharyngeal and esophageal weakness induced by dermatomyositis and polymyositis [15]. • **Dysphagia**, **dysarthria**, **ophthalmoplegia** can result from a NMJ disorder [2].

Q	☐ **Weakness? Sensory loss? Both?** • **Weakness in the absence of sensory impairment** may be caused by disorders of anterior horn cells (e.g. amyotrophic lateral sclerosis), neuromuscular transmission and myopathies [16] • **Sensory loss in the absence of weakness** • **Combined motor and sensory** deficits are seen with neuropathies [16] and pathology involving nerve roots and the brachial and lumbosacral plexus [2] but not with myopathies or NMJ pathology [3]. • **"Weakness":** patients may use the word "weakness" to describe the diffuse, systemic unwellness resulting from cardiovascular, pulmonary, infectious, or metabolic processes [1]. **True weakness** refers to the inability to exert normal force, whereas **fatigue** refers to decreased force with repetitive use [3].
R	☐ **Any relieving or aggravating factors?** • The neurological deficits of mutiple sclerosis may be worsened by small increases in body **temperature**, brought on e.g. by a hot bath, exercise, a warm environment or fever (Uhthoff's phenomenon). • **Repeated stimulation** leads to decreased strength in myathenia gravis, botulism, and organophosphate poisoning, whereas repeated stimulation leads to improved strength with Lambert-Eaton myasthenic syndrome [3]. • **Fatigability** is the hallmark of a neuromuscular junction disorder [2]. For example, the symptoms may be fewer in the morning and get worse in the afternoon [2]. During a specific activity, weakness develops. After a break, muscular strength is restored [2].
S	☐ **Degree of weakness? How does the weakness/paresthesia impair function?**
T	☐ **Constant weakness/paresthesia? Progressing? Fluctuating?** • **Rapid recovery** suggests brain embolism whereas the deficits caused by ICH do not improve during the early period [6]. • **Fluctuating over minutes/hours**: fluctuating symptom or stuttering progression is consistent with thrombosis [6]. • **Migrating over minutes**: weakness / paresthesia that migrates e.g. from hand to arm then face, over the course of minutes suggests a migraine aura [17]. The aura symptoms develop gradually over the course of 5-20 min and last less than 60 min [18]. The aura is believed to correspond to "cortical spreading depression", a phenomenon consisting of a wave of increased neuronal activity followed by decreased neuronal activity spreading over the cortex at a rate of 2-6 mm/min [19]. • **Ascending over days**: symmetrical weakness ascending over the course of 12 hours - 28 days (usually 1-3 weeks) is consistent with the most common variant of Guillain-Barré syndrome (Acute inflammatory demyelinating polyneuropathy) [20] and tick paralysis [3, 4] • **Descending over days**: bilateral weakness (i.e. first involvement of the cranial nerves, then of the respiratory muscles and limbs in a proximal-to-distal pattern) is consistent with botulism [4]. The Miller-Fisher variant of Guillain Barré syndrome also usually presents with a descending paralysis [2]. • **Ascending over ≥ 8 weeks**: symmetrical weakness ascending over ≥ 8 weeks is consistent with chronic demyelinating polyneuropathy [2]. • **Disease progression over weeks** is consistent with arsenic intoxication [4]. • **Fluctuating/progressing over months**: the weakness from myasthenia gravis usually peaks within 2-3 years from onset. Early in the disorder, the symptoms are often transient [21].

	• Change in muscle strength over time (fluctuation) is a key discriminator between disorders of the neuromuscular junction and disorders of the muscle [22]. ☐ **Have you had prior similar episodes?** • **TIA:** A history of TIA is the same vascular territory suggests thrombotic stroke whereas TIAs in > 1 vascular territory suggest embolic stroke [6].
+	☐ **Have you had any trouble finding words or understanding others?** • **Trouble findings words** (expressive dysphasia) suggests left frontal pathology • **Trouble understanding** (impressive dysphasia) suggests left temporal pathology • **Trouble articulating** words (dysarthria) suggests pathology in the telencephalon or brainstem ☐ **Have you had any trouble with your vision?** • **Monocular visual loss** suggests pathology in the eye, retina, or optic nerve proximal to the optic chiasm. Amaurosis fugax suggests a embolic focus in the carotid, less often in the heart (see Chapter 8 Vision Disturbance) • **Heteronymous visual loss** suggests a problem in the optic chiasm • **Homonymous visual loss** suggests a problem in the parietal lobe (lower quadrantanopsia), temporal lobe (upper quadrantanopsia) or occipital lobe (hemianopsia). • **Double vision** suggests brainstem pathology. • **Lights, fortification spectra** preceding weakness suggests migraine (ref). ☐ **Have you had pain anywhere?** • **Headache** with maximal intensity upon onset suggests SAH. The headache associated with ICH usually develops more gradually. Onset headache and vomiting are less frequent with ischemic stroke [6]. Headache current with or following symptom onset may also result from migraine [17]. • **Neck pain** suggests carotid or vertebral artery dissection • **Chest pain** suggests aortic dissection, which can progress to the carotid artery. • "The presence of "red flags" in the patient's history (including fever, chills, unexplained weight loss, unremitting night pain, previous cancer, immunosuppression, or intravenous drug use) should alert clinicians to the possibility of more serious disease, such as tumor or infection." [23] • **Radiculopathic pain**, i.e. severe, electric shock-like pain radiating from the neck down the arm or from the lower back into the leg along a dermatome, suggests a nerve root lesion (or less likely a plexopathy) [2]. • **Back pain** in the presence of a suspected myelopathy suggests a compressive lesion e.g. intravertebral disc herniation, epidural hematoma, tumor, abscess; the absence of pain in the setting of a suspected myelopathy suggests spinal cord infarction or transverse myelitis [3]. • **Proximal muscle pain** suggests an inflammatory myopathy (e.g. polymyositis, dermatomyositis, viral myositis, polymyalgia rheumatica) [3]. • **Groin pain** in the setting of a femoral neuropathy suggests iliopsoas pathology, e.g. a hematoma in a patient with hemophilia or taking anticoagulants [2] ☐ **Have you had any urinary or fecal incontinence?** • **Urinary/fecal incontinence** suggest a spinal cord lesion.

PHYSICAL EXAMINATION

GA	• **Vomiting** is suggestive of ICH, SAH and posterior circulation large artery ischemia

	[6].
VS	• **Hypotension** suggests a systemic cause of diffuse weakness • **Hypertension**: severe hypertension in association with acute onset of weakness suggests ICH. • **Severe alterations in blood pressure and heart rate** suggest autonomic dysfunction, which may occur with botulism [4] and the Guillain-Barré syndrome [20]. • **Pulse deficit** or a difference in arm **SBP > 20 mm Hg** suggests aortic dissection. • **Fever** suggests that the neurological deficit is due to a CNS (e.g. encephalitis, spondylitis) or systemic infection; fever and suspected embolic stroke suggest endocarditis [6].
CV	☐ **Auscultation: irregular heart rate? Murmur?** • **Irregular heart rhythm** suggests atrial fibrillation and increases the risk of embolic stroke. • **New murmur** (SN 48%) or **worsening of a known murmur** (SN 20%) suggest endocarditis [24].

NEUROLOGICAL EXAMINATION

Cortical Function	☐ **Orientation to time & place**
	• **Decreased level of consciousness** suggests:
	  ○ intracerebral hemorrhage
	  ○ large thrombotic or embolic stroke
	  ○ a process affecting the reticular activating system, in particular the tegmentum of the pons [6].
	  ○ poct-ictal state or non-convulsive status epilepticus
	  ○ a CNS or systemic infection (sepsis, encephalitis)
	☐ **Dysphasia (impressive/expressive)? Dysarthria?**
	• **Expressive dysphasia** suggests a cortical lesion in the left frontal lobe (Broca's area).
	• **Impressive dysphasia** suggests a cortical lesion in the left temporal lobe (Wernicke's area).
	• **Dysarthria** suggests dysfunction of cranial nerves VII, IX or XII, the corresponding cranial nerve nuclei, or the motor pathways linking the motor cortex to these nuclei.
	• **Hoarseness** suggests dysfunction of cranial nerve nucleus or cranial nerve X [2].
	☐ **Visual fields? Visual neglect?**
	• **Homonymous anopsia,** i.e. binocular vision loss affecting the same portion of the visual field, suggests pathology affecting the contralateral cortex.
	  ○ Homonymous **hemianopsia** (half of the visual field) suggests an occipital lesion
	  ○ Homonynous **upper quandrantanopsia** (a quarter of the visual field) suggests a lesion of the temporal lobe
	  ○ Homonymous **lower quandrantanopsia** suggests a lesion in the parietal lobe.
	• **Neglect** suggests a cortical lesion affecting the right parietal lobe.

Cranial Nerves	☐ **Pupillary size & light reflex** • Abnormalities in pupillary size and reactivity, including Horner's syndrome, are covered in Chapter 03-D and in Chapter 07-Visual disturbance. • **Bilateral fixed dilated pupils** result may result from dcreased presynaptic

	acetylcholine release caused by botulism or tick paralysis [3].
	• **Bilateral myosis** may result from acetylcholinesterase inhibition, as part of the cholinergic toxidrome.
	☐ **Eye movements**
	• **Conjugate eye deviation** is covered in Chapter 03-D. Other eye movement disturbances are covered in Chapter 09-Visual Disturbances.
	• **Nystagmus** is covered in Chapter 03-D.
	☐ **Facial sensation**
	• **Decreased facial sensation** suggests pathology between the trigeminal nerve and the primary sensory cortex
	☐ **Facial movement**
	• **Unilateral facial weakness involving the forehead** suggests facial nerve pathology (e.g. Bell's palsy) but may also result from pathology of the 7th cranial nerve nucleus in the pons.
	• **Unilateral facial weakness that spares the forehead** suggests contralateral cortical or subcortical stroke; the forehead is spared because these muscles receive bilateral cortical innervation [25]
	• **Decreased facial expression** is suggestive of myasthenia gravis [2].
	☐ **Soft palate and uvula**
	• **Uvular deviation** suggests cranial nerve X dysfunction of pathology in the medulla affected cranial nerve nucleus X.
	☐ **Tongue movement**
	• **Tongue deviation** suggests ipsilateral weakness resulting from either:
	  ○ an ipsilateral lesion to the cranial nerve XII
	  ○ an ipsilateral lesion to the cranial nerve nuclei XII in the medulla
	  ○ a contralateral lesion of the motor pathway from the cortex to the cranial nerve nucleus

Motor	☐ **Distal strength (e.g. finger spreading, walking on toes and on heels)** ☐ **Proximal strength (e.g. shoulder abduction, standing up from sitting)** • **Symmetrical proximal > distal weakness** is consistent with an inflammatory myopathy (e.g. polymyositis or dermatomyositis) [3]. Unilateral weakness of shoulder abduction may be consistent with pathology in the deltoid muscle, the axillary nerve (check), the C5 nerve root and so forth on up to the contralateral cortex. • **Symmetrical distal > proximal weakness,** e.g. decreased grip strength or foot drop, is consistent with a neuropathy [3].
Sensory	☐ **Fine touch hand / leg** ☐ **Pinch hand / leg** • A sensory level suggests a spinal cord lesion: T4 correponds to the level of the nipple, T10 to the level of the navel • In order to identify a sensory level between C4 and T1, test for sensation on the side of the neck, the lateral arm, the fingers and the inside of the arm.
Reflexes	☐ **Arm reflex (e.g. triceps)** ☐ **Leg reflex (e.g. patella)** • **Hyperreflexia** and the **Babinski sign** (upgoing plantar response) suggest an UMN lesion, i.e. a lesion in the brain or the corticospinal tracts of the brainstem and spinal cord • **Hyporeflexia** suggests a LMN lesion, i.e. a lesion of the motor neuron in the

	anterior horn of the spinal cord, the nerve root or peripheral nerve; however, hyporeflexia can also occur with an acute UMN lesion; for example, hyporeflexia occurs in the setting of acute trauma to the spinal cord, a condition referred to as "spinal shock" [2]. Hyporeflexia or areflexia occur with neuropathies [3]. • **Normal reflexes** are present in conditions that affect the neuromuscular junction and muscle, unless the myopathy is quite advanced [1, 3, 16]. Tendon jerks are preserved in acute myopathy [20]. Reflexes with polymyositis and dermatomyositis are decreased in proportion to the degree of weakness [3].
Coordination	☐ **Dysmetria/dysdiadochokinesia hand/leg?** • **Dysmetria** refers to the inability to arrest a muscular movement at the desired point [25]. **Dysdiadochokinesia** refers to the an inability to perform coordinated muscular movements smoothly [25]. Dysmetria and dysdiadochokinesia suggest pathology in the ipsilateral cerebellum [2] or involvement of the cerebellar pathways in the medulla [26]. ☐ **Gait** • **Gait ataxia and truncal instability** suggest midline cerebellar pathology [2]. ☐ **Romberg** • **Inability** to perform the Romberg test is consistent with ataxia due to a brainstem or cerebellar lesion. • **Loss of balance** upon eye closure suggests loss of the proprioception information conveyed by the peripheral nerves and the dorsal columns (sensory ataxia)

See [27]

BEDSIDE TESTS

☐ **CRP if patient > 50 years**

• **Elevated CRP** suggests inflammation.

☐ **EKG if patient > 50 years**

• **Atrial fibrillation** increases the risk for embolic stroke.

MANAGEMENT

1. Where is the pathology located?

An approach to identifying the location of the pathology is to categorize the clinical deficit using the following classification:

• **Limited Deficit**: deficit limited to one side of the face, to one arm or one leg. It is possible to "draw a line" around the location of the deficit.
• **Asymmetrical Deficits**: multiple body parts are affected in an asymmetrical distribution
• **Symmetrical Deficits**: multiple body parts are affected in a symmetrical distribution
• **Diffuse Deficits**: generalized weakness not limited to discrete parts of the body

1-Limited Deficit

• **Total facial hemiparesis:** weakness affecting all the muscles on one side of face, including the forehead and periocular muscles, suggests facial nerve pathology or pathology affecting the cranial nerve nucleus VII.
• **Lower facial hemiparesis**: weakness that affects the lower half of the face but spares the forehead and periocular muscles suggests a contralateral supranuclear lesion, i.e. a lesion affecting the pathway from the contralateral cortex (including the contralateral

corticopontine tract fibers in the brainstem) down to the ipsilateral cranial nerve nucleus VII.

- **Part deficit**: weakness/paresthesia affecting a whole body part (e.g. weakness of the whole arm or leg, weakness affecting all movements of the foot or thumb) suggests a contralateral lesion of the cortex or subcortical lesion. This distribution is a result of the somatotopic organization of the primary motor and sensory cortices according to a homunculus. Lesions of these areas affect the parts of our limbs as we think of them, i.e. the index finger, the hand, the foot, as opposed to limited sides of our limbs.
- **Strip deficit**: weakness/paresthesia affecting a "strip" that courses along the arm or the leg suggests a lesion affecting the nerve root (i.e. a radiculopathy). The "strip" is refered to as a "dermatome" in the context of sensory deficits, while it is referred to as a "myotome" in the context of motor deficits. The motor deficits can be inferred by identifying the muscles lying under the strip and the limb movements that result when these muscles contract. For example, an L5 radiculopathy affects hip abduction, foot dorsiflexion and foot inversion.
- **Patch deficit:** weakness/paresthesia limited to a "patch" of the limb (e.g. weakness with foot dorsiflexion but not with plantarflexion, paresthesia confined to the palmar side of the hand) suggest a mononeuropathy. Peripheral nerves convey as rule both motor and sensory information. The deficits can usually be derived from the anatomical course of the nerve down the limb. The extent of the symptoms depends on where along the course of the nerve the lesion has occurred. For example, a deep peroneal nerve palsy will affect foot dorsiflexion and sensation in the first web space. Preservation of foot inversion and hip abduction distinguishes a deep peroneal nerve palsy from an L5 radiculopathy [2].

Radiculopathies

Root	Pain/Paresthesia	Weakness	Decreased Reflex
C5	Lateral upper arm, medial scapular border	Arm abduction	Supinator
C6	Radial side of forearm, thumb, index finger	Elbow flexion, wrist extension	Biceps
C7	Posterior arm and forearm, third finger	Elbow extension	Triceps
C8	Ulnar side of forearm, fifth finger	Finger flexion	
T1	Medial side of elbow	Finger abduction	
L3	Medial thigh	Hip adduction	
L4	Anterior thigh, medial calf	Knee extension	Patella
L5	Lateral leg, first web space (dig 1-2)	Extension of dig 1	
S1	Posterior leg, sole of the foot, lateral small toe	Foot plantar flexion	Achilles

Mononeuropathies

Nerve	Paresthesia/Numbness	Weakness	↓Reflex
Axillary	Lateral shoulder, medial scapular border	Arm abduction	
Musculocutaneous	Lateral lower arm, thumb, index finger	Elbow flexion, wrist extension	Biceps
Radial	Dorsum of hand between metacarpals 1-2	Elbow, wrist, finger extension	Triceps
Median	Radial palm, tip of the index	Thumb opposition	

	finger		
Ulnar	Ulnar side of forearm, fifth finger	Abduction digits 2-5	
Obturator	Medial thigh	Hip adduction	
Lateral cutaneous	Antero-lateral thigh	None (pure sensory loss)	-
Femoral	Anterior thigh, medial calf	Knee extension	Patella
Sciatic	Posterior thigh + foot	Knee flexion + foot palsy	
Tibial	Sole of the foot, lateral small toe	Foot plantar flexion / inversion, toe flexion	Achilles
Peroneal (common)	First web space (dig 1-2), lateral foot	Foot and toe dorsiflexion	
Peroneal (superficial)	Lateral distal leg + dorsum of foot	Foot eversion	
Peroneal (deep)	First web space (dig 1-2)	Foot and toe dorsiflexion	

2-Asymmetrical Deficits

- **Dysphasia**, **neglect**, or **homonymous anopsia** accompanying the weakness/paresthesia suggests a cortical lesion.
- **Unilateral face, arm and/or leg weakness/paresthesia** unaccompanied by dysphasia, neglect, homonymous anopsia or cognitive deficits suggests a lacunar stroke due to a small vessel thrombotic stroke or a small ICH affecting subcortical areas of the cerebrum and brainstem (most commonly basal ganglia, thalamus, pons, internal capsule, corona radiata) [6, 28]. If the weakness/paresthesia affects face, arm and leg, it suggests a subcortical or brainstem lesion where the fibers course in close proximity to each other, whereas cortical lesions usually lead to face + arm symptoms with sparing of the legs [2].
- **Crossed findings**, i.e. weakness/paresthesia affecting cranial nerves on one side of the body and the limbs on the other side of the body, suggest a lesion in the brainstem [2].
- **Sensory/motor level**: symptoms below a spinal cord level (e.g. below the nipple line (T4) or below the navel (T10)) suggest a spinal cord lesion. The **Brown-Séquard syndrome**, caused by a hemilesion of the spinal cord, leads to asymmetrical deficits consisting of:
  - Ispilateral paresis
  - Ipsilateral loss of touch, vibration and proprioception
  - Contralateral loss of pain and temperature
- **Multifocal deficits** that cannot be explained by a single lesion in the nervous system may be caused by
  - **Multiple central** lesions may result from emboli from the heart or aorta [6], CNS vasculitis, MS, metastases, paraneoplastic
  - **Segmental weakness** involving selected myotomes in a multifocal distribution suggests a disorder of anterior horn cells [16].
  - **Polyradiculopathy**, i.e. a disorder affecting several nerve roots, that may be caused by malignancy (either mechanical or paraneoplastic), collagen-vascular diseases, infections, immune-mediated conditions e.g. sarcoidosis[29]
  - **Mononeuritis multiplex**, also known as asymmetric polyneuropathy, a condition whereby several nerves are affected simultaneously or subsequently. e.g. secondary to diabetes or a vasculitis (particularly polyarteritis nodosa, also Churg-Strauss),

immunologic disorders (e.g. SLE, rheumatoid arthritis) or infectious disorders (e.g. HIV, neuroborreliosis) [2].
    - **Amyotrophic lateral sclerosis** is a neurodegenerative disease that primarily affects the motor tracts and lower motor neuron in the spinal cord. Strength in different body regions is affected. Sensory and autonomic functions are intact [2]. See "78-year-old man unable to speak or swallow"
    - **Plexopathies** give rise to symtoms restricted to one limb that neither fit a radiculopathy nor a mononeuropathy [2].
    - **Functional**

3-Symmetrical Deficits

Symmetrical deficits suggest a lesion in the brainstem, spinal cord, nerves, neuromuscular junction (NMJ) or muscles. In the absence of impaired consciousness, symmetrical deficits argue against cortical and subcortical injury, since the areas involved would have to be extensive.

- **Bowel/bladder incontinence** suggests a spinal cord lesion.
- **Sensory/motor level**: symptoms below a spinal cord level (e.g. below the nipple line (T4) or below the navel (T10)) suggest a spinal cord lesion.
- **Sensory deficits and hyporeflexia** suggest polyneuroapthy, whereas with NMJ pathology and myopathies, sensation and reflexes are preserved [3].
- **Symmetrical leg and arm weakness** suggests peripheral nervous system dysfunction affecting the nerves, NMJ or muscles [22], although the lesion may also be present in the brainstem or cervical spinal cord.
- **Symmetrical leg weakness with sparing of the arms** suggests a myelopathy (i.e. a process involving the spinal cord, a primary spinal cord dysfunction). Midline brain lesions that affect the innervation of the legs bilaterally are rare [22]. The classic triad of a myelopathy is paraparesis, sensory level of the trunk and sphincter dysfunction [2].
- **Symmetrical distal weakness** suggests a neuropathy (i.e. a process involving the peripheral nerves) [16]. Most peripheral nerve disorders affect both motor and sensory function and are more prominent distally [30].
- **Symmetrical proximal weakness** without sensory or reflex abnormalties suggests a myopathy (i.e. a process involving the muscles) or NMJ disorder [22]. The hallmark of a myopathy is symmetrical proximal muscle weakness in the absence of sensory loss [2].
- **Fluctuation in muscle strength** when examining sustained power in an affected limb over 10-30 seconds suggests a NMJ disorder [22].
- **Ocular and/or autonomic symptoms** suggest a NMJ disorder, since myopathies spare ocular and respiratory muscles [4] and are not associated with autonomic symptoms [22]. NMJ pathology is typically characterized by proximal muscle weakness, fatiguability, involvement of bulbar and oculomotor features [2]. Weakness is so proximal that it affects nuchal, facial and ocular muscles [2].
- **Cranial nerve dysfunction** suggests a brainstem lesion or NMJ pathology [3]. NMJ pathology should be considered in the case of generalized weakness combined with acute cranial nerve deficits [3].
- **Locked-in syndrome** is a catastrophic condition characterized by quadriplegia and anarthria (speechlessness) but preserved consciousness resulting from a lesion affecting the brainstem (usually the pons) [31].

Muscle tonus and the briskness of reflexes may help narrow the differential diagnosis by categorizing the deficits into an upper motor neuron (UMN) or lower motor neuron (LMN) syndrome [22].

Upper Motor Neuron (UMN) and Lower Motor Neuron (LMN) Syndromes

	UMN Syndrome	LMN Syndrome
Tonus	• Spasticity to extension in the arms • Spasticity to flexion in the legs	• Flaccidity
Reflexes	• Hyperreflexia • Babinski's sign (upgoing toes upon plantar stimulation)	• Hyporeflexia
Other	• Pronator drift	• Fasciculations and cramps
Pathology	• Cerebral cortex • Corticospinal tract of the brainstem • Corticospinal tract of the spinal cord	• Anterior horn cell of the spinal cord • Nerve root • Peripheral nerve

Symmetrical Spinal Cord Syndromes [32]

Total Cord Transection Syndrome	• **Bilateral paresis** below the level of the lesion, **apnea** if the pathology is above C3, the level at which the phrenic nerve exits the spinal cord. • **Bilateral sensory loss for all modalities** below the pathological level • **Neurogenic shock and Horner's syndrome** with pathology above T1, the level at which sympathetic fibers exit the spinal cord. • **Impotence and loss of voluntary bladder control** with pathology above L2.
Spinal Shock	• **Flaccid paralysis** below the level of injury • **Loss of sensation and reflexes** below the level of injury • **Loss of bowel and bladder reflexes and tone** • **Temporary** physiologic response to trauma to the spinal cord. Recovery occurs within hours to days and the degree of recovery depends on trauma severity[33]
Dorsal (Posterior) Cord Syndrome	• **Motor:** Corticospinal tracts are preserved [2]) • **Bilateral loss of touch, proprioception and vibration** below the affected level, leading to sensory ataxia • **Preserved pain and temperature** sensation. • **Urinary incontinence** from involvement of the descending autonomic tracts (no mention of this in [2])
Ventral (Anterior) Cord Syndrome	• **Bilateral paresis** below the affected level, with LMN signs at the level of the lesion and UMN below the level of the lesion [2]. • **Preserved touch, vibration and proprioception**. • **Bilateral loss of pain and temperature** sensation below the affected level. • **Urinary incontinence** usually present • The syndrome results from **anterior spinal artery** pathology, which may be secondary to aortic dissection
Pure Motor Syndrome	• **Bilateral paresis** results from disruption of the corticospinal tracts or lower motor neuron pathology. The clinical picture may thus be one of an UMN or a LMN syndrome. • **Preserved sensation** for touch, vibration proprioception, pain and

	temperature. • **No bladder / sphincter dysfunction**.
Central Cord Syndrome	• **Impaired arm strength** (mainly distal), since the axons on the inner part of the corticospinal tract supply the hands [2]. • **Preserved touch, vibration and proprioception**. • **"Suspended" segmental pain and temperature deficit** resulting from pathology affecting the tracts as they cross over in the spinal cord. Sensation above and below the pathological segmental level is normal. • **Bladder dysfunction** occurs [2]. • **Hyperextension of the neck** in patients with long-standing cervical spondylosis is the usual mechanism of injury [34].
Conus Medullaris Syndrome	• **Bilateral leg weakness**, affecting mainly the distal legs; an UMN syndrome may be present. According to another source, with a pure conus medullaris syndrome, power in the legs is normal, but that in practice, a cauda equina syndrome is usually also present[2]. • **Saddle anaesthesia** • **Flaccid paralysis of the bladder** resulting in overflow incontinence • **Paralysis of the rectum** resulting in fecal incontinence • **Impotence** is frequent.
Cauda Equina Syndrome	• **Pathology:** Lumbar and sacral roots are affected within the spinal cord prior to exiting through the intervertebral foramina • **Unilateral paresis** (most often) [35] or **paraparesis**, with a LMN syndrome, if the lumbar roots are affected [2] • **Saddle anesthesia** due to involvement of sacral roots S1-S4 [2] • **Sensory loss** in the lateral aspects of the legs and feet due to sacral root involvement[2] • **Urinary retention**, overflow incontinence • **Decreased rectal tone**, fecal incontinence • **Erective dysfunction**

4-Diffuse Deficits

When the weakness is diffuse, consider pathology outside of the nervous system:

- **Systemic hypoperfusion** usually results in diffuse and non-focal, typically bilateral brain dysfunction [6].
- **Infectious**, e.g. mitochondrial dysfunction in severe sepsis
- **Psychiatric**, e.g. depression
- **Drugs**, e.g. sedatives
- **Collagen vascular disease**, e.g. systematic lupus erythematosus, Sjögren's syndrome [22]
- **Electrolyte disturbances,** e.g. hypokalemia, hyperkalemia
- **Brain injury due to a vascular cause** usually result in focal deficits, but generalized deficits occur in the setting of increased intracranial pressure causing global cerebral hypoperfusion [36]

2. What is the most likely nature of the lesion?

The likely location of the lesion, combined with the patient's background (risk factors) and the rate and course of symptom progression, may help identify the cause of the patient's

weakness. This section provides some details regarding selected conditions that affect different parts of the nervous system.

Forebrain and Brainstem

Stroke	• Onset: • Affected MCA • Affecting ACA • Affecting posterior circulation:
Multiple Sclerosis	• Onset: • Deficits: • Course:

Cranial Neuropathy

Bell's Palsy	• Idiopathic. 70% of cases of acute peripheral facial palsy [37]).
Borrelia	• Accounts for 10-20% of patients in Sweden and Norway show signs of Borrelia infection, more often present in patients with meningeal irritation and in children (Nilsson LT 2013), Rickettsiainfektion (Nilsson 2013), mechanical? • Other findings

Spinal Cord

Syringomyelia	• Fluid-filled cavity within the spinal cord impairs fibers crossing over. • Central cord syndrome, hands.
Dissection of the aorta descendens	• Onset: • Deficits: anterior cord syndrome resulting from infarction of the anterior spinal artery • Course:
Transverse Myelitis	•

Radiculopathy

The most common causes of radiculopathy are disc hernication, degenerative spine disease [2]

Mononeuropathy

The most common causes of acute mononeuropathies are trauma and nerve entrapment. [2]

Polyneuropathy

Guillain-Barré Syndrome	• **Ascending paralysis** that progresses during a period of 12 hours to 28 days (usually 1-3 weeks) before reaching a plateau [20]. Symptoms are maximal after 2 weeks in 50% of patients and after 4 weeks in 90% of patients [2]. Respiratory insufficiency develops in 25% of patients [20]. • **Ascending paresthesias and numbness** [20]. Pain precedes weakness in one third of cases and is present during the acute phase of the illness in two thirds of cases [20]. The presence of distal paresthesias increases the likelihood of Guillain-Barré syndrome [20]. • **Generalized hyporeflexia or areflexia** is typical, although 10% of

	patients have normal or brisk reflexes during the course of the illness [20]. In the setting of hyperacute onset of quadriplegia within 48 hours, reflexes may initially be preserved [2]. • **Serious autonomic dysfunction** (e.g. severe bradycardia, hypo- and hypertension) occurs in 20% of cases [20]. • **Sensory symptoms such as neuropathic pain** may occur but are much less prominent that the motor symptoms [2]
Acute motor axonal neuropathy	• Distal weakness with sparing of the cranial nerves and respiratory muscles [4]
Tick paralysis	• **Ascending weakness**; the cranial nerves are usually not involved [4] • **Paresthesias are common** [4] • Usually occur during the **spring and summer months** [4]
Porphyric neuropathy	• **Generalized weakness** [4] • **Distal sensory loss is often present** [4] • **Confusion**, hallucinations, confusion, anxiety, seizures, abdominal pain and vomiting may occur [4]
Arsenic intoxication	• **Distally accentuated weakness** [4] • **Burning in the hands and feet** [4] • Weeks of disease progression [4]

Neuromuscular Junction Disorders

Myasthenia gravis	• Myasthenia gravis is by far the most common neuromuscular junction disorder. It results from autoantibodies to the post-synaptic nicotinic acetylcholine receptors [22] or from antibodies against muscle-specific tyrosine kinase [3]. The end result is a decrease in the number of available receptors. • **Weakness** consists of fluctuating and variable weakness of the **ocular** (ptosis and/or diplopia), **bulbar** (dysarthria, dysphagia, fatigable chewing), **respiratory** and **limb** muscles. **Fatiguability** when examining sustained power in an affected limb over 10-30 seconds [22]. Ocular muscle weakness is the first sign of MG in 40% of patients [3]. The term myasthenic crisis refers to MG-induced respiratory failure requiring mechanical ventilation [3]. • **No paresthesias** [20] • **No autonomic symptoms** [4], e.g. no loss of pupillary reactivity [38] • See "78-year-old man unable to speak or swallow"
Lambert Eaton myasthenic syndrome	• The Lambert Eaton myasthenic syndrome results from antibodies affecting the P/Q-type voltage-gated calcium channels on the presynaptic membrane of the neuromuscular junction [22] • **Limb weakness** typically affects hip and shoulder muscles [3]; the respiratory and eye muscles are typically spared [2, 4]. Slight increases in strength may be noted by examining sustained power in an affected limb over 10-30 seconds [22] • **No paresthesias**; sensation is preserved [3]. • **Autonomic dysfunction** (most commonly dry mouth [3]) may occur and develop in 90% of cases during the first 3 months after symptom onset [22] and result from decreased in the muscarinic effects of acetylcholine [3].

Botulism	• The toxin binds irreversibly to presynaptic nerve terminals of the motor end plate and impedes the release of acetylcholine. Autonomic presynaptic nerve terminals are also affected. The symtoms of food-borne botulism develop 12-36 hours after exposure [39]. • **Cranial nerves** are initially affected, resulting in impaired bulbar function (dysarthria, dysphagia, facial weakness), vertigo, nausea, blurred vision, enlarged pupils, ptosis, diplopia. A **symmetrical, descending**, flaccid paralysis ensues thereafter, resulting in arm weakness, dyspnea (due to involvement of the respiratory muscles), and leg weakness [39]. • **Sensation and mentation are not affected** [39] and fever is absent [4]. • **Autonomic symptoms** (nausea, vomiting, ileus, alterations in blood pressure and heart rate, poor pupil reactivity) are common [4]. Dilated, poorly reactive pupils [38] • **Anticholinergic symptoms** such as dry skin, elevated temperature, constipation, urinary retention may be present [3] • See "78-year-old man unable to speak or swallow"
Other Toxins	• Cholinergic toxidrome (e.g. secondary to organophosphate poisoning), resulting in inhibition of the acetylcholinesterase enzyme leading to overabundance of acetylcholine at the neuronal synapse and neuromuscular junction.

Myopathies

Inflammatory myopathies	• The inflammatory myopathies include polymyosits, dermatomyositis, inclusion-body myositis, viral-induced myositis. • **Dermatomyositis** has distinctive dermal findings, including heliotrope rash, Gottron's papules (purplish papules on the dorsum of the interphalangeal and metacarophalangieal joints), Gottron's sign, shawl sign, V sign, holster sign [15]. • **Inclusion-body myositis** typically affects older patients; it has a more indolent onset, spares the deltoids and preferentially affects the lower arms [15].
Drugs/Toxins	• **Steroids** • **Statins**
Metabolic	• Acute generalized muscle weakness may result from hypokalemia, hyperkalemi, hypocalcemia, hypercalcemia, hypomagnesemia and hypophosphatemia [3]. • e.g. hypoglycemia, liver failure, thyrotoxicosis, anemia, electrolyte derangement (potassium, calcium, phosphorus). Metabolic disorders that cause generalized weakness are painless as opposed to inflammatory myopathies [3].

3. Further Management

Further management depends on the likelihood that the patient is suffering from a time-sensitive condition such as acute stroke as opposed to a non-time-sensitive condition (such as multiple sclerosis).

Stroke and Transient Ischemic Attack

See section in Chapter 09.

Myelopathy
- Testing for perianal sensation if there is a history of bowel or bladder dysfunction. The **rectal examination** correlates reasonably well with anal manometric measurements in determining anal sphincter tone [40].
- "In patients who report urinary incontinence, a postvoid residual should be checked. Acute urinary retention with overflow incontinence can sometimes be the only symptom of neurologic compromise. Any abnormal finding on the neurologic examination suggests the possibility of spinal cord compression." [41]
- **Acute spinal cord injury**: The administration of corticosteroids for the treatment of acute spinal cord injury is not recommended [42].
- **Cauda equina syndrome:** Dexamethasone with the hope of decreasing compression [43]; emergent MRI [43]
- **MR** is first-line investigation modality

Neuroborrelia
- Lumbar puncture to rule-out borrelia depends on pre-test probability
- CSF as well as plasma send for serology.
- Doxycyclin

Bell's Palsy
- Sunnybrook score
- Corticosteroids: NNT 10 to increase by 1 the number of patients with complete recovery. No significant adverse effects. See Cochrane [44].
- Eye patch, Viscotears, advice about driving
- See "Clinical practice guideline CMAJ" [45] and [37]

Guillain Barré Syndrome
- Lumbar puncture: albuminocytologic dissociation (elevated albumin levels, normal cell count) in the cerebrospinal fluid is present in 50% of cases during the first week of illness [20].
- EMG
- IVIg and corticosteroids
- Monitoring PEF or alternative method
- RR variability: autonomic dysfunction?

Botulism

Myasthenic Crisis

Inflammatory Myopathy
- Electromyography and nerve-conduction studies can localize the disorder to the muscle or the NMJ [22].

SYNCOPE/SEIZURE

INTRODUCTION

Transient loss of consciousness (T-LOC) is defined as loss of consciousness of [1]:
- rapid onset
- short duration
- spontaneous complete recovery

T-LOC emcompasses conditions such as syncope, seizure, concussion.

Syncope is defined as T-LOC resulting from transient global cerebral hypoperfusion [1] or as a sudden, transient loss of consciousness with a loss of postural tone [2].

Seizure is defined as an episode of abnormal neurologic functioning caused by pathologically excessive activation of neurons [3]. With certain types of generalized seizures (tonic, clonic, tonic-clonic and atonic), consciousness is also lost transiently.

This section deals with the information needed to estimate the likelihood of causes of T-LOC other than concussion. T-LOC following head trauma is covered in the section Trauma to the Head and Neck. Certain conditions are sometimes mislabeled as syncope. These include conditions resulting in:
- **non-transient** alteration in consciousness, e.g intoxications, metabolic abnormalities
- **no loss of consciousness**, e.g. cataplexia, drop attack, fall, psychogenic pseudosyncope, malingering, transitory ischemic attack (TIA) of carotid origin [1].

Whether patients with **pre-** or **near-syncope**, i.e. a transient feeling of impending loss of consciousness, should be managed in the same way as patients with T-LOC is unclear and should be determined on a case-by-case basis [4].

DIFFERENTIAL DIAGNOSIS

Differential Diagnosis of Syncope

Pathophysiology	Examples
Reflex	• **Vasovagal**: mediated by emotional distress (e.g. fear), mediated by orthostatic stress • **Situational**: cough, sneeze, swallow, defecation, micturition, post-exercise, post-prandial • **Carotid sinus hypersensitivity**: head turning, circumferential neck compression, shaving
Orthostatic	• **Volume depletion**: hemorrhage, diarrhea, vomiting etc • **Primary autonomic failure**: pure autonomic failure, Parkinson's disease, multisystem atrophy, Lewy body dementia • **Secondary autonomic failure**: diabetes, amyloidosis, uremia, spinal cord injuries • **Drug-induced**: alcohol, vasodilators, diuretics, psychiatric medications
Cardiac	• **Arrhythmias**: sinus node dysfunction, atrioventricular conduction system disease, tachycardias • **Pericardial**: pericardial tamponade, constrictive pericarditis • **Myocardial**: cardiomyopathies, myocarditis • **Valvular**: aortic stenosis, pulmonary stenosis, prosthetic valve

	dysfunction • **Coronaries**: acute myocardial infarction / ischemia • **Outflow**: pulmonary hypertension, hypertrophic obstructive cardiomyopathy (HOCM)
Vascular	• Pulmonary embolism • Subarachnoid hemorrhage* • Aortic dissection* • Ruptured abdominal aortic aneurysm* • Ruptured ectopic pregnancy* • Subclavian steal • Vertebrobasilar transitory ischemic attack, vertebrobasilary migraine

* these conditions present with syncope in 15% of cases; Mattu A. Syncope. (In) Head emergencies. Audio series online. Available at http://www.audiodigest.org/pages/htmlos/3449.4.42312525647612647 40/EM2609. Audio-Digest Emergency Medicine Volume 26, Issue 09. May 7, 2009)

Differential Diagnosis of Seizures [3]

Pathophysiology	Examples
Vascular Cardiac	• Intracerebral/subarachnoid hemorrhage • Epi- or subdural hematoma • Sinus thrombosis • Hypertensive encephalopathy • Arteriovenous malformation
Infectious Infiltrative	• Meningitis, encephalitis • Cerebritis • Cerebral abscess • Non-CNS infections
Neurological Neoplastic	• Congenital brain abnormalities • Primary or metastatic tumors • Acute stroke, post-apoplectic seizure
Degenerative Deficiency	• Degenerative neurologic diseases • Sleep deprivation
Intoxication Withdrawal	• Antidepressants, antipsychotics, lidocaine, lithium, stimulants • Withdrawal of alcohol, sedatives • Non-compliance with antiepileptics
Trauma Mechanical	• Head trauma • Acute hydrocephalus
Electrolytes Endocrine Metabolic	• Hypo- & hypernatremia, hypocalcemia, hypomagnesemia • Hypoxia, hypo- & hyperglycemia* • Uremia, hepatic encephalopathy, eclampsia

* Seizures occur with the hyperglycemic hyperosmolar state but not with diabetic ketoacidosis, presumably due to the anticonvulsant effect of ketones [5].

EPIDEMIOLOGY

A	• **Age** affects the prevalence of causes of T-LOC in patients assessed in the ED [6]:

Age	Reflex	Orthostatic	Cardiac	Non	Unexplained

					syncopal	
	< 40 years	51%	2.5%	1.1%	18%	27%
	40 - 60 years	37%	6%	3%	19%	34%
	> 60 years	25%	8.5%	13%	12.5%	41%

- **First episode** of T-LOC **between the ages of 10 and 30 years** is more likely to be a syncope than a seizure (< 1%) [7]
- **Syncope in a young patient** is most likely reflex syncope, but syncope caused by a long QT-syndrome or hypertrophic cardiomyopathy can also occur (Olshansky 2009). The average age of diagnosis of HOCM is 30-40 years old (Mattu HOCM). Carotid sinus syncope is exceptional in patients < 40 years [8].
- **Syncope in the elderly** is more likely to be due to a life-threatening cause such as acute coronary syndrome, dysrhythmias, aortic dissection, rupture abdominal aortic aneurysm, aortic stenosis [9]. However, risk is more strongly correlated to the presence of cardiovascular disease than to age itself [10]. The incidence of vasovagal syncope decreases with age [10].

G
- 80% of patients with psychogenic pseudoseizures are female [11].

H

Certain life-threatening conditions associated with syncope are inheritable:
- **Hypertrophic obstructive cardiomyopathy** (HOCM;only 55% have a family history; Mattu HOCM)
- **Congenital long QT syndrome** (associated with deafness)
- **Brugada** syndromes
- **Subarachnoid hemorrhage**
- **Jervell Lang-Nielson** and **Romano-Ward** syndromes

BACKGROUND

M

☐ **What medications do you take? Any recent changes?**
- **Antihypertensive** medications suggest syncope due to orthostatic hypotension.
- **Antiepileptic** medications suggest seizure. Seizures may result from non-compliance or supratherapeutic levels obtained chronically or after an acute overdose [3].
- **Antipsychotics** (Haldol, Seroquel) and **antidepressants** (tricyclics, Citalopram) suggest orthostatic hypotension or arrhythmia due to prolonged QTc.
- **Antiarrhythmic** medications suggest cardiovascular syncope due to bradycardia or other arrhythmias.
- **Certain antibiotics** (e.g. macrolides) increase the QT interval and the risk for arrhythmias.
- **Antihistamines** (e.g. Loratidine) may prolong the QT interval.

A

☐ **Are you allergic to medications or to contrast?**

P

☐ **What are your past medical conditions?**
- **Prior seizures** suggest seizure.
- **Cardiac disease** suggests cardiac syncope (SN 95%, SP 45%) [12]. The absence of cardiac disease argues against cardiac syncope (SN 97%) [12].
- **Diabetes** suggests syncope due to orthostatic hypotension or a hypoglycemic episode.
- **Parkinson's** disease suggests syncope due to orthostatic hypotension.
- **Psychiatric disease** suggests psychogenic pseudosyncope [1].
- **Prior stroke** suggests post-apoplectic seizure.
- **Pacemaker**: syncope in a patient with a pacemaker raises the possibility of pacemaker

	malfunction[9]. ☐ **Have you previously had episodes of transient loss of consciousness?** • **Repeated episodes** of T-LOC within a short time span suggest a dangerous condition (Olshansky 2009).
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Pregnant** patients (especially during their second and third trimester) are prone to vasomotor and orthostatic syncope; however, pregnancy is also a risk factor for pulmonary embolism [9]. • **Eclampsia** is suggested by seizure in a woman beyond 20 weeks of gestation in the setting of hypertension, edema, and proteinuria.
E	☐ **How much alcohol do you drink and how often?** • **Alcohol abuse** suggests orthostatic hypotension (alcohol is a vasodilator) or seizures due to abstinence.
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?**

HISTORY

Preceding Loss of Consciousness

☐ **What were the circumstances during which the LOC occurred?**

- **Emotional distress, fear, pain, instrumentation, sight of blood** preceding T-LOC suggests reflex syncope [1].
- **Cough, sneeze, swallow, defecation, micturition, visceral pain** immediatetly preceeding T-LOC suggest situational syncope [1].
- **Movement or manipulation of the neck** (e.g. shaving the neck) preceding T-LOC suggests carotid sinus hypersensitivity [2, 9].
- **T-LOC during exercise** (including swimming) suggests arrhythmia, aortic stenosis, or HOCM [9].
- **T-LOC post-exercise** suggest situational syncope [1] or orthostasis [2].
- **Prolonged exposure to heat stress** preceding T-LOC suggests orthostasis [2].
- **Post-prandial T-LOC** suggest situational syncope [1].
- **T-LOC during sleep** suggests arrhythmia.
- **T-LOC following prolonged standing** suggests reflex syncope SN 40%, SP 98%, LR 20.4 [13].
- **Change in position from supine to standing** preceding T-LOC within 3 minutes suggests orthostatic hypotension ([9, 10].
- **T-LOC while supine** suggests arrhythmia or seizure [9, 12]).
- **Exposure to flashing lights** preceding T-LOC suggests seizure.
- **Sudden loud noise or startling event** preceding T-LOC may suggest congenital long QT syndrome (EMC 2012).
- **Trigger**: reflex syncope is almost always triggered; seizure is not triggered (personal communication JG van Dijk).

☐ **How did you feel immediately preceding the LOC? Any pain or palpitations?**

- **Prodomal symptoms** precede loss of consciousness by no more than **10-20 seconds** [14].
- **Absence of prodromal symptoms** is often associated with dysrhythmias [9] and a risk factor for adverse events with 10 days in one study [15] and for death at 1 year in another [16].
- **Sweating** prior to T-LOC suggests vasovagal syncope SN 35-36%; SP 94-98%; LR 5.9-18 [13, 17]).

- **Nausea** prior to T-LOC suggests vasovagal syncope SN 28%; SP 94-98%; LR 4.7-14 [13, 17].
- **Sensation of increased warmth** prior to T-LOC suggests vasovagal syncope [10].
- **Tunnel vision** prior to T-LOC suggest vasovagal syncope [9].
- **Lightheadedness** prior to T-LOC suggests vasovagal syncope SN 73%; SP 73%; LR 2.6 [13, 17] but may also occurs with orthostatic hypotension, in which case nausea and sweating are absent [10].
- **Chest pain** and **palpitations** prior to T-LOC suggest cardiac syncope [12], e.g. secondary to acute coronary syndrome, arrhythmia, aortic dissection, pulmonary embolism [9].
- **Dyspnea** in the setting of T-LOC suggests pulmonary embolism and acute coronary syndrome.
- **Severe headache** around the time of the T-LOC suggests intracranial bleed, especially subarachnoid hemorrhage [9].
- **Upper back pain** in conjunction with T-LOC suggests aortic dissection [9].
- **Abdominal pain** in conjunction with T-LOC suggests ruptured abdominal aortic aneurysm or ectopic pregnancy [9].
- **Rising epigastric sensation** is the most common type of aura associated with temporal lobe epilepsy. Other aura symptoms from temporal lobe epilepsy are **fear** (second most common), memory distorsion such as **déja vu** (experience of familiarly with an unknown situation) and **jamais vu** (experience of unfamiliarly with a known situation), **unusual unpleasant smell**, aura with **gustatory** qualities [18].
- **Limb weakness**, **ataxia**, **diplopia**, **dysarthria** in association with T-LOC suggest vertebrobasilar TIA.

☐ **Did you injure yourself when you lost consciousness?**

- Patients who have truly lost consciousness loose voluntary muscle control as well as postural tone. Patients who are standing when they loose consciousness fall; patients who are sitting slump over. The fall or slump may lead to **trauma**. Concomitant trauma was associated with adverse events within 10 days in one study [15].

During Loss of Consciousness

☐ **Did anyone witness head or limb jerking movements while you were unconscious?**

- **Immediate onset of jerks** upon LOC suggests seizure, while **delayed onset** suggests syncope [14].
- **Jearking movements lasting < 15 seconds** suggest syncope [14] while movements lasting **> 30 seconds** suggest seizure [9].
- **Coarse** (large)**, stiff, rhythmic, synchronous, multiple (**hundreds) jerking movements with the knees and elbows bent suggest seizure.
- **Small, flaccid, non-rhythmic, asynchronous, few** (e.g. 5) movements with the elbows and knees straight suggest syncope. Relatives usually overestimate the duration of the event (personal communication, Dr. J Gert van Dijk).
- **Hemilateral movements** e.g. head turning or unusal posture, suggest seizure SN 43%; SP 97%; LR+ 13.5 [13]. However, head turning is not specific for seizure and may also occur during tilt-induced reflex syncope [19].
- **Psychogenic pseudosyncope** episodes are frequent (> 1/day) and last a long time (e.g. 45 minutes). The eyes are almost always closed.

☐ **What was the patient's skin color while unconscious?**

- **Pallor** suggests vasovagal episode SN 81%; SP 66%; LR 2.8 [13, 17].

- **Cyanosis** suggests seizure SN 29-33%; SP 94-98%; LR 3-5 [13, 17].

☐ **For how long was the patient unconscious?**

- **T-LOC lasting < 20 seconds** suggests syncope [1]. Syncope is generally associated with unconsciousness lasting no more than seconds to minutes [9].
- **T-LOC lasting > 5 minutes** suggests seizure [20] or drug effects [9].

Following Loss of Consciousness

☐ **Were you confused after you regained conscious? What is your earliest memory after the event?**

- **Almost immediate** restoration of orientation and appropriate behaviour suggests syncope [1]. One exception is the "drop attack," a generalized seizure characterized by sudden and complete loss of muscle tone associated with altered mentation and where postictal confusion may be absent [21].
- **Confusion** following return of consciousness (> 5 min; [9]) suggests seizure SN 85-94%; SP 0.69-0.83%; LR+ 3.0-5.0 [13, 17].
- **Memory impairement** lasting for several minutes after the event (e.g. repeating questions) suggests seizure. On the other hand, patients post-syncope looking amazed for a few seconds, and then have the ability to record memories (personal communication J Gert van Dijk).

☐ **Do you have pain anywhere?**

- **Muscle aching** suggests seizure SN 16-39%; SP 85-95%; LR+ 2.6-3.4 [13, 17].
- **Severe headache** suggests subarachnoid hemorrhage; however, the presence of headache after recovery is non-specific and may occur after syncope or seizure [9].
- **Chest pain** suggests aortic dissection, acute coronary syndrome & dysrhythmia.
- **Abdominal pain** suggests ruptured aortic aneurysm, ruptured ectopic pregnancy, perforation of a gastric or duodenal ulcer [22].
- **Leg pain** preceding T-LOC may result from a deep venous thrombosis and suggest pulmonary embolism. Leg pain occurring in conjunction with the T-LOC suggests aortic dissection or ruptured abominal aortic aneurysm [9].

PHYSICAL EXAMINATION

VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?** • **Tachypnea** suggests pulmonary embolism, sepsis. • **Decreased SpO2** suggests pulmonary embolism [9]. • **Tachycardia** may suggest a tachydysrhythmia, pulmonary embolism, or be secondary to shock [9]. • **Bradycardia** (< 50 bpm) suggests arrhythmic syncope [23]. • **Hypotension** suggests intravascular volume depletion or cardiogenic shock, e.g. due to acute coronary syndrome or dysrythmias [9].
H&N	☐ **Signs of head or neck trauma?** ☐ **Tongue bite?** • **Lateral tongue bite** suggests seizure SN 41-45%; SP 94-97%; LR+ 7.3-16.5 [13, 17]. • **Bite on the tip** of the tongue suggests syncope (the tip of the tongue gets caught between the front teeth when the patient falls) [1].
CV	☐ **Heart sounds?**

	• **Decreased intensity of the second heart sound** suggests aortic stenosis LR 3.1-50 [24].
	• **Increased intensity and delay of the second heart sound** suggests pulmonary hypertension.
	☐ **Murmurs?**
	• **Systolic murmur** with a mid-to-late peak intensity suggests aortic stenosis LR 8.0-101 [24]. The absence of a systolic murmur rules out aortic stenosis [25].
	• **Absence of murmur radiation to the right carotid artery** argues against aortic stenosis LR 0.05-0.10 [24].
	• **Systolic ejection murmur** which is louder at the lower sternal border or apex and that becomes **louder with maneuvers that decrease preload** (valsalva**,** change in the patient's position from squatting to standing) and softer with the Trendelenburg position suggests hypertrophic cardiomyopathy [26].
	☐ **Carotid pulse?**
	• **Pulsus tardus** (slow rate of rise of the carotid pulse) suggests aortic stenosis LR 2.8-130 [24].
	• The presence of ≥ 3 of the following argues strongly for aortic stenosis [25]:
	  ○ **Pulsus parvus** (a diminished carotic pulse amplitude)
	  ○ **Pulsus tardus** (a prolonged carotic pulse upstroke)
	  ○ **Systolic murmur best heard over the second intercostal space**
	  ○ **Diminished intensity of the second heart sound**

Leg	☐ **Leg swelling?** • **Unilateral leg swelling** suggests deep venous thrombosis and pulmonary embolism.
NS	☐ **Neurological Deficits?** • **Focal neurological deficits** increase the likelihood that a seizure occurred. The American College of Cardiology/American Heart Association recommend performing a basic neurological examination on patients presenting with T-LOC [27].

BEDSIDE TESTS

☐ **Lactate +/- WBC**

• Blood tests after a seizure may reveal a lactic acidosis [3].
• Leukocytosis is frequently seen after seizure [28].

☐ **EKG**

O	• **Sinus rate < 50/min or > 100/min** is associated with adverse events according to the Boston Syncope Rule [29]. Asymptomatic sinus bradycardia (< 50/min) suggests arrhythmic syncope [23]. • **Second and third degree atrioventricular block** are associated with adverse events according to the Boston Syncope Rule [29]. Stokes-Adams syndrome refers to syncope resulting from asystole or atrioventricular block. • **First degree atrioventricular block** does not suggest syncope secondary to dysrhythmia [30]. • **Rapid atrial fibrillation** is associated with adverse events according to the Boston Syncope Rule [29]. • **Premature atrial or ventricular complexes** have no diagnostic significance [9].
P	• **Signs of left atrial hypertrophy** may be present in HOCM but are non-specific.

	• **Short PR** interval suggests Wolff-Parkinson-White syndrome.
Q	• **Deep, narrow (<0.04 sec) Q waves in lateral leads** (I, aVL, V5-V6), sometimes inferior leads, are specific but not sensitive for HOCM (Mattu HOCM) (EKG 26 yo). • **Q waves** suggesting prior myocardial infarction are associated with adverse events according to the OESIL risk score [16]. • **Intraventricular block** is associated with adverse events according to the Boston Syncope Rule [29]. • **Delta wave** suggests reentry tachyarrhythmia. • **Episolon wave** is a small positive deflection buried in the end of the QRS complex. It is the characteristic finding in arrhythmogenic right ventricular dysplasia. (http://lifeinthefastlane.com/ecg-library/basics/epsilon-wave/)
R	• **High left-ventricular voltage** (i.e. tall R waves in the precordial leads) is consistent with HOCM, sensitive but not specific (Mattu HOCM) (EKG 26 yo). • **Tall R wave in V1** may be present in HOCM and mimic a posterior myocardial infarction [31].
S	• **ST elevation or ST depression > 0.1 mV** are associated with adverse events according to the Boston Syncope Rule [29]. • **Brugada** pattern in the context of syncope suggests polymorphic VT or VF; the Brugada pattern is associated with adverse events according to the EGSYS score [32].
T	• **Notched or biphasic T wave** suggests congenital long QT syndrome [33]. • **Prolonged QTc tid** (> 450 msec in children, > 500 msec in adults EMC0252012) increases the risk for syncope resulting from torsade de pointes. Prolonged QTc is part of the Boston Syncope Rule and the Canadian Arrhythmia Risk Score. • **Short QT syndrome** (QTc < 340 msec, < 360 msec in patients with a family history of sudden death) should be investigated (EMC 2012).

☐ Ultrasound

H	•
I	•
J	•
K	•
L	•
+	•

MANAGEMENT

1. Transient Loss of Consciousness?

It may be difficult to ascertain whether consciousness was lost, and whether the loss of consciousness was transient. Non-accidental falls in the elderly may be caused by syncope despite patients not remembering the loss of consciousness [34]. Patients with vasovagal episodes may have amnesia for LOC, in particular patients > 60 years (42% according to one source [35]). Conversely, many conditions may be falsely labeled as T-LOC.

Differential Diagnosis of Conditions Falsely Labeled as Transient Loss of Consciousness [3, 4, 10]

Pathophysiology	Examples
Neurologic	• Transient Global Amnesia • Movement disorders

Sleep Disorders	• Cataplexy/narcolepsy • Periodic leg movements of sleep • Arousal disorders • Parasomnia associated with REM sleep
Toxic	• Carbon monoxide poisoning [4] • Extrapyramidal symptoms of antipsychotics • Delirium tremens • Tetanus
Metabolic	• Hypoglycemia [4] or hyperglycemia • Hyperthyroidism • Hyperventilation (e.g. secondary to anxiety) leading to hypocarbia and cerebral vasoconstriction [10]
Psychogenic	• Panic attacks • Psychogenic pseudoseizure [36] • Psychogenic pseudosyncope

2. Seizure?

When it is unclear whether the patient suffered from syncope or seizure, the following clinical score, derived from 539 patients with ≥ 1 episode of loss of consciousness, may be useful [37]:

Questions		**Points**
Pre	• At times do you sweat before your spells?	-2
	• At times is emotional stress associated with losing consciousness?	1
	• At times do you have a sense of déjà vu or jamais vu before your spells?	1
	• Have you ever had lightheaded spells?	-2
	• Is prolonged sitting or standing associated with your spells?	-2
During	• Has anyone ever noted that you are unresponsive, have unusual posturing or have jerking limbs during your spells or have no memory of your spells afterwards?	1
	• Has anyone ever noted your head turning during a spell?	1
	• At times do you wake with a cut tongue after your spells?	2
Post	• Has anyone ever noted that you are confused after a spell?	1

• A point score of ≥ 1 suggests seizure, while a point score < 1 suggests syncope.

Management of patients with suspected seizure includes:

- **Detailed neurological examination**
- **Blood tests**: glucose, electrolytes and anticonvulsant levels when appropriate
- **CT scan** if [3]
  - first time seizure
  - different sort of seizure
  - new focal abnormalities on the neurological examination
  - head trauma
  - history of anticoagulation
- **Consider presence of triggers:**
  - infection?
  - medications/non-compliance?

- intoxication/withdrawal (in particular alcohol withdrawal)?
- electrolyte abnormalities?
- sleep deprivation?

- **Admission or discharge** depending on the likelihood of seizure triggers (e.g. infection), investigation results, patient's condition, support at home and availability of timely follow-up.
- **Restrictions**: driving restrictions and warning about potentially dangerous activities (e.g. swimming, climbing ladders, operating machinery) [3].

3. Vascular Syncope?

Certain conditions, e.g. subarachnoid hemorrhage, aortic dissection, ruptured abdominal aortic aneurysm, ruptured ectopic pregnancy and pulmonary embolism, may present with syncope.

One study reported that pulmonary embolism was identified in 17% of patients admitted to the hospital for a first syncope episode, including in 13% of patients who had an alternative explaination for syncope, making the prevalence of PE among all patients presenting to the ED with syncope > 3.7% [38]. However, a meta-analysis of 9 other studies including > 6,000 patients found a prevalence of PE among all syncope patients to be 0.8% [39].

4. Cardiogenic Syncope?

A review of EKGs taken in the preshospital arena and in the ED may strongly suggest that an arrhythmia was the cause of the patient's syncope. Yet certain arrhythmias may remain undetected during the initial ED evaluation. According to one study, 70% of patients hospitalized for suspected arrhythmias had no cause of syncope identified during hospitalization, yet 2.5% of patients with syncope discharged from the ED suffered serious adverse events during the following 30 days [40]. Risk scores have been derived to estimate the likelihood of cardiogenic syncope and guide the decision to admit for cardiac monitoring.

The Canadian Syncope Arrhythmia Risk Score

Purpose: The purpose of the Canadian Syncope Arrhythmia Risk Score [41] is to evaluate the risk for death, arrhythmia or procedural interventions to treat arrhythmias within 30 days from ED evaluation in patients for whom arrhythmias were not evident during the initial evaluation in the emergency department. The score does not obviate the need to perform a thorough clinical evaluation in the ED and attempt to assign an etiology to the syncope.
Inclusion: adults (age ≥ 16 yr) with syncope who presented within 24 hours after the event.
Exclusion: prolonged loss of consciousness (> 5 min), a change in their mental status from baseline after the syncope, an obvious witnessed seizure or head trauma causing loss of consciousness, major trauma requiring hospital admission, intoxication with alcohol or illicit drugs, a language barrier, arrythmia and non-arrhythmic serious conditions identified during the ED evaluation.
Evidence: The risk score has been derived from a prospective cohort study carried out at six large EDs. The study included 5010 patients [41]. The score has yet to be validated in a separate population.

CATEGORY	POINTS	SCORE	RISK
Clinical Evaluation		-2	0.2%
• Vasovagal predisposition*	-1	-1	0.5%
		0	0.9%

• History of heart disease÷	+1	1	1.9%
• Any ED SBP < 90 or > 180 mm Hg‡	+1		
Investigations		2	3.8%
• Troponin > 99%ile	+1	3	7.5%
• QRS duration > 130 ms	+2	4	14.3%
• QTc interval > 480 ms	+1	5	25.4%
Diagnosis in Emergency Department		6	41.1%
• ED diagnosis of vasovagal syncope	-1	7	58.8%
• ED diagnosis of cardiac syncope	+2	8	74.5%

Score of ≥ 0 had SN 97% and SP 53% for death/arrhythmia/intervention within 30 days.

*Warm-crowded place, prolonged standing, fear, emotion or pain
÷ Includes history of coronary or valvular heart disease, cardiomyopathy, congestive heart failure or non-sinus rhythm (ECG evidence during the index visit or documented history of ventricular or atrial arrhythmias, or device implantation)
‡ Includes blood pressure values from triage until ED disposition
At a threshold score of ≥ 0, the sensitivity was 97.1% (91.6%-99.4%) and specificity was 53.4% (52.0%-54.9%).

There are also published guidelines regarding the decision to admit patients presenting with syncope.

The **Canadian Cardiovascular Society** categorized risk factors into [42]:
- **Major** risk factors: identified in > 1 study and justifying urgen cardiac assessment within two weeks.
- **Minor** risk factors: identified in 1 study only, may justify urgent cardiac assessment

Major Risk Factors	Minor Risk Factors
• **Abnormal EKG**: any bradyarrhythmia, tachyarrhythmia or conduction disease; new ischemia or old infarct • **History of cardiac disease**: ischemic, arrhythmic, obstructive, valvular • **Heart failure**: either past history or current state • **Hypotension**: SBP < 90 mm Hg	• **Age** > 60 years • **Dyspnea** • **Anemia**: hematocrit < 30% • **Hypertension** • **Cerebrovascular disease** • **Family history**: early (< 50 years) sudden death • **Specific situations**: syncope while supine, during exercise, or with no prodromal symptoms

The **European Society of Cardiology** Task Force for the Diagnosis and Management of Syncope identified the following short-term high risk criteria justifying hospitalization or intensive evaluation [1]:

Historical Criteria	EKG Criteria
• Heart failure • Previous myocardial infarction	• Non-sustained VT • Bifascicular block (LBBB or RBBB combined with LAHB or LPFB) or other intraventricular conduction abnormalities with

• Structural heart disease • Syncope during exertion or supine • Palpitations at the time of syncope • Family history of SCD	QRS duration ≥ 120 ms • Inadequate sinus bradycardia (< 50 bpm) or sinoatrial block in absence of negative chronotropic medications or physical training • Pre-excited QRS complex • Prolonged or short QT interval • Brugada pattern • Features suggestive of Arrhythmogenic Right Ventricular Cardiomyopathy

Patients with suspected cardiogenic syncope should:
- be admitted to a bed with cardiac monitoring
- undergo echocardiography

5. Orthostatic Hypotension?

The initial diagnostic test of choice when orthostatic hypotension is 'active standing,' in which the BP is measured using a sphyngmomanometer with the patient supine, and then repeatedly during 3 min after the patient has actively arisen from supine to erect. The test is diagnostic when there is one of the following:
- **symptomatic fall in SBP ≥ 20 mm Hg**
- **symptomatic fall in DBP ≥ 10 mm Hg**
- **symptomatic fall in SBP to < 90 mm Hg.**

The test may be considered diagnostic in the setting of asymptomatic BP falls of the same degree [1]. One source reports, however, that a fall in SBP > 20 mm Hg upon standing has poor sensitivity and specificity for intravascular volume depletion and that up to 30% of patients with cardiac-related syncope have orthostatic vital sign changes [9].

Patients with orthostatic or medication-related syncope have no increased risk of cardiovascular morbidity and mortality [43] and can be discharged from the ED.
Management consists in:
- Encouring patients with drink **2-3 liters per day** and consume **10 g of salt** [1].
- Considering **discontinuation or dose-reduction** of medications such as antihypertensives, diuretics, tricyclic antidepressives, phenothiazines, and alcohol [1].
- Prescribing the alpha-agonist **midodrine** 5-20 mg x 3 or **fludrocortisone** 0.1-0.3 mg x 1 [1].
- Recommending that patients sleep with the **head of bed elevated** by 10° to avoid nocturnal polyuria and hypertension [1]
- Considering **compression stockings** and **physical counterpressure maneuvers to decrease venous pooling**.

6. Reflex Syncope?

Patients with a history suggestive of reflex syncope and a normal electrocardiogram likely have reflex syncope. **Carotid sinus massage** may be carried out in patients > 40 years old with suspected carotid sinus hypersensitivity [1]. Patients with reflex syncope have no increased risk of cardiovascular morbidity and mortality [43] and can be discharged from the ED:
- Patient should receive instructions regarding **isometric physical counterpressure maneuvers** (leg crossing, hand grip and arm tensing)

- **Driving** should be restricted if the reflex syncope episodes are very frequent, unpredictable and/or occur during high-risk activities [1].

7. Syncope of Uncertain Etiology

One study reported that physicians can make a certain or highly likely diagnosis in 63% of patients with T-LOC using only a standardized history, physical examination and EKG with 88% diagnostic accuracy [44]. Other sources report that a thorough history, physical examination and EKG interpretation help identify or suspect a cause of syncope in roughly half [9, 10]. For the remaining patients, the physician needs to decide whether to admit to the hospital for observation and/or urgent evaluation. The main concern is that the patient's syncope resulted from a dysrhythmia (see above **4. Cardiogenic Syncope**).

MISCELLANEOUS

DIARRHEA

INTRODUCTION

Diarrhea is generally defined as the passage of ≥ 3 unformed stools per day, or the passage of > 250 g of unformed stool per day [1].

- **Acute diarrhea** is defined as lasting ≤ 14 days [2].
- **Persistent diarrhea** is defined as lasting > 14 days [2].
- **Chronic diarrhea** is defined as lasting ≥ 30 days [2].

Tourist diarrhea is definied as [3]:

- ≥ 3 unformed stools / day
- ≥ 1 of the following: fever, nausea, vomiting, crampy abdominal pain, tenesmus, bloody stools
- occurring during or shortly after travel

Diarrhea occurs through one or more of the following four pathological processes [2]:

- **secretory** diarrhea results from increased cellular permeability leading to oversecretion of water and electrolytes into the intestinal lumen. Most diarrheas encountered in the ED are secretory [2].
- **inflammatory** diarrhea results from cellular damage leading to hypersecretion of water, electrolytes, blood, mucus, and plasma proteins. Invasive bacteria and inflammatory bowel disease are examples of conditions that result in infalmmatory diarrhea [2].
- **osmotic** diarrhea results from osmotically active solutes that lead to movement of water into the intestinal lumen.
- **hypermotility** results in limited absorption of fluid and electrolytes due to decreased contact time between luminal contents and absorbing mucosa.

DIFFERENTIAL DIAGNOSIS [2]

Pathophysiology	Examples
Viral infections	• Rotavirus (#1 cause worldwide), norovirus (calicivirus), astrovirus, adenovirus
Bacterial infections	• **Invasive**: Salmonella, shigella, campylobacter, Vibrio, Yersinia • **Toxigenic**: Bacillus cereus, Clostridium botulinum, Staphylococcus aureus, Enterohemorrhagic E coli O157:H7, Enterotoxigenic E. coli
Parasitic infections	• **Protozoal**: Giardia lamblia, Entamoeba histolytica, Cryptosporidium, Cyclospora • **Helminths**: Ascaris lumbricoides, Hookworms, Schistosoma species
Medications	• Laxatives, antibiotics, caffeine, chemotherapy agents, opiate withdrawal
Toxins	• **Fish toxins**: Ciguatera, Scombroid, shellfish poisoning • **Plant toxins**: herbal preparations, Amanita mushrooms, nicotine
Gastrointestinal pathology	• Appendicitis, gastrointestinal bleeding, irritable bowel syndrome, ischemic bowel, inflammatory bowel disease
Endocrine	• Carcinoid syndrome, hyperthyroidism, systemic mastocytosis, adrenal insufficiency, diabetes enteropathy

EPIDEMIOLOGY

A	• Patients at the **extremes of age** have the highest risk of diarrhea-associated morbidity and mortality [2].

BACKGROUND

M	☐ **What medications do you take?** • **Laxatives**, **antibiotics**, **caffeine**, **chemotherapy agents**, **opiate withdrawal** • **Beta-blockers** and **other antiarrhythmics** may prevent tachycardia despite dehydration [2]. ☐ **Have you taken antibiotics during the preceding X months?** • **Antibiotics** use (especially . . . ; within the past X months) suggests Clostridium difficile [4].
A	☐ **Are you allergic to medications or to contrast?**
P	☐ **What are your past medical conditions?** • **Immunocompromised** patients have the highest risk of diarrhea-associated morbidity and mortality and the differential diagnosis is broader [2]. • **Recent hospitalization** is a risk factor for Clostridium difficile [2].
L	☐ **Life circumstances: occupation? social support? activities of daily living?** • **Male homosexuality** is a risk factor for Giardia lamblia, Entamoeba histolytica [2]. • **Day care** is a risk factor for rotavirus, norovirus, Shigella, Giardia [2, 4]. • When diarrhea develops in a patient who has been **hospitalized** for > 3 days, the etiologic pathogen is almost always Clostridium difficile [4]. • Epidemic diarrhea in **institutions**, **hospitals**, **nursing homes**, **cruise-ships** suggests norovirus, less commonly Campylobacter, Salmonella, Cryptosporidium [4].
E	☐ **How much alcohol do you drink and how often?**
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?**

HISTORY

O	☐ **Recent travel?** • **A history of recent travel**, especially foreign travel, is associated with a high probability (80%) of bacterial diarrhea [4]; persistent post-travel diarrhea suggests a protozoal etiology [4]. • **Bloody diarrhea in an immigrant or traveler** should raise the possibility of Entamoeba histolytica [4]. • **Wilderness exposure** is a risk factor for Giardia and Cryptosporidium [2, 4]. ☐ **Recent food intake?** • **Shellfish** suggests norovirus or Vibrio species; **raw shellfish** ingestion is a risk factor for shellfish toxin. • Epidemics of severe gastroenteritis traced to **eggs, poultry, meat or dairy products** suggests Campylobacter jejuni, Salmonella [4]. • **Acute vomiting and diarrhea** after eating potentially contaminated food suggests preformed toxins from Bacillus cereus, Clostridium botulinum, Staphylococcus aureus [2]. ☐ **Recent contact with animals?** • **Pets**, especially **reptiles** (snakes, turtles, lizards) and **amphibians** (frogs, toads, newts, salamanders) suggest Salmonella [4]. • Animal contact at **agricultural fairs, petting zoos, and county fairs** suggests E coli

	O157:H7 and non-O157 Shiga toxin–producing E coli [4].
Q	☐ **Is the diarrhea watery, bloody, black?** • **Bloody diarrhea** suggests a non-viral etiology [4]. • **Watery diarrhea** is consistent with a viral etiology or an uncomplicated bacterial ("norovirus-like") etiology [4], • **Black diarrhea** suggests melena from upper gastrointestinal bleeding.
R	☐ **Does the diarrhea persist despite fasting?** • Diarrhea that persists despite fasting suggests an **inflammatory process** [2].
S	☐ **Volume?** • **Voluminous diarrhea** argues against a "norovirus-like" infection [4]. ☐ **Frequency?** • **> 6 stools per 24 hours** argues against a viral or uncomplicated bacterial etiology [4].
T	☐ **Duration?** • **Acute diarrhea** (< 14 days) is usually caused by viral or bacterial infections [2]. • **Persistent diarrhea** (> 14 days) is usually caused by bacterial or protozoal infections [2]. • **Chronic diarrhea** (≥ 30 days) is usually caused by non-infectious causes [2] with the exception of protozoal infections: prolonged diarrhea is the major clinical feature of protozoal infection (Entamoeba histolytic, Giardia, Cryptosporidium) [4]. ☐ **Have you had prior similar episodes?**
+	☐ **Fever?** • **Fever** > 38.5°C argues against a viral or uncomplicated bacterial infection [4] ☐ **Pain?** • **Severe abdominal pain** suggests severe bacterial infection (Salmonella, Campylobacter, Shigella, EPEC, Yersinia or Vibrio species), inflammatory bowel disease, or a surgical cause of abdominal pain (e.g. bowel ischemia) [2]. • **Proctitis** suggests a bacterial cause [2].

PHYSICAL EXAMINATION

VS	☐ **RR, O2%, HR, BP, AVPU, Temp?** • **Tachycardia, hypotension and decreased mental status** suggest hypovolemia and hypoperfusion [2]. In children, the number of wet diapers may be used as a surrogate measure of urine output [2]. • **Fever > 38.5°C** argues against a viral or uncomplicated bacterial infection [4]. • **Kussmaul breathing** suggests metabolic acidosis, either from shock (lactic acidosis) or from bicarbonate loss (hyperchloremic acidosis).
AB	☐ **Palpation** • **Focal abdominal peritonitis** suggests a surgical cause [2].
PR	☐ **Faeces color?** • **Melena and hematochezia** suggest gastrointestinal bleeding [2]. • **Gross blood** is consistent with invasive, infectious diarrhea [2].

BEDSIDE TESTS

☐ **CRP**

• Elevated CRP suggests . . .

☐ **Electrolytes & Creatinine**

• May suggest dehydration

MANAGEMENT

1. Sepsis?

• See section in Chapter 07 for likelihood assessment and management.

2. Gastrointestinal bleed?

• See section in Chapter 07 for management of gastrointestinal hemorrhage.

3. Contagious infection?

• Isolate the patient while in the ED.

4. Syndrome management

Most cases of acute diarrhea resolve within 5 days [4]. Goodgame recommends categorizing adults with acute infectious diarrhea into three categories for the sake of further management:

Category	Features	Infectious agent	Management
Viral or "norovirus-like" diarrhea	• No specific epidemiologic risk factor • No clinical feature suggestive of severe bacterial infection	• Norovirus • Bacteria (including e.g. Salmonella) and protozoa producing an uncomplicated gastroenteritis syndrome	• No specialized diagnostic testing or antimicrobial management • Avoid milk products • Loperamid 4 mg once and 2 mg with each liquid stool
Severe bacterial infection	• Fever > 38.5°C • Bloody diarrhea • Voluminous diarrhea • Severe abdominal pain • > 6 stools per 24 hours • Diarrhea persisting > 7 days	• Salmonella, Campylobacter, Shigella • Shiga-toxin producing E coli • Yersinia • Vibrio • Clostridium difficile	• Stool testing for bacterial (or amoebic) infection, shiga toxin • If the signs and symptoms are severe, presumptive antibiotic therapy is recommended (unless E coli O157:H7 is suspected[1])
Epidemiologic risk factors	• Travel[2]	• 80% probability of bacterial etiology • Persistent diarrhea suggests a protozoa	• Presumptive antibiotic therapy combined with clinical observation
	• Hospitalized > 3 days • Antibiotic use • Contact with health-care personnel	• Clostridium difficile	• Stools for Clostridium difficile toxin • Presumptive treatment while awaiting test results is appropriate in severely ill patients[3]
	• Immunocompromised host	• Virus, bacteria, mycobacteria, protozoa	• The cause may be non-infectious (drugs, graft-vs host). Consult a specialist

1-Hemolytic-Uremic Syndrome
Diarrhea occurring in the setting of hemolysis, thrombocytopenia and uremia suggests hemolytic-uremic syndrome. Most cases are caused by E coli O157:H7. Treatment?

2-Tourist Diarrhea
Loperamide, in therapeutic doses (up to 8 mg per day for up to 2 days), decreases secretion from the bowel mucosa and is recommended, alone or in combination with antibiotics, for the treatment of tourist diarrhea [3].

3-Clostridium difficile infection
Treatment: http://onlinelibrary.wiley.com/doi/10.1111/1469-0691.12418/abstract

DYSPNEA

INTRODUCTION

Dyspnea refers to a sensation of breathlessness and breathing difficulties. Patients may decribe the sensation as "shortness of breath," "chest tightness", or "air hunger" [1].

DIFFERENTIAL DIAGNOSIS

Approximately two thirds of symptomatic patients presenting to the ED with dyspnea have a pulmonary or cardiac condition [2].

Anatomy-Pathophysiology		Examples
L U N G	Upper airway	• Epiglottitis, anaphylaxis, foreign body, mass, abscess
	Lower airway	• Asthma, COPD exacerbation, foreign body
	Alveoli	• Pneumonia, pulmonary edema, alveolar proteinosis
	Blood vessels	• Pulmonary embolism, pulmonary occlusive venopathy
	Parenchyma	• Interstitial fibrosis, viral pneumonia, cancer
	Pleura	• Pneumothorax, pleural effusion, hemothorax
	Neuromuscular, skelettal, mechanical	• Guillain Barré, polymyositis, myasthenia gravis, ALS, bolulism, kyphoscoliosis, abdominal loading (ascites, obesity, pregnancy)
H E A R T	"In" problem	• Increased fluid and/or salt intake
	"Out" problem	• Poor compliance with diuretics, renal failure, NSAID
	Pericardium	• Tamponade, constrictive pericarditis
	Myocardium	• Myocarditis, cardiomyopathy
	Valves	• Chordae tendiniae rupture, infective endocarditis
	Blood vessels	• Acute coronary syndrome, angina equivalent
	Electrical system	• Tachyarrhythmia, bradyarrhythmia
	Outflow tract	• Pulmonary embolism, HOCM, hypertensive crisis
4 H	Low Hb	• Decreased erythropoiesis, hemorrhage, hemolysis
	Low pH	• Diabetes ketoacidosis, renal failure, lactic acidosis, diarrhea
	Hyperthyreoidism	• From increased metabolism, muscle weakness, goiter
	Hyperventilation	• Anxiety, salicylic acid intoxication, progesterone, nicotine

EPIDEMIOLOGY

A	• 36% of patients > 65 years have dyspnea on exertion [3].
P	• A prospective observational study carried out in a French urban teaching hospital reported the following prevalence of causes of acute respiratory distress **among patients ≥ 65 years** [4]: o cardiogenic pulmonary edema (43%) o community-acquired pneumonia (35%) o acute exacerbation of chronic respiratory disease (32%) o pulmonary embolism (18%) o acute asthma (3%) o 47% had more than two diagnoses
G	• Among patients > 65 years, women are more likely to report dyspnea than men [3].

BACKGROUND

M	☐ **What medications do you take?** • **Furadantin, NSAID, Cordarone, Methotrexate, other chemotherapeutic agents, IV drug abuse, and statins** are among the substances associated with an increased risk of **interstitial lung disease.** ☐ **Do you take oral contraceptives?** • **Oral contraceptives** containing estrogen increase the risk for venous thromboembolism [5].
A	☐ **Do you have any allergies to medications or other substances?** • **Exposure to a known allergen** can lead to upper or lower airway obstruction.
P	☐ **What are your past medical conditions?** ☐ **Have you ever had clots in our legs or clots in your lungs?** • **Prior venous thromboembolism** is a risk factor for pulmonary embolism (PE) adjusted OR 2.90 (2.32-3.64) [6]. ☐ **Do you have any known heart problems?** • **Known heart failure** suggests heart failure LR+ 5.8 (4.1-8.0); LR- 0.45 (0.38-0.53) [7]. • **Previous myocardial infarction** suggests heart failure LR+ 3.1 (2.0-4.9); LR- 0.69 (0.58-0.82) [7]. • **Coronary artery disease** suggests heart failure LR+ 1.8 (1.1-2.8); LR- 0.68 (0.48-0.96) [7].
L	☐ **Life circumstances: occupation? social support? activities of daily living? pets?** • **Certain occupational exposures** increase the risk of interstitial lung disease. • **House pets** increase the risk for asthma exacerbation. • **Pregnancy** is a risk factor for PE. Pregnant women > 20 weeks of gestation may develop eclampsia leading to pulmonary edema. • **Post-partum period** suggests PE and peripartum cardiomyopathy.
E	☐ **How much alcohol do you drink and how often?** • **Ethanol abuse** is associated with dilated cardiomyopathy.
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?** • **Smoking** is a risk factor for COPD, ischemic heart disease, heart failure.

HISTORY

O	☐ **When did the shortness of breath start? What were you doing when it started?** • **Paroxysmal nocturnal dyspnea** (sudden onset of dyspnea while reclining at night [1]) suggests left ventricular heart failure LR+ 2.6 (1.5-4.5); LR- 0.70 (0.54-0.91) [7]. ☐ **How long did it take for the problem to reach its maximal intensity: seconds, minutes, hours?** • **Sudden onset** of dyspnea suggests PE or spontaneous pneumothorax according to traditional teaching [1]. • **Dyspnea that builds slowly over hours or days** suggests a flare of asthma or COPD, pneumonia, recurrent small PE, congestive heart failure [1].
P	☐ **Is the shortness of breath worsened by lying down?** • **Orthopnea** (dyspnea in the recumbent position) suggests left ventricular heart failure LR+ 2.2 (1.2-3.9); LR- 0.65 (0.45-0.92) [7] but may also be caused by COPD and neuromuscular disorders (e.g. diaphragmatic weakness) [1]. • **Platypnea** (dyspnea in the upright position) suggests right-to-left intracardiac shunting (e.g. from a patent foramen ovale).

Q	☐ **How would you describe the shortness of breath?** • Dyspnea is often ill defined by patients. Descriptions of dyspnea correlate poorly with severity and underlying pathophysiology [1].
R	☐ **Is the shortness of breath worsened by exertion?** • **Exertional dyspnea** is seen with COPD and poor cardiac reserve [1].
S	☐ **How does the shortness of breath affect your usual activities?** • The degree to which the shortness of breath affects the patient's activities of daily living can be quantified by asking about the **number of stairs or number of blocks** the patient can manage before the onset of dyspnea [1].
T	☐ **Has the shortness of breath been constant, intermittent, increasing?** ☐ **Have you had prior similar episodes?**
+	☐ **Do you have any chest pain or discomfort?** • **Sharp chest pain that worsens with deep breathing** but not with movement suggests pneumonia, PE, pleural effusion, pleurisy, spontaneous pneumothorax [1]. • **Dull, constant chest pain** suggests myocardial infarction or PE [1]. ☐ **Have you had any fever or chills?** • **High grade fever** suggests pneumonia. • **Low grade fever** is consistent with pneumonia and PE. ☐ **Have you had leg pain or swelling?** • **Bilateral leg swelling** suggests congestive heart failure. • **Unilateral leg swelling or pain** suggests DVT and PE. ☐ **Do you have a cough? If so, it is dry, productive, blood-tinged?** • **Hemoptysis** is consistent with PE. It can also occur with fulminant congestive heart failure (check).

PHYSICAL EXAMINATION

GA	• **Inability to speak in more than one word at a time** signals the presence of significant respiratory distress [1]. • **"Tripoding" position** suggests COPD or asthma with severe distress [1]. • **"Sniffing" position** suggests epiglottitis [1].
VS	☐ **Respiratory Rate, SpO2, Heart Rate, Blood Pressure, Consciousness, Temperature?** • **Increased respiratory rate** is non-specific. • **SpO2** depends on age and the presence of COPD. The SpO2 can help determine whether the dyspnea is caused by hypoxia. • **Tachycardia** can be secondary to the process which causes the dyspnea (e.g. blood loss, PE) or the cause of the dyspnea (pulmonary edema resulting from a tachyarrhythmia). • **Hypotension** suggests sepsis, bleeding, massive PE. • **Fever > 39°C** suggests pneumonia. • **Fever 37.5 – 39°C** is consistent with pneumonia and with PE.
CV	☐ **Auscultation: S3/S4? Murmurs?** • **S3** suggests heart failure LR+ 11.0 (4.9-25.0); LR- 0.88 (0.83-0.94) [7]. • **S4** does not affect the likelihood of heart failure LR+ 1.6 (0.47-5.50); LR- 0.98 (0.93-1.00) [7]. • **Pansystolic murmur** with radiation to the axilla suggests mitral regurgitation. Mitral regurgitation occurring suddenly days after a myocardial infarction suggests

	papillary muscle rupture. • **Crescendo-decrescendo murmur** with radiation to the carotid artery suggests aortic stenosis. • Article reviewing evidence of the physical examination for cardiovascular disease: [8] ☐ **Jugular venous pressure?** • **Jugular venous distention** can be detected by measuring the level of the venous pulsations of the internal jugular vein relative to the level of the manubriosternal junction [9]. The upper limit of a normal central venous pressure (9 cm H2O) corresponds to a jugular venous pulsation level of 4 cm above the sternal angle [9]. Jugular venous distension suggests heart failure LR+ 5.1 (3.2-7.9); LR- 0.66 (0.57-0.77) [7].
CW	☐ **Inspection of chest wall movements** • **Decreased chest excursions** may suggest a neuromuscular problem e.g. Guillain-Barré syndrome. • **Asymmetrical chest excursions** suggests diaphragmatic or phrenic nerve dysfunction or pneumothorax. • **Intercostal recessions** and **use of accessory respiratory muscles** suggests increased work of breathing. • **Increased expiratory time** relative to inspiratory time suggests lower airway obstruction, e.g. asthma or COPD exacerbation. • **Barrel chest** (see Chapter 13 in Rational Clinical Examination Evidence-Based Clinical Diagnosis)
Abdo	☐ **Inspection** • **Paradoxical abdominal movements** (abdominal wall retracts inward with inspiration, so-called "Hoover's sign") suggests a flattened diaphragm which occurs with emphysema.
Lung	☐ **Auscultation: wheeze? crackles? decreased breath sounds?** • **High-pitched breath sounds on inspiration** (stridor) suggests upper airway obstruction. • **High-pitched breath sounds on expiration** (wheezing) suggests asthma, COPD, bronchiolitis or foreign body and argues against heart failure LR+ 0.52 (0.38-0.71); LR- 1.3 (1.1-1.7) [7]. However, wheezing may occur with cardiogenic pulmonary edema ("cardiac asthma"). • **Crackles** suggests heart failure LR+ 2.8 (1.9-4.1) LR- 0.51 (0.37-0.70) [7]. • **Unilateral decreased breath sounds** suggests pneumothorax or pleural fluid. • **Unilateral rales** in the setting of cough and fever suggests pneumonia [1]. • **Hyperresonance to percussion** suggests pneumothorax. • **Dullness to percussion** suggests pleural fluid.
Leg	☐ **Unilateral leg swelling?** • **Unilateral swelling** suggests DVT and concomittant PE. ☐ **Peripheral edema?** • **Bilateral lower extremity edema** suggests heart failure LR+ 2.3 (1.5-3.7) LR- 0.64 (0.47-0.87) [7], yet the presence or absence of bilateral leg edema is not useful in discriminating between cardiac and pulmonary causes [2].

BEDSIDE TESTS

☐ **pH, pCO2, HCO3, CRP**

- pH, pCO2, HCO3. Venous values.
- CRP may be elevated with pneumonia, PE, ACS, perimyocarditis.

☐ EKG if patient > 50 years

Heart failure (HF) is very unlikely (likelihood < 2%) in patients presenting acutely and with a completely normal ECG [10]. The risks of HF, ACS, PE increase with age and hence the value of a routine EKG arguably increases with patient age. An EKG can be rapidly acquired. One may thus argue for routinely taking an EKG among patients > 50 years presenting to the ED because of dyspnea.

O	• The EKG may reveal **brady- och tachyarrhythmias** • **Atrial fibrillation** suggests heart failure LR+ 3.8 (1.7-8.8) LR- 0.79 (0.65-0.96) [7]
Q	• **Q waves** may be present with myocardial ischemia/infarction but are absent in pericarditis [11] • **New onset bundle branch block** suggests myocardial ischemia. • New onset **right bundle blanch block** is consistent with a large PE
R	• **Loss of R wave voltage** often occurs with myocardial ischemia but does not occur with pericarditis [11]
S	• **Localized convex ST elevation** with reciprocal ST-segment depression suggests ACS • **Localized ST depression** suggests ischemia
T	• **T wave inversion** while the ST-segments are still elevated suggests myocardial ischemia, while T wave inversion after ST-segments have normalized suggests pericarditis [11]. • **Negative T waves in leads V1 and III** suggests PE (SN 90%, SP 97%) [12]

☐ Ultrasound

- Several studies have shown that ultrasound adds value to the work-up of patients with dyspnea. One study showed that a rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound could accurately differentiate acute heart failure syndromes from primary pulmonary disease SN 94%, SP 92% [13]. Another study conducted in the ED among patients seeking because of acute dyspnea showed that the addition of ultrasound (limited echocardiography, lung and IVC) to history, physical examination and EKG interpretation increased the accuracy of the initial diagnosis from 53% to 77% (p=0.003) [14].

H	• **Pericardial fluid** may suggest an effusion from a perimyocarditis or hemopericardium from an AD. • **Right ventricular dilation** suggests massive PE. • **Restrictive mitral pattern** suggests heart failure SN 82% SP 90% LR+ 8.3 (4.0-16.9) LR- 0.21 (0.12-0.36) [15] • **Reduced ejection fraction** suggests heart failure SN 81% SP 81% LR+ 4.1 (2.4-7.2) LR- 0.24 (0.17-0.35) [15] • **Increased left ventricular end-diastolic dimension** suggests heart failure SN 80% SP 69% LR+ 2.5 (1.5-4.2) LR- 0.30 (0.16-0.54) [15]
I	• **IVC** of 23.2 mm +/- 2.1 was reported among 80 patients with decompensated heart failure seeking care in the ED or cardiology department, whereas the IVC was 19.7 mm +/- 1.9 among 56 patients with compensated heart failure, and 14.5 mm +/- 1.6 among

	50 patients without heart failure. • **IVC ≥ 20.5 mm** could distinguish decompensated from compensated HF with SN 90% and SP 73% [16] • **IVC size** is also increased with PE causing hemodynamic obstruction
J	• **Pleural effusion** suggests heart failure SN 64% SP 72% LR+ 2.0 (1.4-2.8) LR- 0.49 (0.22-1.10) [15]
L	• **Absence of lung sliding** is consistent with pneumothorax. • **Lung point** is diagnostic for pneumothorax. • **Positive B-line scan** suggests heart failure SN 85% SP 93% LR+ 7.4 (4.2-12.8) LR- 0.16 (0.05-0.51) [15]

☐ End-Tidal pCO2

- End-tidal pCO2 (EtCO2) . . .

MANAGEMENT

1. Upper airway obstruction?

- Upper airway obstruction may be caused by foreign body, epiglottitis, mediatinitis, thermic injury to the upper airway. See relevant sections in Chapter 07 for initial management.

2. Acute coronary syndrome?

- Patients with acute coronary syndrome may present with dyspnea in the absence of chest pain. See relevant section in Chapter 09 for likelihood assessment and initial management.
- See relevant section in Chapter 07 for the initial management of **cardiogenic pulmonary edema** and **STEMI**.

3. Pulmonary embolism?

- See relevant section in Chapter 09 for likelihood assessment and initial management.

4. Pneumonia?

- See relevant section in Chapter 09 for likelihood assessment and initial management.

5. Further management

- Further investigation and treatment will depend on the diagnostic hypothesis.

BNP

- Pro-BNP < 300 pg / ml argues against heart failure SN 99%; LR 0.1 [17].
- Pro-BNP > 900 pg / ml suggests heart failure SP 85%; LR 6 [17].
- BNP ≥ 100 pg/ml LR+ 2.7 (2.0-3.9) LR- 0.11 (0.07-0.16) for heart failure [7].

Chest X-Ray

- Pulmonary venous congestion suggests heart failure LR+ 12.0 (6.8-21.0); LR- 0.48 (0.28-0.83) [7].
- Interstitial edema suggests heart failure LR+ 12.0 (5.2-27.0); LR- 0.68 (0.54-0.85) [7].

POISONING/INTOXICATION

INTRODUCTION

Patients suffering from poisoning may present with altered level of consciousness, vomiting, trauma, seizure, burns. Patients who present because of suspected poisoning may suffer from conditions other than poisoning (e.g. trauma to the head and neck) with or without concurrent poisoning.

Overdoses may be intentional or unintentional. Toxicity from medications may result from changes in renal function (e.g. digoxin toxicity) or interactions between medications (e.g. serotonin syndrome caused by prescribing Tramadol to a patient taking a serotonin reuptake inhibitor).

Intoxicated patients may be unable to provide a history, and when the history is obtainable, it may be unreliable [1-5]. One study suggests that patients more often exagerate than trivialize their poisoning [6]. A meta-analysis reported that the agreement between history and laboratory diagnosis was moderate for paracetamol ingestion--K statistic of 0.69 (0.65-0.73)--but poor for street drugs, e.g. K statistic for ecstasy 0.35 (0.14-0.56) [7]. Relatives, friends, prehospital health personnel and medical records may provide valuable corroborative information.

EPIDEMIOLOGY

A	• In one series of intoxications in patients ≥ 14 years old, **mean age of intoxication was 34 years**, standard deviation 13 years, range 14-81 [8]. • Trends in Sweden [9].
G	• Most intoxication patients are **women (63%)** [8].

BACKGROUND

M	☐ **What medications does the patient normally take?** • Patients are more likely to overdose on **medications and substances they have access to**, i.e their own medications, over-the-counter medications, medications taken by their relatives. ☐ **Any recent medication changes?** • **Interactions** between various medications can lead to toxicity.
A	☐ **Is the patient allergic to medications or to contrast?**
P	☐ **What are the patient's past medical conditions?** ☐ **Has the patient overdosed or poisoned him/herself or otherwise attempted to harm him/herself previously?** • **Prior psychiatric conditions, overdoses and self-harm events** impact on the assessment of risk for further self-harm.
L	☐ **Life circumstances: occupation? social support? children < 18 years? activities of daily living?** • The patient's **life circumstances** impacts on the assessment of risk for further self-harm. • **Substance abuse among parents or guardians** raises concerns about children's physical and pyschological well-being and, in Sweden, should lead to contact with social services according to Socialtjänstlagen 14 kap., 1§, (SFS 2001:453).
E	☐ **How much alcohol do you drink and how often?**

	• **Alcohol abuse** is a varible in the SAD PERSONS score assessing the risk for further self-harm.
S	☐ **Do you smoke? Have you smoked previously and if so, when did you stop?**

HISTORY

☐ **What substances did you take (nature, quantity, route)?**

• One series revealed the following [8]:

Single substance	29%
Benzodiazepines and benzodiazepine-like medications	44%
Analgesics	27.5%
Paracetamol	13.7%
Antidepressants	27%
Ethanol	50%
Drugs of abuse	26%

☐ **When did you take these substances?**

• **Time of intake** of substances impacts on decisions regarding activated charcoal, gastric lavage, admission and observation.

☐ **Why did you take these substances? Were you trying to kill or harm yourself?**

• **Intent** impacts on decisions regarding admission and monitoring. One study randomized 443 patients with symptoms of depression to questions regarding suicidal risk versus questions regarding diet and lifestyle; being asked questions about suicidal risk did not increase subjective report that life was not worth living 10-14 days later [10].

• In one series, 69% of poisonings were suicide attempts, 25% unintentional overdoses of drugs of abuse and 6% medication errors [8].

☐ **Current somatic condition: pain? nausea?**

• Patients may injure themselves, intentionally or unintentionally, in conjunction with intoxication.

☐ **Current psychological condition: do you still want to harm or kill yourself?**

• The patient's current psychological state impacts on decisions regarding admission and monitoring.

PHYSICAL EXAMINATION

☐ **ABCDE**

When the patient with suspected poisoning is potentially unstable, the management starts with the ABCDE (Chapter 03). The ABCDE is also a suitable "generic physical examination" in the setting of a hemodynamically stable patient with suspected poisoning, from which a reliable history is unobtainable. The ABCDE may reveal:

• a toxidrome (Chapter 07).

• signs of trauma, e.g. secondary to self-harm, falls, physical abuse.

• sequelae from prolonged immobility, e.g. rhabdomyolysis, nerve palsies, even compartment syndrome.

BEDSIDE TESTS

☐ **Acid-base**

• **Acid-base** values allow for the detection of acid-base toxidromes (see below).

☐ **Electrolytes and anion gap**

- The **anion gap** can be calculated using Na, Cl and HCO3 (Chapter 04).
- Intoxications may result in **hyperkalemia** through a variety of mechanisms.

☐ EKG

O	• **Bradycardia and/or AV block** suggest intoxication with substances such as beta-blockers, calcium channel blockers, cardiac glycosides (e.g. digoxin, foxglove).
Q	• **Wide QRS** (> 120 msec) can be caused by intoxication with a substance that blocks fast cardiac sodium channels. This blockage results in so-called membrane stabilization. In the presence of a TCA intoxication, a QRS > 100 msec is associated with an increased risk of ventricular arrhythmias and seizures. The differential diagnosis includes hyperkalemia (Chapter 05, Wide QRS syndromes).
T	• **Prolonged QTc** interval suggests intoxication with substances that block myocyte potassium channels. Prolonged QTc is associated with an increased risk of the polymorphic ventricular arrhythmia torsade de pointes. The differential diagnosis includes electrolyte abnormalities (hypokalemia, -magnesemia, -calcemia) and inherited / idiopathic long QTc-syndrome.

☐ Pregnancy Test

- The health of the fetus is in general contingent upon the health of the mother. The management of poisoning in the pregnant woman is as a rule the same as in the non-pregnant patient, with the exception of carbon monoxide intoxication where the threshold for hyperbaric therapy is lower in the pregnant patient. However, knowing that the patient is pregnant may impact on further management.
- One study showed that two drops of whole blood (SN 95.8%, SP 100%) could be used instead of urine (SN 95.3%, SP 100%) to test for pregnancy using a point-of-care rapid human chorionic gonadotropin (hCG) immunoassay (the criterion standard being a quantitative serum hCG≥5 mIU/mL) [11]. Another study using the same brand of point-of-care pregnancy assay reported 99.6% concordance between results obtained using blood and urine [12], yet such assay use is off-label [13].

MANAGEMENT

1. Are toxidromes present?

- The management of toxidromes is covered in Chapter 07.
- When several toxidromes are present (e.g. Sodium channel blockade + opioid toxidrome), toxidrome therapies can be administered simultaneously (e.g. sodium bicarbonate + naloxone).
- The first-line treatment for **agitation** is a benzodiazepines. The addition of antipsychotics (Olanzapine, Droperidol) decreases the time to adequate sedation [14]. Yet antipsychotics can decrease the seizure threshold and prolong the QTc time.

2. Contact the Poison Control Center?

- Consider contacting the poison control center.
- In addition, many valuable resources are available on the internet. In Sweden, see www.gic.se, lösenord "intox"

3. Tests

☐ Paracetamol +4 hour

- **Paracetamol** is an over-the-counter medication that can seriously damage the liver. The frequency of paracetamol intoxication in Sweden appears to be increasing [15]. Testing for paracetamol blood levels is relatively easy and cheap and an effective antidote is available. Routine measurement of paracetamol levels is thus justifiable [16-18]. On the other hand, routine measurement of **salicylate** levels is not recommended [16, 17, 19].
- If the time of ingestion is relatively certain, an acetaminophen level should be taken when 4 or more hours have elapsed since ingestion.

☐ Ethanol

- **Ethanol** was present in 50% of deliberate poisonings in one series [8].

☐ Additional investigations?

- There is no good evidence that the results of a urinary drug screen impact on the acute management [20].
- Additional investigations can be justified depending on the circumstances

Circumstances	Additional Investigations
Acetaminophen overdose	Liver function tests, INR
Prolonged immobilization, seizures	Total CK, myoglobin
Specific medication blood levels	Blood levels of certain sustances can be measured
Increased anion gap	Ethylene glycol, methanol, salicylate levels
Risk for liver injury	Liver function tests
Intoxication with toxic alcohols	Plasma osmolarity
'Body packing' or 'body stuffing'	Unenhanced CT [21]

4. Thiamine?

- Thiamine (500 mg intravenous over 30 minutes once or twice daily for 3 days) treatment should be administered liberally in patients with chronic ethanol abuse who are deemed at increased risk for Wernicke's encephalopathy.
- The recommended treatment for suspected WE is thiamine 500 mg IV 3 times daily for 2-3 days then 250 mg IV or IM for an additional 3-5 days [22-24].

5. Measures to decrease absorption?

- **Activated charcoal** 50 g (1 g/kg in children) given orally or via large bore nasogastric tube to unconscious patients after intubation [25] is indicated within 1 hour of ingestion of a potentially toxic overdose. Beyond an hour after ingestion, activated charcoal may be considered for medications of a type and in quantities that may be truly toxic beyond the requirement for supportive care (e.g. tricyclic antidepressants, beta-blockers, calcium antagonists). Activated charcoal is less effective at adsorbing metals (lithium, iron), alcohols (methanol, ethylene glycol), or petroleum distillates (white spirit) [25]. A repeated dose 2-4 hours later may be beneficial in cases of sustained-release compounds [26].
- **Gastric lavage** is indicated within 1 hour of ingestion of a highly toxic substance (e.g., calcium channel blocker and cyclic antidepressant). It is contraindicated in the presence of hydrocarbon ingestion with high aspiration potential, ingestion of a corrosive substance, and when the airway is not protected [27].
- **Whole bowel irrigation** is indicated in cases of large ingestions of iron, lead, lithium, potassium or large ingestions of sustained-release cardiotoxic substances (e.g. calcium channel blockers) [26]. It is contraindicated in the setting of bowel obstruction, perforation

and ileus [27]. The dosage is 2 L/hr of a polyethylene glycol solution given via a nasogastric tube until the rectal effluents are clear.

6. Antidotes / specific treatments?

For indications and dosages, see e.g. www.giftinfo.se, lösenord: intox.

Substance	Antidote
Acetaminophen	N-acetylcystein (NAC) (see below)
Anticholinergics	Physostigmine
Arsenic	British anti-Lewisite (BAL)
Benzodiazepines	Flumazenil (see Sedative-hypnotic toxidrome Chapter 07)
Beta-blockers	See AV nodal blocker toxidrome Chapter 07
Calcium channel blockers	See AV nodal blocker toxidrome Chapter 07
Cyanide	Hydroxycobalamin
Digitalis glycosides	Digoxin-specific antibody fragments (Fab) (see below)
Ethylene glycol	Fomepizole
Iron	Deferoxamine
Isoniazid (INH)	Pyridoxine (Vitamin B6)
Lead	British anti-Lewisite (BAL), dimercaptosuccinic acid (DMSA)
Lipid-soluble, cardiotoxic	Intravenous Fat Emulsion (see below)
Metformin	Hemodialysis, methylene blue [28]
Methanol	Folate, Ethanol, Fomepizole
Methemoglobin-forming agents	Methylene blue 1-2 mg/kg IV over 5 min [29]; contraindicated if the patient has G6PD deficiency [30]
Mercury	British anti-Lewisite (BAL)
Opioids	Naloxone
Organophosphates and carbamates	Atropine, Protopam
Salicylates	NaHCO3 infusion to a target pH of 7.50-7.55 "traps" ionized salicylate in the blood and prevents its entry into the brain [31]; hemodialysis
Serotonin syndrome	Cyproheptadine
Sulfonylureas	Octreotide
Tricyclic antidepressants	Sodium bicarbonate
Valproic acid	Carnitine

N-acetylcystein is the antidote for acetaminophen poisoning. An acetaminophen level above the Rumack-Mattew nomogram in the case of a single exposure and known exposure time during the window between 4 hrs and 24 hrs postingestion is an indication for treatment. In the case of staggered exposures, a conservative approach is to assume that a single exposure occurred at the earliest possible time stated by the patient [32]. Treatment is also indicated in the setting of hepatotoxicity combined with either unknown time of ingestion or ingestion > 24 hours prior to presentation [32]. The following are toxic ingestions:

- > 10 g or 200 mg/kg as a single ingestion
- > 10 g or 200 mg/kg over a 24-hr period
- > 6 g or 150 mg/kg per 24-hr period for at least 2 consecutive days

The goal is to initiate treatment within 8 hours of ingestion. If a level can be obtained within 8 hours of ingestion, the decision to treat can be postponed until the level is available.

Otherwise, treatment can be initially pending the level and terminated if the level is subtoxic. The standard regimen for IV acetylcysteine consists of:
- a loading dose of 150 mg/kg over 15-60 min
- a first maintenance dose of 50 mg/kg infused over 4 hrs
- a second maintenance dose of 100 mg/kg infused over 16 hrs

Digoxin-specific antibody fragments (Fab) are effective in managing the toxicity from digoxin, digitoxin, and cardiac glycosides from plants and animals, e.g. oleander, fox glove, lily of the valley, and toad venom [33]. Fab therapy is indicatet in the setting of acute toxicity:
- **consequential rhythm or conduction disturbances**, e.g. symptomatic bradycardia, progressive heart block unresponsive to atropine, ventricular tachycardia, ventricular fibrillation
- **serum potassium > 5 mmol/L** in the absence of another identifiable cause
- firm evidence of ingestion of **> 4 mg of digoxin by a child or > 10 mg by an adult**
- indications in the setting of chronic toxicity are less clear and consist mainly of life-threatening or potentially life-threatening **dysrhythmia** [33].

Intravenous fat emulsion (Intralipid® 20%) may be useful in the management of cardiovascular collapse caused by lipid-soluble drugs when advanced supportive care and traditional antidotal therapy have failed, although the evidens for intravenous fat emulsion is weak [34]. Lipophilic drugs toxic to the myocardium include:
- Tricyclic antidpressants e.g. Amitryptiline
- Some Calcium channel blockers, especially verapamil and diltiazem
- Some beta-blockers, e.g. Propranolol, Atenolol, Metoprolol
- Bupropion
- Lamotrigine
- Carbamazepine
- Quetiapine, Chlorpromazine

The dose is 100 ml (1.5 ml/kg) of a 20% solution administered over 1-2 minutes by IV push [33].

7. Enhanced elimination?
- Diuretics . . . .
- Alkalinization of the urine, e.g. in the setting of salicylate poisoning.
- Dialysis

8. Does the patient require admission to receive somatic treatment?
There are no well established guidelines to identify intoxicated patients who require admission for somatic therapy. One study suggested that patients who present to the ED after an intoxication do not require admission for somatic reasons after 6 hours of observation in the ED unless they have one or more of the following [8]:
- Respiratory rate < 12/min or > 24/min
- Heart rate < 60/min or > 109/min
- MAP < 70 mm Hg
- GCS < 10
- EKG abnormalities

- Intoxication with one of the following: antidiabetics, carbamazepine, colchicine, coumarine derivatives, corroding substances, disulfiram, diuretics, ferrous compounds, lamotrigine, lithium, metformin, mirtazapine, monoamine oxidase inhibitors, paracetamol, salicylates, slow release preparations, tricyclic antidepressants, valproic acid.

9. Does the patient require admission because of the risk for further self-harm/suicide?

A systematic review identified four risk factors for suicide following self-harm[35]:

- Previous episodes of self-harm HR 1.68 (1.38-2.05)
- Suicidal intent HR 2.7 (1.91-3.81)
- Physical health problems HR 1.99 (1.16-3.43)
- Male gender HR 2.05 (1.70-2.46)

There are several scoring systems that attempt to predict future self-harm. One systematic review evaluated the modified SAD PERSONS score [36], the British Manchester Self-Harm Rule [37] and the Södersjukhuset Self-Harm Rule SoS-4 [38], and found that none of these scales reached a sensitivity exceeding 80% and a specificity exceeding 50% [39]. Another systematic review evaluated the Beck Hopelessness Scale, Suicide Intent Scale and Scale for Suicide Ideation, and concluded that none of these risk scales had adequate predictive value [35]. The authors conclude that overreliance on risk scales and the identification of risk factors is potentially dangerous, and no substitute for a comprehensive psychosocial assessment of the needs and risks specific to the individual patient. Suicide assessment should ideally be carried out or repeated after the patient has metabolized any drugs or alcohol.

10. Reporting to social services/guardians?

If the patient is a **child** (< 18 years in Sweden):

- **Parents/guardians** should be contacted in Sweden according to the Socialtjänstlagen.
- **Socialnämnden** should be contacted in Sweden according to Lagen om vård av unga (LVU) if "den unge utsätter sin hälsa eller utveckling för en påtaglig risk att skadas genom . . . missbruk av beroendeframkallande medel"

if the patient is an **adult**, Socialnämnden should be contacted in the following circumstances:

- **Parent/guardian:** substance abuse among parents or guardians raises concerns about children's physical and pyschological well-being and, in Sweden, should lead to contact with social services according to Socialtjänstlagen 14 kap., 1§, (SFS 2001:453).
- **Destructive Substance Abuse:** in Sweden, an adult with destructive substance abuse can be treated according to Lag om vård av missbrukare i vissa fall (LVM) and should be reported to socialnämnden if he or she fulfills a general condition + > 1/3 specific conditions.
  - The general condition is as follows: "att en missbrukare till följd av ett fortgående missbruk av alkohol, narkotika eller flyktiga lösningsmedel är i behov av vård för att komma ifrån sitt missbruk och att vårdbehovet inte kan tillgodoses enligt socialtjänstlagen eller på annat sätt" (Eriksson 2015 Klinisk Handbok).
  - The three special conditions are that the patient, as a result of his/her drug abuse (Eriksson 2015 Klinisk Handbok): "1. utsätter sin fysiska eller psykiska hälsa för allvarlig fara. 2. löper uppenbar risk att förstöra sitt liv, eller 3. kan befaras komma att allvarligt skada sig själv eller någon närstående"

CHAPTER 09–DIAGNOSES

”Medicine is a science of uncertainty and an art of probability.” Sir William Osler
"The whole is greater than the sum of its parts." Aristotle

The typical acute appendicitis presents with abdominal pain that started diffusely in the periumbilical region, migrated to the right lower quadrant, fever, anorexia, and tenderness to palpation. Unfortunately, not all appendices have read the textbook and some sources report that one third of acute appendices present in an atypical manner (ref Gallagher?). Diagnoses present with a constellation of features, with some occurring more frequently than others. For example, a subarachnoid hemorrhage typically presents with a thunderclap headache, yet some patients may present with a coma while others present with a headache reaching maximal intensity over the course of one hour or more. One author used the bell curve as analogy to depict the distribution of presentations (Gallagher). Physicians have unconscious, mental representations of how diagnoses present; these representations are termed 'illness scripts' (CHECK + Find reference). In order to make judicious investigation and treatment decisions in the ED, physicians need to develop rich illness scripts to be able to weigh the relative probabilities of competing diagnoses.

This chapter focuses on a selection of diagnoses that are relevant within the realm of Emergency Medicine, with a special emphasis on 'don't miss' diagnoses, i.e. diagnoses for which treatment within minutes to days impacts on morbidity and mortality. The sections covering each diagnosis include:

- the possible presenting complaints of the patients suffering from these conditions; for example, patients with an acute coronary syndrome may present with chest pain, shoulder pain, shortness of breath, arrhythmias, weakness
- test characteristics (sensitity, specificy, likelihood ratios) of symptoms and findings on physical examination, and bedside tests (blood tests, EKG, ultrasound) associated with these diagnoses, in order to help physicians develop rich illness scripts for these diagnoses
- clinical decision rules and risk stratification scales for diagnosis and management, when available
- management steps; this management recommendations need to be revised when several potential diagnoses are deemed possible, and adapted to the individual patient's characteristics, e.g. allergies, other medical conditions, prognosis with and without treatment, patient wishes.

Some of these diagnoses (e.g. pulmonary embolism) may present in an extreme, life-threatening form (e.g. high-risk (massive) pulmonary embolism). In these settings, the ABCDE and bedside tests may allow for recognition of a so-called 'resuscitation syndrome'. Theses syndromes and their initial management are covered in Chapter 07.

CARDIOVASCULAR DIAGNOSES

ACUTE CORONARY SYNDROMES

DEFINITIONS & PATHOPHYSIOLOGY

Myocardial ischemia is a condition resulting from a mismatch between oxygen supply to the myocardium and oxygen demand.

Stable angina refers to reversible myocardial ischemia that occurs only when activity induces O2 demands beyond the supply restrictions imposed by a partially occluded coronary vessel [1].

Unstable angina (UA) refers to symptoms suggestive of acute myocardial ischemia (new onset angina, rest angina, crescendo angina) in the absence of ST-elevation on EKG and no biochemical evidence of myocardial infarction [2]. See [3].

Myocardial infarction refers to irreversible myocardial necrosis resulting from profound and sustained ischemia.

Acute myocardial infarction requires by definition the detection of a rise and/or fall of cardiac biomarker values (preferably cardiac troponin) with at least one value above the 99th percentile upper reference limit [4], although it should be pointed out that patients with a subacute myocardial infarction (10-18 hour old) may present with stable troponin levels (so-called "plateau phase") [5, 6].

Type 1 myocardial infarction results from coronary artery disease. The decreased blood flow in the coronary artery may result from [1]:
- disruption or erosion of atherosclerotic plaques
- platelet aggregation or thrombus formation at the site of an atheroclerotic lesion
- coronary arterial spasm
- coronary artery dissection (accounts for up to 30% of ACS in women < 50 years [7])
- aortic dissection

Type 2 myocardial infarction results from from an imbalance in myocardial oxygen supply and/or demand other than coronary artery disease [4]. Examples of conditions that may lead to type 2 myocardial infarctions [1]:
- increased myocardial demand secondary to tachyarrythmias, fever, thyrotoxicosis, high catecholamines associated with non-cardiac surgery
- systemic reduction in blood flow, i.e. hypotension
- reduced O2 delivery secondary to anemia or hypoxia

When the cause of the myocardial ischemia is extrinsic to the coronary arteries, the resulting myocardial ischemia may be global or focal depending on the presence of coronary atherosclerotic disease in the coronary arteries.

STEMI (ST-Elevation Myocardial Infarction) refers to a suspected acute, type 1 myocardial infarction associated with ST-elevations on the EKG. The ST-elevation suggests total coronary artery occlusion and on-going transmural ischemia, justifying acute reperfusion therapy (PCI or fibrinolysis).

NSTEMI (Non-ST-Eleveation Myocardial Infarction) refers to a suspected acute, type 1 myocardial infarction in the absence of ST-elevations on the EKG.

Acute coronary syndrome refers to a condition where focal myocardial ischemia results from an acute decrease in blood flow in a coronary artery. The acute coronary syndromes are:
- STEMI, presumed to be due to a type-1 myocardial infarction
- NSTEMI, presumed to be due to a type-1 myocardial infarction
- UA

PRESENTING SYMPTOMS
Patients with an acute coronary syndrome may present with **chest or upper abdominal pain or discomfort.** However, it should be emphasized that patients with an acute myocardial infarction, especially elderly patients and patients with diabetes, may lack chest pain and may present with shortness of breath or non-specific symptoms. The absence of chest pain on presentation among patients with myocardial infarction is associated with increased mortality [8]. Factors associated with the **absence of chest pain** are:
- female gender: 42% of women vs 30% of men with myocardial infarction lack chest pain [9] OR 1.11 [8]
- advanced age OR 1.37 for each 10-year interval [8].
- diabetes OR 1.30 (1.29-1.31) [8].
- history of heart failure OR 1.80 [8].
- NSTEMI (44%) vs STEMI (27%) OR 1.93 [8].

Presenting symptoms for ACS other than chest pain/discomfort include:
- Shortness of breath
- Fainting
- Unexplained weakness, easy fatiguability [1]
- Palpitations
- EKG changes

EPIDEMIOLOGY

A	• Increasing age increases the likelihood of ACS among patients presenting to the ED with non-traumatic chest pain. The impact of age on ACS likelihood depends on the patient population seeking care in the ED. • **Age < 40 years** prevalence 0-1.8% [10, 11], LR 0.02 [11] • **Age 40-65 years** prevalence 8.2%-10.3% [10, 11], LR 0.8 (0.6-1.0) [11] • **Age > 65 years** prevalence 12.4%-19.4% [10, 11], LR 1.6 (1.4-1.9) [11]
G	• The clinical manifestations of cardiovascular disease develop 7–10 years later in **women** than in men. The lower ACS prevalence among women at younger ages (< 60 years) is largely explained by a lower risk factor burden [12]. • Among patients with MI, 42% of women presented **without chest pain** vs 31% of men [9]. • Women of all ages with ACS present less often with chest pain and more often with **vaso-vegetative symptoms** relative to men [12] • See [13]

BACKGROUND

<table>
<tr><td>M</td><td>
• Acetylsalicylic acid use during the 7 days prior to hospitalization is an adverse prognostic factor among patients with UA/NSTEMI OR 1.86 (1.26-2.73) [14]
• Oral contraceptives: current use of oral contraceptives that included ethinyl estradiol at a dose of 30 to 40 μg among nonpregnant, 15-49 year old women with no history of cardiovascular disease increased the risk of myocardial infarction by a factor of 1.3-2.3 while the relative risk with ethinyl estradiol at a dose of 20 μg was 0.9 to 1.7 [15]
</td></tr>
<tr><td>P</td><td>
• Prior abnormal stress test among patients presenting to the ED with suspected ACS has SP 96% LR 3.1 (2.0-4.7) for ACS [16]
• Peripheral artery disease among patients presenting to the ED with suspected ACS has SP 97% LR 2.7 (1.5-4.8) for ACS [16] SP 98% LR+ 2.0 (0.8-5.1) [11]
• Prior myocardial infarction LR 1.6 (1.4-1.7) [16]
• Prior coronary artery disease LR 2.0 (1.4-2.6) [16]
• Diabetes LR 2.4 (1.8-3.2) [11]
• Previous stroke LR 2.1 (1.4-3.2) [11]
• The classic atherosclerotic risk factors (diabetes, smoking, hypercholesterolemia, hypertension and heredity) are of decreasing diagnostic significance as the patient's age increases [10]:
<table>
<tr><th>Age</th><th>0 risk factors</th><th>≥ 4 risk factors</th></tr>
<tr><td>< 40 years</td><td>LR 0.17</td><td>LR 7.4</td></tr>
<tr><td>40 – 65 years</td><td>LR 0.53</td><td>LR 2.13</td></tr>
<tr><td>> 65 years</td><td>LR 0.96 (NS)</td><td>LR 1.09 (NS)</td></tr>
</table>
• In another study, the absence of classic atherosclerotic risk factors was associated with LR 0.61 whereas the presence of ≥ 4 risk factors was associated with LR 1.18 [17]
</td></tr>
<tr><td>L</td><td>
• Pregnancy is a risk factor for coronary artery dissection--the hormonal and hemodynamic alterations may lead to morpho- logic changes in the collagen of coronary arteries and weaken the media layer [18]
</td></tr>
<tr><td>S</td><td>
• Smoking is a classic atherosclerotic risk factor (see above)
</td></tr>
</table>

HISTORY

<table>
<tr><td>O</td><td>
• Abrupt onset LR+ 1.1 (1.0-1.2), LR- 0.75 (0.61-0.91) [16]
</td></tr>
<tr><td>P</td><td>
• Pain localized to a coin-sized area LR 0.6 (0.3-1.0) [19]
• Pain below the nipple LR 0.8 (0.7-0.9) [19]
• Pain in the back LR+ 1.49 (0.62-3.56), LR- 0.93 (0.77-1.13) [20].
• Pain in the epigastrium LR+ 1.05 (0.35-3.20), LR- 0.98 (0.88-1.08) [20]
• Radiation to both arms LR+ 2.6 (1.8-3.7), LR- 0.93 (0.89-0.96) [16]
• Radiation to the left arm LR+ 1.3 (1.2-1.4), LR- 0.88 (0.81-0.96) [16]
• Radiation to the right arm LR+ 1.3 (0.78-2.1), LR- 0.99 (0.96-1.0) [16]
• Radiation to the neck or jaw LR+ 1.5 (1.3-1.8), LR- 0.91 (0.87-0.95) [16]
• Radiation to the back OR 0.86 (0.60–1.22) for AMI, coronary revascularization, or death within 30 days [21]
• Radiation to the abdomen OR 0.34 (0.08–1.42) for AMI, coronary revascularization, or death within 30 days [21]
</td></tr>
<tr><td>Q</td><td>
• "Pressure" LR 1.3 (1.2-1.5) [19]
• "Sharp" or "stabbing" LR 0.3 (0.2-0.5) [19]
• "Burning" LR+ 1.0-1.4, LR- 0.97-1.0 [16]
• "Discomfort", "heaviness", "tightness", "fullness", or "squeezing" are pain
</td></tr>
</table>

	descriptions consistent with ACS [1] • **"Oppressive" pain** LR+ 1.68 (1.40-2.02), LR- 0.66 (0.56-0.77) [20]
R	• **Pain worse with breathing** LR+ 0.35-0.61, LR- 1.1-1.2 [16] • **Positional pain** LR 0.3 (0.2-0.5) [19] • **Pain worse with exertion** LR+ 1.5-1.8, LR- 0.66-0.83 [16] • **Pain improved by nitroglycerin** LR+ 1.1 (0.93-1.3) LR- 0.90 (0.85-0.96) [16]
S	• **Severe pain** (VAS 9-10) non-significant, i.e. the presence or absence of severe pain does not impact on the likelihood of ACS [22]
T	• **Pain lasting only seconds** speaks against ACS [19] • **Pain similar to prior ischemia** LR+ 2.2 (2.0-2.6); LR- 0.67 (0.60-0.74) [16]
+	• **Nausea/vomiting** LR+ 0.92-1.1, LR- 0.98-1.0 [16] • **Dyspnea** LR+ 1.2 (1.1-1.3), LR- 0.89 (0.92-0.96) [16] • **Syncope** LR+ 0.55 (0.39-0.76), LR- 1.1 (1.1-1.1) [16]

PHYSICAL EXAMINATION

GA	• **Deceptively well-looking** [1] • **Diaphoresis** LR+ 1.3-1.4; LR- 0.91-0.93 [16] • **Altered mental status** as a result of poor perfusion to the brain [1] • **Palor**, **cyanosis** may be present [1] • **Respiratory distress** may be present[1]
VS	• **Blood pressure may be decreased** due to pump failure or decreased left ventricular preload [1]. The following have been reported: o SBP ≤ 80 mm Hg LR 3.1 [23] o SBP < 100 mm Hg LR+ 3.9 (0.98-15), LR- 0.98 (0.95-1.0) [16] o DBP < 60 mm Hg LR 2.5 (1.3-4.8) [24] • **Blood pressure may be normal or elevated** due to baseline hypertension, anxiety or sympathetic stimulation [1]. • **Tachycardia (**HR > 120/min) LR+ 1.3 (0.42-3.94), LR- 0.99 (0.96-1.0) [16]. • **Bradycardic rhythms** are more common with inferior wall myocardial ischemia [1]. In the setting of an anterior wall infarction, a bradycardic rhythm or heart block is an extremely poor prognostic sign [1].
CV	• **Third heart sound (S3)** may imply a failing myocardium SN 15-20% [1]; LR 3.2 [23]; LR 3.2 (1.6-6.5) [24]. • **New systolic murmur** may suggest papillary muscle dysfunction, a flail leaflet of the mitral valve with resultant mitral regurgitation, or a ventricular septal defect [1]. • **Jugular venous distension** suggests right-sided heart failure [1]; LR 2.4 (1.4-4.2) [24].
Lung	• **Rales** suggest left-sided heart failure [1]; LR+ 2.0 (1.0-4.0), LR- 0.95 (0.90-1.0) [16].
MSK	• **Chest wall tenderness** argues against ACS LR 0.17 (0.11-0.26) [20]. However, chest wall tenderness may occur, possibly because of pericardial inflammation [1]. • **Pain reproduced by palpation** argues against ACS LR+ 0.28 (0.14-0.54), LR- 1.2 (1.0-1.2) [16]. • **Pain reproduced with position change** LR 0.3 (0.2-0.5) [24].
Leg	• **Peripheral edema** suggest right-sided heart failure [1].

BEDSIDE TESTS

Electrocardiogram

- A single ECG has approximately SN 60% and SP 90% for AMI [25].
- **A normal EKG** among patiens with acute chest pain argues against AMI LR 0.2 (0.1-0.3) [24]. However, 1-5% of patients with a normal or non-diagnostic EKG have AMI and 4-23% have unstable angina [1]. When the EKG is normal, the presence or absence of chest pain when the EKG was taken does not impact on likelihood of ACS OR 0.77 (0.45-1.33) [26].
- The EKG should be repeated at 15-30 min intervals in patients with a high clinical suspicion of ACS and a non-diagnostic EKG [1].

Q	• **New Q waves** LR 22 (7.6-62) among patients with acute chest pain [24]. • **Conduction defect** LR 2.4 (0.4-15) among patiens with acute chest pain [24]. • Diagnosis of STEMI equivalent in the setting of a left bundle branch block: Chapter 07 STEMI. • "New right bundle-branch block with a Q wave preceding the R wave in lead V1 is a specific but insensitive marker of proximal occlusion of the left anterior descending artery in association with anteroseptal myocardial infarction" [27]
R	• **Tall R wave in relation to the S wave in V1 / V2** suggests posterior infarction [28]
S	• **New ST elevation** LR 22 (16-30) among patients with acute chest pain [24]. The location of the ST elevation correlates with the culprit lesion (Chapter 07 STEMI) • **Diffuse ST elevation** suggests pericarditis or generalized cardiac ischemia. • **ST-segment depression** SN 25% (16-34), SP 95% (92-99), LR+ 5.3 (2.1-8.6) LR- 0.79 (0.71-0.87) [16]. ST depression may be reciprocal in the setting of a STEMI, e.g. depression in aVL in the setting of an inferior STEMI. "New horizontal or down-sloping ST depression ≥ 0.05 mV in two contiguous leads and/or T inversion ≥ 0.1 mV in two contiguous leads with prominent R wave or R/S ratio > 1: EKG criteria for the diagnosis of acute myocardial ischemia" [4] • **ST depression in V1-V3** may occur in the setting of a posterior myocardial infarction; leads V7-V9 (infero-basal wall) may reveal ST elevation. • **Non-specific ST changes** LR 0.2 (0.1-0.6) among patients with acute chest pain [24]
T	• **Hyperacute T waves**, prominent symmetrical T waves in at least two contiguous leads, is an early sign of myocardial infarction [4]. • **T wave inversion** SN 24% (15-38), SP 87% (69-95), LR+ 1.8 (1.3-2.7), LR- 0.89 (0.86-0.93) [16]. • **Negative T waves in the precordial leads** can occur in ACS and PE; the presence of negative T waves in both V1 and III suggests PE SN 90%, SP 97% [29]; SN 88%, SP 99% [30] • **Negative** (Wellens type 1) (EKG 49 yo) or **biphasic** (Wellens type 2) (EKG 47 yo) T waves in the precordial leads may suggest proximal LAD stenosis [31]

Ultrasound

- Cardiac ultrasound may reveal hypokinetic or akinetic segmental wall motion abnormalities that indicate coronary occlusion (STEMI equivalent) and justify reperfusion therapy [32].

DIAGNOSIS

1. ST-Elevation Myocardial Infarction?

Symptoms suggestive of acute-onset myocardial ischemia, coupled with ST-elevation on EKG or STEMI-equivalent findings (Sgarbossa criteria in the setting of a left bundle branch block, de Winter EKG pattern, hypokinetic or akinetic segmental wall motion abnormalities on cardiac ultrasound) are sufficient to make a diagnosis of presumed STEMI and manage the patient accordingly (see Chapter 07).

2. Measure 0h-Troponin?

The test threshold for ACS has been calculated to be around 2% [33]. This means that it is not in the patient's interest to further investigate for ACS if the likelihood of ACS is < 2%. To estimating the likelihood of ACS, the physician needs to factor in:

- epidemiological factors such as age, prior medical conditions, risk factors
- the history, in particular whether the chest pain is suggestive of myocardial ischemia
- the EKG
- the likelihoods of competing diagnoses

Troponin T and Troponin I are proteins found exclusively in cardiac myocytes. Elevated troponin levels in the blood suggests myocardial injury. Measuring troponin for the sake of ruling-out ACS is unlikely to be of value for a patient whose likelihood of ACS is < 2%. For example, a patient whose chest pain originated after chest trauma is highly unlikely to have an acute coronary syndrome, and measuring troponin value is of questionable value. A patient with chest discomfort following the onset of rapid atrial fibrillation may have an elevated Troponin value due to a supply-demand imbalance in myocardial oxygenation, and not due to an ACS. Again, the value of measuring troponin in this situation is unclear. There are at present no validated clinical decision rules to determine whether the patient's ACS risk is below 2% based exclusively on history, physical examination and EKG-interpretation, presumably because such rules would need to be able to assess the likelihoods of competing diagnoses. The physician needs to rely on his or her gestalt.

If ACS is deemed to be a possible cause of the patient's symptoms, then measuring Troponin is of value, since ACS cannot be ruled-out based on the basis of history, physical examination and EKG-interpretation alone [16]. According to the European Society of Cardiology (ESC) guidelines, a high-sensitivity cardiac Troponin T (hs-cTnT) < 5 ng/L at presentation [3] or ≤ 14 ng/L when the blood test was taken ≥ 6 hours from symptom onset [34] are sufficient to rule-out AMI. Yet a normal hs-cTnT value does not rule out UA. From the emergency physician's perspective, a more relevant outcome measure is 30-day MACE (Major Adverse Cardiac Events), which includes AMI, UA, cardiac arrest, cardiogenic shock, ventricular arrhythmia requiring intervention, high-degree atrioventricular block requiring intervention, or death from a cardiac or unknown cause. A study reported that emergency physicians do not feel comfortable discharging a patient with an estimated 30-day MACE risk > 1% [35].

One study assessed the value of a single hs-cTNT with or without taking into consideration the history and EKG to rule-out 30-day MACE [36]. The study showed that the sensitivity of a hs-cTnT < 5 ng/L increased from 96.8% to 99.2%, and the NPV increased from 98.8% to 99.7%, when history and EKG interpretation were factored in to the analysis. The same study reported that the sensitivity of a hs-cTnT ≤ 14 ng/L increased from 74.4% to 92.0%, and the NPV increased from 96.2% to 98.7%, when history and EKG interpretation were factored in to the analysis. This result contrasts with the findings of another study reporting that clinican gestalt, combined with a normal EKG and normal initial troponin level, has a 100% NPV for

acute myocardial infarction, coronary revascularization, or death from cardiac or unknown cause within 30 days [37].

A hs-cTnT > 14 ng/L argues for myocardial injury, but not necessarily ACS. In fact, most ED patients with elevated high-sensitivity troponin values do not have ACS [38]. Myocardial injury may result from several causes[39]:

Pathophysiology	Examples
1-Primary myocardial ischemia	• Plaque rupture • Intraluminal coronary artery thrombus formation
2-Myocardial ischemia due to supply/demand imbalance	• Tachy-/brady-arrhythmias • Aortic dissection or severe aortic valve disease • Hypertrophic cardiomyopathy • Cardiogenic, hypovolaemic, or septic shock • Severe respiratory failure • Severe anaemia • Hypertension with or without left ventricular hypertrophy • Coronary spasm • Coronary embolism or vasculitis • Coronary endothelial dysfunction without significant CAD
3-Injury not related to myocardial ischemia	• Cardiac contusion, surgery, ablation, pacing, or defibrillator shocks • Rhabdomyolysis with cardiac involvement • Myocarditis • Cardiotoxic agents, e.g. anthracyclines, herceptin
4-Multifactorial or indeterminate myocardial injury	• Heart failure • Stress (Takotsubo) cardiomyopathy • Severe pulmonary embolism or pulmonary hypertension • Sepsis and critically ill patients • Renal failure • Severe acute neurological diseases, e.g. stroke, subarachnoid haemorrhage • Infiltrative diseases, e.g. amyloidosis, sarcoidosis • Strenuous exercise

An elevated hs-cTroponin thus needs to be interpreted within the context of the patient's past medical history, history of current illness and EKG findings. The higher the Troponin value, the more ACS is likely [40].

3. Measure 1h-Troponin?

Repeating a measurement of hs-Troponin after some time has elapsed allows for the detection of a rise (or fall) in levels, which indicates that the myocardial injury is acute as opposed to the result of chronic conditions such as renal failure. A repeat troponin is therefore of value in patients for whom ACS cannot be ruled-out or ruled-in with a single troponin value.

The ESC gives a class I recommendation to either a +3h Troponin or a +1h Troponin [3]. A +1h algorithm has the advantage of expediency. One multicenter prospective study derived from 436 patients and validated on 436 patients an algorithm based on initial hs-cTnT and +1

hour hs-cTnT dynamic in unselected patients with acute chest pain onset presenting the ED [40].

- The algorithm ruled-out myocardial infarction in 60% of patients with a baseline hs-TnT of < 12 ng/L AND a +1h increase (+1hΔ) < 3 ng/L with SN 100% and NPV 100%.
- The algorithm ruled-in myocardial infarction in 17% of patients with a baseline hs-TnT of ≥ 52 ng/L OR a +1hΔ ≥ 5 ng/L with SP 97% and PPV 84%.
- The remaining patients (23%) where categorized as indeterminate, of which 8% had a final diagnosis of acute myocardial infarction.

Three multicenter studies evaluated this algorithm[41-43] and reported that AMI could be ruled-out with a NPV of 99.1 - 99.9%.

None of these studies used 30-MACE as outcome measure, nor did they incorporate the physician's assessment of the likelihood of ACS based on history and EKG interpretation. One study evaluated the +1h algorithm with or without the inclusion of history and EKG interpretation among 1038 patients presenting to the ED with chest pain and used as outcome measure 30-day MACE[44]. This study found the following:

- 0h hs-TnT < 12 ng/L AND +1hΔ < 3 ng/L ruled-out 30-day MACE with a SN of 87.6% and NPV of 97.8%. The addition of non-ischemia EKG and patient history not high risk increased the SN to 97.5% and the NPV to 99.5%. Inclusion of history and EKG interpretation reduced the number of patients in the rule-out group from 65.7% to 60.2%, yet markedly improved SN for 30-day MACE.
- 0h hs-TNT ≥ 52 ng/L OR +1hΔ ≥ 5 ng/L ruled-in 30-day MACE with a SP of 96.4% and PPV of 67.3%. The addition of 0h or 1h hs-cTnT > 14 ng/L combined with either ischemic EKG or high risk patient history yielded SP 94.0% and PPV 62.3%. Inclusion of history and EKG interpretation thus resulted in a marginal drop in SP and PPV.
- Patients who fulfilled neither of the criteria above (26%) fell into an observational zone. Among these patients, the rate of 30-day MACE was 10%. Inclusion of history and EKG did not alter the proportion of patients in the observational group.

MANAGEMENT

1. STEMI?

See Chapter 07.

2. ACS Considered Ruled-Out?

For patients in who ACS is considered ruled-out (0h hs-cTnT < 12 ng/L AND +1hΔ < 3 ng/L AND non-ischemia EKG AND patient history not high risk), further management consists in considering alternative diagnoses, and if all potential "don't miss" diagnoses are deemed unlikely, discharging the patient.

3. ACS Considered of Indeterminate Risk?

For patients for whom ACS can neither be ruled-in nor ruled-out, options include further serial troponin measurement or stress testing / myocardial imaging. One study showed that selected patients with indeterminate probability for ACS could be initially discharged and undergo outpatient testing for myocardial ischemia within 72 hours [45].

The following steps apply to patients for whom ACS is considered ruled-in.

4. Oxygen?

- **Indications**: SpO2 < 90% or respiratory distress [3].

5. Nitrates?

- **Indication**: ischemic symptoms (otherwise not routinely indicated) [3].
- **Contraindication**: recent intake of phosphodiesterase type 5 inhibitor (i.e. within 24 h for sildenafil or vardenafil and 48 h for tadalafil) due to the risk of severe hypotension [3]. Caution if SBP < 90 mm Hg) [34].
- **Administration**: sublingual or intravenous. Intravenous nitrates are more effective than sublingual nitrates and prefered in patients with recurrent angina, uncontrolled hypertension or signs of heart failure. The dose is titrated upwards until symptom relieve is achieved, or until normal blood pressure is normalized in patients with hypertension [3].

6. Beta-blocker?

- **Indication**: ongoing ischemic symptoms. Beta-blockers reduce myocardial demand through decreased heart rate, contractility and blood pressure[3]. Intravenous beta-blocker treatment at the time of admission should be considered for patients in a stable haemodynamic condition (Killip class < III) with hypertension and/or tachycardia [34].
- **Contraindications**: patients with age > 70 years, heart rate > 110 beats/min and blood pressure < 110 mm Hg if the ventricular function is unknown (beta-blocker use has been associated with an increased risk of shock or death) [3]. Also contraindicated in patients with symptoms related to coronary spasm or cocaine use [3].

7. Morphine?

- **Indication**: when ischemic symptoms are not relieved by nitrates and beta-blockers [3]. Morphine may reduce pain-induced sympathetic activation.
- **Caution** is required in the presence of hypotension [46]. Morphine may slow the intestinal absorption of oral platelet inhibitors [3].
- **Administration**: Morphine 3-5 mg IV or SC [34].

8. Metoclopramide?

- **Indication**: all patients with nausea [46].
- **Adminstration**: 5-10 mg IV.

9. Acetylsalicylic acid?

- **Indication**: all patients without contraindications. Irreversibly suppresses thromboxane A2 throughout the platelet life-span.
- **Contraindications**: hypersensitivity to acetylsalicylic acid, active gastrointestinal bleed, clotting disorder, severe liver disease [46].
- **Administration**: 150-300 mg of plain (non-enteric-coated) acetylsalicylic acid PO or 150 mg IV, followed by 75-100 mg daily.

10. PGY$_{12}$ inhibitor?

- **Indications**: a P2Y$_{12}$ inhibitor (preferably Ticagrelor) is recommended as soon as NSTE-ACS is diagnosed in patients planned for conservative management [3]. For patients with planned invasive management with angiography, no recommendation can be given as to whether the PGY12 inhibitor should be given before or after angiography [3].
- **Ticagrelor** is contraindicated in the setting of prior hemorrhagic stroke and moderate-to-severe liver disease [47]. The loading dose is 180 mg PO followed by 90 mg twice per day [3].

- **Prasugrel** is contraindicated in the setting of prior stroke/transient ischemic attack, age ≥ 75 years, weight < 60 kg, and moderate-to-severe liver disease [47]. The loading dose is 60 mg PO followed by 10 mg PO daily [3].
- **Clopidogrel** is indicated if ticagrelor and prasugrel are not an option [34] and contraindicated in the setting of excessive bleeding risk [3]. The loading dose is 300-600 mg PO followed by 75 mg daily [3].

11. Anticoagulant?

- **Fondaparinux** has the best efficacy-safety profile. Fondaparinux is not recommended when the eGFR is < 20 mL/min/1.73m^2. The recommended dose is 2.5 mg SC daily [3].
- **Enoxaparin** is recommended when Fondaparinux is not available. Enoxaparin is not recommended when the eGFR is < 15 mL/min/1.73m^2. The dose is 1 mg/kg SC twice daily or one daily when the eGFR is 15-30 mL/min/1.73m^2 [3].
- **UFH** is recommended when Fondaparinux is not available. The dose of UFH does not need to adjusted for renal function. 60–70 IU/kg i.v. (max 5000 IU) and infusion (12–15 IU/kg/h) (max 1000 IU/h), target aPTT 1.5–2.5x control[3].

12. Statin?

- **Indication**: as early as possible after admission in all NSTE-ACS patients without contraindications [3].

13. Proton Pump Inhibitor?

- **Indication**: higher risk of gastrointestinal bleeds, e.g. a history of gastrointestinal haemorrhage or peptic ulcer, chronic NSAID/corticosteroid use or ≥ 2 of following: age ≥ 65 years, dyspepsi, gastroesophageal reflux disease, helicobacter pylori infection, chronic alcohol use [3].

14. Coronary Angiography and Revascularization

- **Angiography within 2 hours** ("Immediate Invasive Strategy") is recommended for patients with ≥ 1 very-high-risk criterion [3]:
  - Haemodynamic instability or cardiogenic shock
  - Recurrent or ongoing chest pain refractory to medical treatment
  - Life-threatening arrhythmias or cardiac arrest
  - Mechanical complications of MI
  - Acute heart failure
  - Recurrent dynamic ST-T wave changes, particularly with intermittent ST-elevation
- **Angiography within 24 hours** ("Early Invasive Strategy") is recommended for patients with ≥ 1 high-risk criterion:
  - Rise or fall in cardiac troponin compatible with MI
  - Dynamic ST- or T-wave changes (symptomatic or silent)
  - GRACE score >140
- **Angiography within 72 hours** ("Invasive Strategy") is recommended for patients with intermittent symptoms, known ischemia on non-invasive testing, or ≥ 1 intermediate-risk criterion:
  - Diabetes mellitus
  - Renal insufficiency (eGFR < 60 mL/min/1.73m^2)
  - LVEF <40% or congestive heart failure
  - Early post-infarction angina
  - Prior PCI

- Prior CABG
- GRACE risk score >109 and <140

15. Continuous EKG monitoring?

- Which patients with suspected ACS require admission to a ward with EKG monitoring? [48] [49]

AORTIC DISSECTION

DEFINITIONS & PATHOPHYSIOLOGY

Aortic dissection (AD) occurs when the aortic intima tears and a column of blood gains access to the media. Arterial dissections may be brought on by trauma, stretching or other mechanical stresses to the artery. Acquired or inherited abnormalities in the connective tissue elements in the media and elastica of the arteries are risk factors for AD [1].

In 65% of cases, the tear occurs within 3 cm of the coronary ostia; in 10% of cases, the tear occurs within the arch and in 10% in the descending thoracic aorta [2]. The hematoma that forms in the media may progress distally and/or proximally. Blood in the media may dissect back through the intima or dissect through the adventitia. The dissection is considered acute if present for < 2 weeks and chronic if present for > 2 weeks [3].

Two other conditions--intramural aortic hematoma and penetrating aortic ulcer--share similar features with aortic dissection and together these conditions are referred to as **acute aortic syndromes** [2].

PRESENTING SYMPTOMS

AD may present with any of the following problems, alone or in combination:

- **Pain** occurs in 90% (85-94) of patients with AD [4]. Most cases of painless AD are chronic [3]. The pain most often includes the chest, since tear in the intima occurs most often at the level of the aortic valve where shear stress is greatest. However, the pain can involve all parts of the body.
- **Syncope** occurs in 9% (8-12) of patients with thoracic AD [4].
- **Prolonged unconsciousness** and even **cardiac arrest** may occur due to pericardial tamponade.
- **Stroke syndromes** may occur due to occlusion of or embolisation to the cerebral arteries. A left middle cerebral artery stroke may cause aphasia, preventing the patient from reporting chest pain and potentially leading to thrombolysis with disastrous consequences [5].
- **Paraplegia or quadriplegia** may occur due to occlusion of the vessels feeding the anterior spinal artery.
- **ST-elevation** may occur when the dissection compromises the circulation in the coronary arteries, leading to thrombolytic therapy with catastrophic consequences.

EPIDEMIOLOGY

A	• **Average age**: 60 years old (men), 67 years old (women) [6]. • **Bimodal age distribution**: younger patients with predisposing conditions (e.g. Marfan's syndrome) and patients > 50 years with chronic hypertension [7].
G	• **M:F 2:1** [8].
P	• One study reported 1 case of AD per 1,000 atraumatic chest pain ED visits [9].

BACKGROUND

M	• **Crack cocaine** and **stimulant** use are risk factors for AD [3].

P	• **Hypertension** SN 64% (54-72); LR+ 1.6 (1.2-2.0); LR- 0.5 (0.3-0.7) [4]. • **Marfan's syndrome** SN 5% [3, 4]. AD occurs in as many as 44% of patients with Marfan's syndrome [3]. • **Ehlers-Danlos syndrome**, **Turners syndrome**, **Noonans syndrome**, **osteogenesis imperfecta** are other collagen disorders that predispose to AD [2]. • **Temporal arteritis, Bechets, syphilis, aortitis** are inflammatory conditions that predispose to AD. • **Bicuspid aortic valve** SN 14% [3], preexisting **aortic aneurysm**, **coarctation** of the aorta are risk factors for AD. • **Trauma**, intra-aortic **catheterization, intra-aortic balloon pump** [3], **cardiac surgery** SN 18% [3], **aortic valve** replacement are risk factors for AD.
L	• **Third trimester pregnancy** is a risk factor for AD [10].

HISTORY

O	• **Sudden-onset** pain SN 84% (80-89); LR+ 1.6 (1.0-2.4); LR- 0.3 (0.2-0.5) [4].
P	• **Chest pain** SN 67% (56-77) [4]. • **Anterior chest pain** SN 57% (48-66) [4] from dissection of the ascending aorta. • **Posterior chest pain** SN 32% (24-40) [4] in the interscapular region from dissection of the posterior aorta. • **Neck and jaw pain** from dissection of the arch of the aorta [3]. • **Back pain** SN 32% (19-47) [4] from dissection of the aorta below the diaphragm. • **Abdominal pain** SN 23% (16-31) [4] from dissection of the aorta below the diaphragm, which may lead to mesenteric ischemia [3]. • **Limb pain and pulse deficits** may e.g. result from compromised arterial circulation to the extremities. • **Bilateral testicular pain** in isolation has even been reported [11]. • **Migrating pain** SN 31% (12-55) [4] corresponds to the spreading of the dissecting hematoma.
Q	• **Sharp pain** SN 64% [7]. • **Ripping or tearing pain** SN 39% (14-69) [4].
R	• **Non-pleuritic pain** is typical. However, if the dissecting hematoma ruptures through the adventitia into the pleural cavity, the pain may acquire a **pleuritic** component.
S	• **Severe pain, worst ever** SN 90% (88-92) [4].
T	• **Cessation of symptoms** may result from rupture of the dissection into the true aortic lumen [7].
+	• **Syncope** SN 9% (8-12) [4] may occur due to pericardial tamponade, interruption of blood flow to the brain, hypovolemia, excessive vagal tone, or cardiac arrhythmias [3]. • **Diaphoresis**, **nausea**, **vomiting**, **lightheadedness**, and **severe apprehension** are visceral pain symptoms that often accompany AD [3]. • **Focal weakness** or **change in mental status** may occur SN 17% [3].

PHYSICAL EXAMINATION

VS	• **Hypertension** SN 49% (41-57) [4]. Severe hypertension may occur if the dissection involves the renal artery with subsequent renin release [3]. • **SBP < 100 mm Hg** SN 25% [12]. A low blood pressure may result from pericardial tamponade or hypovolemia due to rupture through the adventitia [3].

	• **Pseudohypotension** may result from dissection involving the subclavian arteries, resulting in a low blood pressure in the arms but normal or high central blood pressure [3]. • **Pulse deficit** (unilateral absence of a pulse) **or blood pressure differential between the arms > 20 mm Hg** SN 31% (24-39); LR+ 5.7 (1.4-23); LR- 0.7 (0.6-0.9) [4].
CV	• **Muffled heart sounds** and **jugular venous distension** may result from pericardial tamponade [3]. • **Diastolic murmur** SN 28% (21-36); LR+ 1.4 (1.0-2.0); LR- 0.9 (0.8-1.0) [4] suggests aortic insufficiency.
NS	• **Focal neurological deficit** SN 17% (12-23); LR+ 6.6-33 (1.6-549); LR- 0.71-0.87 (0.6-0.9) [4]. • **Paraparesis** and **loss of pain/temperature perception** below the affected level may result from occlusion of the anterior spinal artery [3]. • **Dysphagia, hoarseness** may result from aneurysmal dilation of the aorta and compression of the esophagus and recurrent laryngeal nerve [7]. • **Horner's syndrome** (unilateral ptosis and miosis) may occur due to aneurysmal dilation of the carotid artery or a vertebral artery dissection leading to brainstem infarction.

BEDSIDE TESTS

Electrocardiogram

- **Normal** SN 30% [13].
- **New myocardial infarction** SN 7% (4-14) [4].

O	•
P	•
Q	•
R	• **Left ventricular hypertrophy** SN 26% reflecting low-standing hypertension [3].
S T	• **ST elevation** SN 5% [13] may result from the spreading of the dissection into the ostium of coronary artery. The right coronary artery is most frequently involved, resulting in an infero-posterior infarction [3]. • **Nonspecific ST-T changes** SN 40% [13]. • **Signs of ischemia** SN 15% [13].
+	•

Ultrasound

- **Transthoracic** ultrasound is insensitive to rule-out AD but may be of value to rule-in AD.
- **Pericardial fluid** may be present if the dissection has led to hemopericardium (US 67 yo aorta).
- **Dilated aortic root** (> 4 cm) on the parasternal long axis view suggests AD [14].
- **Intimal flap in the ascending aorta** may be visualizable using the right parasternal or high left parasternal views. An intimal dissection flap in the ascending aorta was detected in 92% of patients with a type A aortic dissection according to a retrospective study [15].
- **Intimal flap in the aortic arch and proximal descending aorta** may be seen using the suprasternal view (US 66 yo aortic dissection).
- **Intimal flap in the descending aorta** (behind the left atrium) may be seen using the parasternal and modified apical two-chamber view.

- **Intimal flap in the abdominal aorta** may be seen during the subcostal view [2] (US 71 yo aorta).

DIAGNOSIS

1. Is aortic dissection possible?

Whether aortic dissection is deemed possible or not will depend on the characteristics of the case and whether or not another diagnosis can be ruled-in. If aortic dissection is deemed possible, the next step is to assess its likelihood.

Note that CXR in patients with aortic dissection may show the following findings:
- **Abnormal** chest radiograph SN 90% (87-92) [4]
- **Abnormal aortic contour** SN 71% (56-84) [4]
- **Wide mediastinum** SN 64% (44-80) [4], SN 48.6% among patients with an Aortic Dissection Detection risk score of 0 [16]
- **Enlarged aorta or wide mediastinum** LR+ 2.0 (1.4-3.1); LR- 0.3 (0.2-0.4) [4]
- **Pleural effusion** SN 16% (12-21) [4]
- **Calcium sign** SN 9% (6-13) [4] refers to an increased distance (> 5 mm) between the outermost portion of the aorta and intimal calcification.

2. What is the likelihood of aortic dissection?

The Aortic Dissection Detection (ADD) risk score [16] assigns a pretest probability score of 0-3 depending on the number of categories in which **any single high risk factor** is present:

CATEGORY 1: HIGH RISK CONDITIONS	CATEGORY 2: HIGH RISK PAIN FEATURES	CATEGORY 3: HIGH RISK EXAM FEATURES

• Marfan syndrome
• Family history of aortic disease
• Known aortic valve disease
• Recent aortic manipulation
• Known thoracic aortic aneurysm
	Chest, back or abdominal pain described as:
	• Abrupt in onset
	• Severe in intensity
	• Ripping or tearing
		• Evidence of perfusion deficit
		  ○ Pulse deficit
		  ○ Systolic BP differential
		  ○ Focal neurologic deficit (in conjunction with pain)
		• Murmur of aortic insufficiency (new or not known to be old and in conjunction with pain)
		• Hypotension or shock state

The ADD was evaluated retrospectively using a population of 2,538 patients with acute aortic dissection [16].
- 108 patients (4.3%) were identified as low risk (ADD score 0)
- 927 patients (36.5%) were intermediate risk (ADD score 1)
- 1,503 patients (59.2%) were high risk (ADD score 2 or 3).

3. d-dimer?
- A systematic review and meta-analysis of four studies that used a d-dimer cutoff of 0.50 µg/ml found that a positive d-dimer had SN 98.0% (96.3 - 99.1) for AD and that a negative d-dimer was associated with LR 0.05 (0.03 - 0.09) for AD, suggesting that a negative d-dimer is useful to rule-out acute AD in low-risk patients [17]. A systematic review and meta-analysis of 22 studies reported that a d-dimer cutoff of 0.50 µg/ml was associated with

SN 95.2% (90.1 - 97.8) SP 60.4% (48.5-71.2) LR+ 2.4 (1.8-3.3) LR- 0.079 (0.036-0.172) for AD [18].
- Several studies suggest that a negative d-dimer in the setting of an ADD risk score ≤ 1 is sufficient to rule-out AD. A large cohort study reported that, among patients with ADD score ≤ 1, d-dimer with a cutoff of 0.50 µg/ml had SN 98.7% (95.3-99.8) for acute AD[19]. One retrospective study of 376 patients presenting to the ED with chest pain reported that, among patients with a ADD score ≤ 1, a d-dimer with a cutoff of < 0.50 µg/ml had SN 93.5%; SP 63.2%; NPV 98.9% for the detection of acute aortic syndromes[20].

4. Imaging?

For patients with an ADD score of 2-3, aortic imaging are recommended. The investigation of choice is a CT of the entire aorta. Alternative imaging modalities are transesophageal echocardiogram (TEE), recommended if the patient is unstable, and MR.

- **Helical contrast CT** SN 100% (96-100) SP 98% (87-99) according to a systematic review and meta-analysis [21]. It is the investigation of choice to rule in or rule out the diagnosis [16] (XR 88 yo)
- **Transesophageal ultrasound** can document AD involving the aortic valve [16]. It is highly sensitive SN 98% [21] in experienced hands and may be the diagnostic procedure of choice in unstable patients [3].

The Aortic Dissection Detection risk score recommends considering secondary imaging in patients with a negative initial study despite a high clinical suspicion for aortic dissection.

MANAGEMENT

1. Morphine

- Opioids control pain and decrease sympathetic tone [3].

2. Beta-blockers

- The goal of beta-blocker therapy is to **reduce BP and the rate of rise of the arterial pulse** to diminish shearing forces and mitigate the progression of the dissecting hematoma [3].
- Targets: **SBP 100 – 120 mm Hg, HR 60 beats/min** [3].
- **Labetalol 20 mg IV bolus**; repeat every 5 to 10 minutes and incrementally increase the bolus to 80 mg IV; max dose 300 mg [3].
- **Metoprolol** is an alternative, e.g. in patients with asthma or chronic obstructive pulmonary disorder [3]: **5 mg IV bolus**; repeat up to 15 mg [7].

3. Nitroprusside or Nitroglycerin

- Nitroprusside is the drug-of-choice for additional blood pressure if beta-blockers alone are insufficient [3]. **50 mg is mixed in 500 mL of D5W** and initially infused at a rate of **0.5 to 3 ug/kg/min** [3].
- Nitroglycerin IV infusion is an alternative to Nitroprusside for additional blood pressure if beta-blockers alone are insufficient [3].

4. Type A vs Type B

- Prompt surgery is indicated in acute aortic dissections involving the ascending aorta (Type A according to the Stanford classification). The mortality rate exceeds 1%/hr after AD onset [3].
- Endovascular repair may be an alternative to surgery [7].

- The management of Type B dissections (not involving the ascending aorta) may involve surgery, interventional endovascular techniques or be limited to blood pressure control [3].

RUPTURED ABDOMINAL AORTIC ANEURYSM

DEFINITIONS & PATHOPHYSIOLOGY

Abdominal aortic aneurysm (AAA) is defined as a permanent, localized, full-thickness dilatation of the abdominal aorta exceeding 3 cm [1]. The risk of AAA rupture increases with aortic diameter. The mean AAA diameter at rupture is 5 cm in women and 6 cm in men [2]. Mortality upon rupture is 85-90% and 30-50% among patients who reach the hospital [1].

PRESENTING SYMPTOMS

An AAA may be asymptomatic. Upon rupture or during the days preceding rupture, patients may present with the following problems, alone or in combination:

- **Abdominal pain** 61% [3]
- **Back or flank pain** 42% [3]
- **Syncope** 25% [3]
- **Nausea or vomiting** 22% [3]
- **Groin/hip/pelvic pain** 21% [4]
- **Chest pain** 16% [4]
- **Testicular pain** [5]
- **Para- or tetraparesis**
- **Melena** [4]
- **Hematemesis** [4]

EPIDEMIOLOGY

A	• The incidence of AAA increases with age as of age **60 years** [6]. • The mean age upon rupture is around **70 years** [3].
G	• **M:F 4:1** prevalence of AAA [1, 6].
H	• **Family history** of AAA is associated with a four times higher risk of AAA [1]. In one case-control study, a positive family history of AAA was associated with risk for AAA OR 4.77 (1.26-18.1) [7].

BACKGROUND

P	• **Coronary disease disease** is present in >25% of patients with AAA [6]. • **Hypertension** is a risk factor for AAA rupture [6]. • **Peripheral arterial disease** is present in 12% of patients with AAA [6]. • **Connective tissue disease** (e.g. Marfans, Ehlers-Danlos) is risk factor for AAA. • **Abdominal fat** is a risk factor for AAA [8]; > 94 cm abdominal girth for men and > 80 cm for women was associated with 30% increased risk for AAA HR 1.30 (1.05-1.60). Body-mass-index per se is not a risk factor. • **Elevated cholesterol level** is a risk factor for AAA [1]. • **Diabetes** is a risk factor for atherosclerosis, yet is protective against the development of AAA OR 0.65 (0.6-0.7) [9].
E	• **High levels of alcohol intake** (> 30 g/day) have been associated with increased risk of AAA OR 1.65 (1.03-2.64) [10], whereas moderate alcohol consumption may be protective [6].
S	• **Smoking** increases the risk of AAA 7.6-fold [11]. Smoking > 25 cigarettes per day is associated with HR 14.6 (9.6-22) compared with never-smoking in men [10].

HISTORY

O	• Patients may have mild pains in the abdomen or back during the **4-5 days prior to the rupture** [12].
P	• **Abdominal pain** 61% [3] • **Back or flank pain** 42% [3] • **Groin/hip/pelvic pain** 21% [4] • **Chest pain** 16% [4] • **Radiation to the testicles, rectum, groin** [12], **one or both flanks** [13]
T	• The pain is typically **constant** but may be **colicky** [13].
+	• **Syncope** occurs in 25% upon rupture [3]. • **Hematemesis** or **melena** can result from rupture of the AAA into the duodenum [12]. • **Neurological symptoms** occur in 5% of patients, e.g. paresthesias in the anterior thigh, weakness with hip and pain flexion [14].

PHYSICAL EXAMINATION

VS	• **Hypotension or shock** in 46% of cases [3].
Abdo	• **Pulsatile mass** is present in 45% of patients with RAAA [3]. Palpation has a SN 75% to detect an AAA > 5 cm and a LR+ of 15.6 (8.6-28.5) LR- 0.51 (0.38-0.67) to detect an AAA ≥ 4 cm [15]. • **Palpation of a tender mass in the left lower quadrant** may lead to the misdiagnosis of diverticulitis [12].
GU	• **Blue scrotum sign of Bryant**: acute scrotum ecchymosis caused by blood pooling within the scrotum after aortic rupture as a result of a patent processus vaginalis [16].
Leg	• **Blue-toe syndrome**: ischemic, painful extremity or cyanotic toes due to atheroembolism. Initial manifestation of AAA in 5% of patients [13].

BEDSIDE TESTS

Bedside Blood Tests

- **WBC > 10** SN 80% [17].
- **Renal failure** may result from atherosclerotic emboli to the renal arteries.

Ultrasound

- A systemic review showed that emergency department bedside ultrasound had SN 99% (96-100) and SP 98% (97-99) for the diagnosis of an AAA > 3 cm [18]. Another review and meta-analysis reported that ultrasound carried out by non-radiologists had SN 97.5% and SP 98.9% for AAA [19]. Ultrasound cannot reliably visualize rupture and extravasation [20].
- **Unilateral hydronephrosis** may result from compression of the ureter by the expanding abdominal aneurysm [21]

Urinalysis

- **Microscopic hematuria** may occur with RAAA [13].

DIAGNOSIS

1. Is ruptured / rupturing abdominal aortic aneurysm possible?

The classic triad (back or flank pain, pulsation abdominal mass and hypotension) occurs in only 30-50% of ruptured AAA (RAAA) [22] and the initial misdiagnosis rate is around 30-

40% [3]. The symptoms of a ruptured or leaking aneurysm may mimic other acute conditions [3, 4] such as:
- Renal colic
- Diverticulitis
- Pancreatitis
- Inferior wall coronary ischemia
- Mesenteric ischemia
- Biliary tract disease

For these reasons, routine bedside ultrasound imaging of the abdominal aorta in patients > 60 years presenting with back, abdominal or flank pain or hypotension/chock can be justified.

2. CT?

CT with contrast is highly accurate to identify signs of AAA rupture and signs of impending rupture [23]. A diagnostic CT is indicated in the following settings:
- When RAAA is considered possible and the abdominal aorta cannot be adequately visualized with ultrasound.
- To rule-in or rule-out other causes of the patient's presentation when an abdominal aortic aneurysm identified on ultrasound may be an incidental finding.
- When RAAA is considered likely, the patient is a candidate for Endovascular Aneurysm Repair (EVAR), and the CT can be obtained expeditiously.

MANAGEMENT

1. Active Treatment versus Comfort Measures?

Contact the vascular surgeon regarding emergency surgery. Untreated RAAA is uniformly fatal [23]. Risk factors for mortality in association with open aneurysm repair are [24]:
- Advanced age (e.g. age > 80 years)
- History of ischemic heart disease
- Cardiac arrest
- Loss of consciousness
- Hypotension (e.g. SBP < 80 mm Hg)
- Hemoglobin < 90 g/L at presentation
- Raised creatinine (e.g. > 150 umol/L at presentation)

Surgical options are open surgery versus Endovascular Aneurysm Repair (EVAR). One randomized control trial reported similar 30-day mortality when patients with a clinical diagnosis of RAAA were randomized to EVAR (35.4%) versus open surgery (37.4%) [25]. CT is necessary to determine whether the patient's anatomy is suited to EVAR [23].

2. Target Blood Pressure

- Permissive hypotension is recommended in the setting of hemorrhagic shock resulting from an RAAA [26, 27].

3. Blood Tests

- Type and cross match for ≥ 4 units PRBCs.
- Trombocytes and INR.

4. Tranexamic Acid

- The value of tranexamic acid in this patient population is the subject of an on-going Canadian trial.

PULMONARY DIAGNOSES

PULMONARY EMBOLISM

DEFINITIONS & PATHOPHYSIOLOGY

The most common cause of pulmonary embolism (PE) is a clot, formed in the deep veins of the leg or pelvis, that dislodges, travels through the venous system, traverses the right ventricle, and lodges in the precapillary pulmonary arteries [1]. Other causes of pulmonary embolism include endocarditis-related vegetation and tumor emboli [2].

PRESENTING SYMPTOMS

The symptoms of PE and the rate at which they develop are highly variable and depend on the size of the clot and the presence of underlying cardiopulmonary disease. Conceptually, PE may be thought of as 'small,' 'medium' or 'large':

- A small peripheral PE does not substantially affect the pulmonary circulation nor induce a pulmonary infarction. Chest pain may be absent (30% of patients with PE have no chest pain [3]) and dyspnea absent or present only on exertion.
- A medium-sized peripheral PE may impair blood flow to a lung segment resulting in pulmonary infarction. Sharp, pleuritic chest pain may develop as well as fever, hemoptysis and a consolidation on the chest radiograph. Dyspnea and hypoxia may result from ventilation-perfusion inequality in the lung (shunting).
- A large central PE affects the circulation to the degree that left-ventricular filling is impaired, resulting in hypotension and in cardiac arrest in cases of massive pulmonary embolism. The EKG and ultrasound may show evidence of right-ventricular strain. See [4]

A prospective, multicenter study showed the following reported symptoms and physical findings among 1,880 patients presenting to the ED with subsequent confirmation of PE [5]:

Symptoms reported		Physical findings in the ED	
• Dyspnea at rest	50.1%	• Extremity swelling suggestive of DVT	23.5%
• Pleuritic chest pain	39.4%	• Respiratory distress	16.4%
• Dyspnea with exertion	27%	• Rales	8.4%
• Cough without hemoptysis	22.9%	• Diaphoresis	7.1%
• Substernal chest pain	15.2%		
• Dizziness	12.2%		
• Diaphoresis	11.7%		
• Upper abdominal pain	10.7%		
• Fever	9.7%		
• Cough with hemoptysis	7.6%		
• Unilateral extremity pain	5.9%		
• Syncope	5.5%		
• Altered mental status	4.8%		
• Angina	3.9%		

EPIDEMIOLOGY

See [6]

A	• **> 50 years** adjusted OR 1.35 (1.10 – 1.67) [7]
G	• **Female gender** adjusted OR 0.57 (0.47 – 0.69) [7]; this finding may have been due to selection bias. Another study reported SN 58% [8]

H	• **Family history** of venous thromboembolism adjusted OR 1.51 (1.14 – 2.00) [7]

BACKGROUND

M	• **Estrogen** adjusted OR 2.31 (1.63 – 3.27) [7] • Risk of venous thromboembolism in **oral contraceptive** users compared to non-users ([9]): o Ethinylestradiol 30-40 μg + levonorgestrel RR 2.9 (2.2-3.8) o Ethinylestradiol 30-40 μg + desogestrel RR 6.6 (5.6-7.8) o Ethinylestradiol 30-40 μg + gestodene RR 6.2 (5.6-7.0) o Ethinylestradiol 30-40 μg + drospirenone RR 6.4 (5.4-7.5) o Progestogen only or hormone releasing intrauterine devices: no increased risk • **Chemotherapy** OR 2-9 [10]
P	• **Fracture of lower limb** OR > 10[10] • **Hospitalization for heart failure or atrial fibrillation/flutter within previous 3 months** OR > 10 [10] • **Hip or knee replacement** OR > 10 [10] • **Spinal cord injury** OR > 10 [10] • **Major trauma** OR > 10 [10] • **Prior venous thromboembolism** adjusted OR 2.90 (2.32 – 3.64) [7] • **Cancer**, active or metastatic adjusted OR 1.92 (1.43 – 2.57) [7]. Adenocarcinomas (e.g. ovarian, pancreatic, colon, prostate) increase the age-adjusted risk for venous thromboembolism by 5-fold to 20-fold [3]. Inactive cancer OR 0.82 (0.56 – 1.18) [7] • **Thrombophilia**, not cancer-related adjusted OR 1.99 (1.21 – 3.3) [7] • **Surgery within the past 4 weeks** adjusted OR 2.27 (1.70 – 3.02) [7] • **Immobilization**, not travel-related adjusted OR 1.72 (1.34 – 2.21) [7] • **Obesity**; risk increases with a BMI > 35 kg/m^2 [1] • **Paralytic stroke** OR 2-9 [10]
L	• **Pregnancy**: the risk of thromboembolic disease is 4-6 times higher during pregnancy compared with the non-pregnancy population [11, 12]. The risk increases with each trimester and peaks in the first week after delivery [1]. PE is the most common cause of nontraumatic death in pregnant women [3]. • **Puerperium**: the risk of venous thrombosis is highest during the puerperium [12]. 43-60% of of pregnancy-related episodes of PE appear to occur in the puerperium [11]. • **Postpartum**, the risk for VTE is highest during the first week (incidence of 9.2 episodes / 10,000 deliveries) and then drops steadily through week 12 [13]. Another study found that OR for thrombotic events (venous thromboembolism, stroke, myocardial infarction) of 10.8 (7.8-15.1) within 6 weeks after delivery and an OR of 2.2 (1.5-3.1) during the period of 7-12 weeks after delivery [14].
S	• **Current smokers** had a decreased risk of PE according to one study adjusted OR 0.59 (0.46 – 0.76) [7]; this finding may have been due to selection bias. Other sources have not found a significant association between smoking and PE in the ED population [3]. Smoking is not a risk factor for venous thromboembolism according to [10]

HISTORY

O	• **Sudden onset** of symptoms adjusted OR 0.88 (0.73-1.06) [7]. • Onset of chest pain **within seconds** SN 46% [15], **within minutes** SN 26% [15]. • Fewer than half of patients with PE describe symptom onset as sudden [1]

	• Some patients report having had chest pain and dyspnea in association with exercise that has gradually increased over months.
P	• The pain may anterior, posterior and lateral chest, upper back, upper flank • A large PE can cause epigastric pain, presumably from right ventricular pathology [1] • Purely retrosternal pain argues against PE adjusted OR 0.58 (0.46-0.72) [7]; isolated substernal pain should not be considered a reason to evaluate for PE [1]
R	• **Pleuritic** chest pain is due to distal emboli causing pulmonary infarction and pleural irritation [4]. SN 44% [15]; SN 47% [8]; adjusted OR 1.53 (1.26 – 1.86) [7] • **Non-pleuritic** chest pain, some with an angina character, may occur with central PE and result from RV ischemia [16]. SN 17% [8] • Some patients report chest pain and/or dyspnea aggravated by exertion, i.e. a history suggestive of unstable angina
+	• **Dyspnea** at rest or with exertion SN 73% [15]; SN 79% [8]; dyspnea on exertion only SN 16% [8]. Dyspnea may be acute and severe with central PE, mild and transient with peripheral PE [16] • **Rate of onset of dyspnea**: seconds (41%), minutes (26%), hours (14%), days (19%) [8] • **Initial symptoms** may help distinguish PE from pneumonia [17]: o **Dyspnea and/or pleuritic chest pain first** occurred in 80% of PE and 9% of pneumonia cases o **Fever, chills and/or cough first** occurred in 80% of pneumonia and 13% of PE cases • **Calf or thigh swelling** SN 39% [8] • **Calf or thigh pain** SN 42% [8] • **Cough** SN 34% [15]; SN 43% [8] • **Hemoptysis** secondary to hemorrhage resulting from small distal emboli [16]. Blood-red hemoptysis on the same day as chest pain onset may suggest PE while rust-tinged sputum following several days of productive cough may suggest pneumonia [3] • **New onset confusion, near or full syncope, convusion**-like activity in 5-8% of patients with PE in the ED [1]

See [18]

PHYSICAL EXAMINATION

VS	• **RR ≥ 20/min**: SN 57% [8]. **RR ≥ 25/min**: OR 1.13 (0.76-1.69) [7] • **O2% < 95%** OR 2.10 (1.70 – 2.60) [7]. SpO2 < 95% on room air SN 90% SP 64% for short-term complications from PE [3] • **HR ≥ 100/min**: SN 26% [8]. **HR ≥ 95/min**: OR 1.52 (1.24 -1.87) [7] • **SBP < 90 mm Hg** is highly specific for severe PE and associated with increased mortality [3] • **Low grade fever**: SN 14% (Stein 2000). **Temp > 38.0°** C: OR 1.13 (0.76 – 1.69) [7]. **Temp > 38.5°** C: SN 2% [8]. 10% have a temperature > 38° C, < 2% a temperature > 39.2° C [1]
Pulm	• **Crackles** SN 21% [8] • **Wheezing** suggests bronchospasm and argues against PE [3]
Leg	• **Unilateral swelling** SN 47% [8]; OR 2.60 (2.05 – 3.30) [7]
Msk	• **Reproduction of chest pain upon palpation** of the chest wall does not help distinguish between PE and musculoskeletal causes [19]

BEDSIDE TESTS

Electrocardiogram

O	• **Tachycardia** SN 26% [8], **bradycardia** in pre-arrest situations [20] • **Numerous rhythm abnormalities** may be present: atrial fibrillation, atrial flutter, ectopic atrial tachycardia, atrial premature contractions [20]
P	• **P pulmonale** (> 2.5 mm in lead II) may be present [20]
Q	• **Right bundle branch**, new complete or incomplete, may be present [20] • **S1Q3T3 pattern** refers to the presence of an S wave in lead I > 1.5 mm, a Q wave in lead III > 1.5 mm and a negative T wave in lead III. One series of 300 patients with precordial negative T waves found that the pattern was 100% SP but only 25% SN for PE [21].
R	• **Right axis deviation**, **left axis deviation**, and **indeterminate axis** occur with PE [20]. • **Tall R wave or R' wave in V1** as a sign of right ventricular strain (Mattu EKG of the week June 25th 2012)
S	• **S wave in lead I** > 1.5 mm (see S1Q3T3 pattern above) • **ST depression** may occur [20] • **Significant ST-elevation** as in STEMI occurs rarely [20]
T	• **Negative T waves in the precordial leads** (V1-V4) are often seen in patients with ACS and PE. In a series of 300 patients with negative precordial T waves, the presence of negative T waves **in both III and V1** suggests PE as opposed to ACS (SN 90%, SP 97%) [21, 22]. Lead III faces the inferior region of the right ventricle while leads V1 and V2 face its anterior region [21]. Pressure overload may impair coronary flow and the inverted T waves may reflect ischemia. (EKG 62 yo) • **Peak negative T wave in leads V1-2** is considered present if the magnitude of the negative T wave is the same in leads V1 and V2, and absent if the magnitude of the negative T wave was the same in leads V2 and V3. Peak Neg T in leads V1-2 had Sn 87% Sp 96% for APE in one study [23] • **Negative T in leads III and V1 and/or peak Negative T in leads V1-2** had SN 98% SP 92% in one study [23]

Ultrasound

- **Cardiac ultrasound** may reveal RV dilation or hypokinesis SN 86% SP 39% for short-term complications from PE. However, the reported NPV of echocardiography for the diagnosis of PE is 40-50%, and signs of RV overload or dysfunction may be due to non-PE causes (e.g. prior cardiac or respiratory disease) [16]. Echocardiography is not recommended as part of the diagnostic work-up in haemodynamically stable, normotensive patients with suspected PE [16].
- **McConnell's sign** refers to hypokinesis at the base and middle of the right ventricle, with relative sparing of the apex. It is found in patients with right ventricular strain [24].
- **Leg ultrasound** may reveal deep venous thrombosis (DVT); evidence of DVT is considered confirmatory of PE in the appropriate settng [16, 25]. Leg ultrasound may be used as the initial test in a pregnant patient, in a patient with clinical findings suggestive of concurrent DVT or as an additional test when the clinical picture strongly suggests PE despite a non-diagnostic CT or V/Q scan.

DIAGNOSIS

1. Massive pulmonary embolism?

For the signs and management of a massive pulmonary embolism, see Chapter 07.

2. Is pulmonary embolism possible?

The question "is pulmonary embolism possible?" can be rephrased as "is the likelihood of pulmonary embolism greater that the test threshold?" (Chapter 01). The test threshold for PE has been estimated as approximately 2% [1].

The **Pulmonary Embolism Rule-out Criteria** (PERC) score purports to rule-out PE without blood tests or radiographic investigations in patients with a pretest probability of PE of < 10-15%. The PERC rule includes the following 8 criteria [26]:

• Age < 50 yo
• Heart rate < 100 bpm
• Oxyhemoglobin saturation ≥ 95%
• No hemoptysis
• No estrogen use
• No prior DVT or PE
• No unilateral swelling
• No surgery or trauma requiring hospitalization within the past four weeks

Singh et al [27] carried out a systematic review and meta-analysis of the diagnostic value of PERC. They found 12 qualifying cohorts and report SN 97% (96-98), SP 23% (22-24), LR+ 1.24 (1.18-1.30) and LR- 0.17 (0.13-0.23). The LR- implies that the post-PERC probability of PE is < 2% as long as the pretest probability of PE is < 10% according to clinical gestalt. The two studies that showed an increased frequency of PE missed by the PERC score were both European studies in which the prevalence of pulmonary embolism in the cohort was 21-26%. A later systematic review and meta-analysis showed similar findings [28].

In general, the gestalt of experienced physicians has equivalent accurary to clinical decision rules [25, 29]. However, one study found that the inter-rater reliability for pre-test probability in PE, based on information from the history and physical examination, was poor (kappa=0.33) [30]. Whether physicians can reliably distinguish between "no risk" for PE, "very low risk for PE" (in which case PE can be ruled out with the PERC), and higher than "very low risk" (in which case the Wells score should be applied) is unclear. The physician would have to make this probability assessment using criteria other than those in the PERC rule, otherwise the PERC rule cannot be considered independent and used sequentially.

Some experts have suggested using the Wells score to determine whether the patient's risk of PE is sufficiently low that the PERC rule can be applied. However, given that 5 of the 8 PERC criteria are part of the Wells score, it is hard to argue that the rules are independent from each other and can be used sequentially. One study found that the combination of Wells score < 2 and PERC score of 0 had suboptimal sensitivity to rule out PE in patients presenting to the ED [31]. Another retrospective study revealed that the PERC rule missed 8% of confirmed PE's among patients with a Wells score < 4 [32].

The bottom line is that physicians need to use their gestalt and take into consideration the likelihood of competing diagnoses (e.g. heart failure). It may be helpful to think of PE causing two different syndromes:

- large, central PEs cause chest pain, dyspnea and hemodynamic effects (including EKG changes) of acute onset
- smaller, peripheral PEs cause pleuritic thoracic pain developing over the course of hours

Yet some PEs cause a syndrome remarkably like unstable angina.

Note that:

- **Leucocytosis** may be present in the setting of a PE-induced acute pulmonary infarct [33]
- A peripheral PE can result in a pulmonary infarction that presents as an **apex-central, pleural-based, wedge-shaped infiltrate** on the CXR; this finding, known as **Hampton's hump**, can be misinterpreted as pneumonia.

3. D-dimer?

If the likelihood of PE is considered to be higher than the test threshold, then some test is necessary to rule-out PE, unless diagnosing a PE does not change patient management (e.g. a patient who required anticoagulant therapy for another reason, e.g. atrial fibrillation).

A negative d-dimer can rule-out PE if the pretest probability for PE is low. A "stand-alone d-dimer" strategy whereby a d-dimer < 750 ug/L is used to rule out PE regardless of pretest probability has, according to one retrospective study, a suboptimal negative predictive value of 79 - 96% in various subgroups [34].

There are several scoring systems that can be used to determine whether the pretest probability of pulmonary embolism is sufficiently low that pulmonary embolism can be ruled out with a negative d-dimer. One study compared the **Wells Rule**, the **Simplified Wells Rule**, the **Revised Geneva Score** and the **Simplified Revised Geneva** score and found similar performance for exclusion of acute PE in combination with a normal d-dimer result [35].

The Simplified Wells (Canadian) Scoring System [36]

Risk factors	Points
• Clinical signs and symptoms of deep venous thrombosis*	3
• Alternative diagnosis less likely than pulmonary embolism	3
• Heart rate > 100/min	1.5
• Immobilization (> 3 days) or surgery in the previous 4 weeks	1.5
• Previous pulmonary embolism or deep vein thrombosis	1.5
• Hemoptysis	1
• Malignancy (receiving treatment, treated in the last 6 mo or palliative)	1

* minimum of leg swelling and pain with palpation of the deep veins

A prospective cohort multicenter study of consecutive patients (3306 in total) with clinically suspected acute pulmonary embolism evaluated the Wells score combined with the d-dimer test to rule out PE. Both outpatients and inpatients were included in the study. Roughly 1000 patients had a Wells score ≤ 4 and a normal d-dimer, and subsequent non-fatal venous thromboembolism occurred in 5 patients (false negative rate of 0.5%) [37]. Another study evaluated 598 adults with suspected pulmonary embolism presenting to their primary care physician. 272 patients had a Wells score ≤ 4 and a normal d-dimer, and of these, 3-4 cases of pulmonary embolism were subsequently diagnosed (false negative rate of 1.1 - 1.5%) [38].

D-dimers are breakdown products of cross-linked fibrin. The half-life of circulating d-dimer is < 8 hours [3], and the test may be falsely negative if symptoms have been present for > 5 days [1]. Quantitative tests (e.g. ELISA) have a SN of about 95% and a SP of about 55%. A negative d-dimer rules out PE if the pretest probability is less than 40% and the symptoms recent [3]. High d-dimer concentrations more strongly suggest PE but no cut-off concentration can be used to confirm the diagnosis [3]. LR- 0.1, LR+ 2 [1]. There is an algorithm that combines pretest probability with d-dimer results with two different cut-offs to determine whether CT is warranted [39].

One study validated the use of **age-adjusted d-dimer** cutoff levels of rule-out pulmonary embolism [40]. In this study, the d-dimer cutoff was 0.5 mg/L among patients < 50 years and 10 times the patient's age in ug/L among patients > 50 years. Among 673 patients > 75 years old with non-high pretest probability of PE, the use of age-adjusted d-dimer cutoff levels increased the number of patients in whom PE could be ruled out with d-dimer from 43 to 200 without any additional false-negative findings. Adapting the results of this study should take into consideration the performance characteristics of the local d-dimer assay. See also [41-43]. The American College of Physicians has endorsed the use of an age-adjusted d-dimer threshold (age x 10 ng/ml) in patients older than 50 years, based on a meta-analysis [44].

D-dimer levels increase with the progression of a normal **pregnancy** [38]. The European Society of Cardiology argued in 2014 that "A normal D-dimer value has the same exclusion value for PE in pregnant women as for other patients with suspected PE" [16]. However, the American Thoracic Society/Society of Thoracic Radiology recommend against d-dimer use in pregnancy [45] on the basis of a small retrospective study of 37 pregnant women with suspected PE who had both V/Q scans and d-dimer testing showed a d-dimer sensitivity of only 73% [46], as well as two case reports of negative d-dimers in the setting of acute PE in pregnancy.

Whether d-dimer can be used in pregnant women is controversial, for two reasons:

- the d-dimer level increases during a normal pregnancy, and therefore there is an increased likelihood that the d-dimer will be false positive as pregnancy progresses. For example, one study recommends not using the d-dimer in patients in the third trimester [47].
- the Wells score is not validated in pregnant women. This means that physicians need to use their gestalt to determine whether the likelihood of PE in the pregnant woman is sufficiently low that a negative d-dimer is. See [48].

If the Wells score is > 4, symptom duration is > 7 days or the d-dimer is positive, imaging is necessary to rule-out PE.

4. Leg ultrasound?

- Leg ultrasound may reveal deep venous thrombosis (DVT); evidence of DVT is considered confirmatory of PE in the appropriate settng [16, 25].
- Leg ultrasound may be used as the initial test in a **pregnant** patient[16], in a patient with clinical findings suggestive of concurrent DVT or as an additional test when the clinical picture strongly suggests PE despite a non-diagnostic CT or V/Q scan.

5. VQ Scan versus CT Angiography?

If PE cannot be rule-out with a negative d-dimer or ruled-in with a positive leg ultrasound, CT angiography or VQ scan are the usual modalities used to study the pulmonary vasculature.

The choice depends on availability, presence of cardiopulmonary disease, risk for contrast-induced nephropathy, age (younger patients have an increased risk for radiation-induced cancer), pregnancy and the likelihood of alternative pulmonary conditions that can be diagnosed by CT.

CT	• CTPA (Computed Tomography Pulmonary Angiogram) is preferable to a V/Q scan in patients with air-space disease (e.g. COPD) [3]. CTPA may suggest an alternative diagnosis while at the same time ruling-out PE [3]. • CTPA LR- 0.12, LR+ 12 (Kline 2012) (XR 79 yo). • CTPA in **pregnancy** increases the risk of childhood cancer by < 1 case in 1,000,000 [11]. • CTPA exposes the breast to a high dose of radiation.
V/Q	• V/Q scan is preferable to CTPA in patients with an increased risk of contrast-induced nephropathy. V/Q scan with SPECT is presumably a little more sensitive but a little less specific for peripheral emboli than CT [49]. • V/Q scan in **pregnancy** increases the risk of childhood cancer by 1 case in 280,000 [11]. A V/Q scan with only the perfusion part (Q) can be ordered initially to rule out PE in a pregnant woman (the aim being to reduced all unnecessary radiation) [11, 50]. SPECT V/Q scan with perfusion only is recommended over CTPA by some experts for the pregnant patient with suspected PE [50].

6. Consider Further Testing

If the likelihood of PE is still considered high despite a negative CTPA or V/Q scan or an ambiguous result (e.g. changes resulting from a previous PE), consider further testing with another modality (e.g. leg ultrasound, d-dimer, CTPA or V/Q scan).

MANAGEMENT

See [51]

1. Cardiac Arrest?

Recommended treatments for patients with PE-induced **cardiac arrest** are:

- rt-PA 50 mg intravenous bolus [52-54]
- Unfractionated heparin 5000 [54]
- Repeat rt-PA 50 mg intravenous bolus after 30 minutes [53, 54]
- CPR for up to 90 min [55]

2. Massive PE?

The management of patients with **massive** or **"high-risk PE"** is covered in Chapter 07.

3. Heparin Prior to Diagnosis?

- **Heparin** reduces the formation of new clots. In patients with high or intermediate clinical pretest probability for PE (and no major contraindications to anticoagulation), parenteral heparin should be initiated while awaiting the results of diagnostic tests [16]. One option is to administer a bolus of 80 U/kg of unfractionated heparin.

4. Risk Stratification

The Pulmonary Embolism Severity Index (PESI) was developed to identify patients with pulmonary embolism at low risk of short-term adverse events [56]:

Risk factors	Points		Points	30-day mortality
• Age	1/year		≤ 65 (Class I)	0-1.6%
• Male sex	10		66-85 (Class II)	1.7-3.5%
• History of cancer	30		86-105 (Class III)	3.2-7.1%
• History of heart failure	10		106-125 (Class IV)	4.0-11.4%
• History of chronic lung disease	10		> 125 (Class V)	10.0-24.5%
• Pulse ≥ 110 beats/min	20			
• SBP < 100 mm Hg	30			
• Respiratory rate ≥ 30/min	20			
• Temperature < 36°C	20			
• Altered mental status	60			
• Oxygen saturation < 90%	20			

Eleven observational studies including > 20,000 patients have shown that patients with ≤ 85 points have an overall short-term mortality of < 2% and a pulmonary embolism-specific short-term mortality of < 1% [57].

A simplified version of the PESI score has been derived [58]:

Risk factors	Points		Points	30-day mortality
• Age > 80 years	1		0	1% (0-2.1%)
• History of cancer	1		≥ 1	10.9% (8.5-13.2)
• Chronic cardiopulmonary disease	1			
• Pulse ≥ 110 beats/min	1			
• SBP < 100 mm Hg	1			
• Oxygen saturation < 90%	1			

Patients with 0 points are classified as being at low-risk of adverse outcomes. A validation cohort study involving 7106 patients with pulmonary embolism classified 36% as being low-risk, and mortality in this group was 1.1% (ref). A trial randomized 344 patients with pulmonary embolism at low-risk for adverse outcomes according to PESI to in-hospital or out-patient care [59]. Mortality was 0.6% in both groups.

Another study including 526 patients with pulmonary embolism identified 198 patients with a low-risk PESI score of 0, 214 patients with a high-sensitivity troponin (hsTnT) of < 14 pg/ml, and 127 patients with both. The primary end-point was death, symptomatic recurrent PE, major bleeding or cardiopulmonary resuscitation within 30 days. 1.9% of patients with hsTnT < 14 pg/ml, 1.0% of the patients with PESI score of 0 and none of the patients with both criteria reached the primary endpoint [60]. In summary, patients with a simplified PESI score of 0 can be treated as outpatients. Also see [61]

Another study derived and validated a multimarker model that predicts all-cause mortality, hemodynamic collapse and/or recurrent PE within 30 days for normotensive patients with acute PE [62]. The model combines:
- the simplified PESI score (sPESI)
- Troponin I (TnI) as a marker of cardiac injury

- Brain natriuretic peptide (BNP) as a marker of right ventricular dysfunction
- Bilateral lower limb venous compression ultrasound testing (CUS)

The combination of sPESI score of 0 and BNP < 100 pg/mL had Sn 97% (88-99) for adverse events within 30 days. The combination of sPESI ≥ 1, BNP > 100 pg/mL, TnI > 0.05 ng/mL and presence of DVT confered a 5 fold increased risk of adverse event during the following 30 days. www.PEprognosis.org allows for individualized prognostication.

Troponins (Tn; as markers of cardiac injury) and Brain Natriuretic Peptide (BNP) or Pro-BNP (as a marker of right ventricular dysfunction) should be measured in patients who are not low-risk according the PESI or sPESI scores in order to further risk stratify these patients. Troponin T > 0.04 ng/ml Sn 60% Sp 85% for short-term complications from PE [3]. BNP > 90 pg/ml Sn 85% Sp 75% for short-term complications from PE [3]. Pro-BNP > 900 pg/ml suggests massive or submassive PE [1].

In addition, RV function should be assessed with by CT or echocardiography. CT signs of RV dysfunction is defined as an increased end-diastolic RV/LV (left ventricular) diameter ratio (with a threshold of 0.9 or 1.0). Echocardiographic signs of RV dysfunction include:

- RV dilation and/or an increased end-diastolic RV–LV diameter ratio (threshold value of 0.9 or 1.0)
- hypokinesia of the free RV wall
- increased velocity of the tricuspid regurgitation jet

Classification of patients with acute PE based on early mortality risk Adapted from [16]

Risk	PESI / sPESI ≥ 1	Signs of RV dysfunction	Elevated Troponin or Brain Natriuretic Peptide
Intermediate-high	Class III-V / ≥ 1	Both positive	
Internmediate-low	Class III-V / ≥ 1	Either one or none positive	
Low	Class I-II / 0	Assessment optional; if done, both negative	

5. Trombolysis and Other Primary Reperfusion Therapy?

- Thrombolysis for massive, life-threatening pulmonary embolism is covered under Chapter 07-Massive Pulmonary Embolism. Contraindications and rtPA regimens are also provided in that section.
- A systematic review and meta-analysis showed that systemic thrombolytic therapy for acute PE, followed by anticoagulation, reduced total mortality compared with anticoagulation alone OR 0.59 (0.36-0.96) [63]. However, the decrease in overall mortality was not significant when high-risk PE patients (i.e. those with sustained arterial hypotension) were excluded. Thrombolysis was associated with an increased risk of major haemorrhage OR 2.91 (1.95–4.36) and fatal or intracranial bleeding OR 3.18 (1.25–8.11).
- Another study [64]
- Thrombolysis is evidence-based in patients with a SBP < 90 mm or an SBP > 40 mm Hg lower than baseline [65].
- **Kateterburen behandling**, **kirurgisk embolektomi** och **extrakorporeal membranoxygenering** kan övervägas vid kvarstående livhotande emboli eller om trombolys bedöms kontraindicerad [66]
- The PEITHO study [67] assessed the risks and benefits of thrombolysis versus placebo in normotensive patients with intermediate-risk pulmonary embolism. The primary outcome measure was death or hemodynamic decompensation within 7 days. Thrombolysis

decreased the risk of the primary outcome from 5.6% to 2.6%. However, there was no statistically significant difference in death at 30 days and thrombolysis increased the risk of stroke at 7 days from 0.2% to 2.4%.

- The ESC does not recommend routine thrombolysis in patient who are intermediate-high risk, but rather observation and consideration of thrombolysis (or surgical / catheter-delivered intervention) if clinical signs of haemodynamic decompensation appear[16].
- There is no evidence that intermediate-low risk patients benefit from primary reperfusion therapy [16].

6. Heparin and/or Oral Anticoagulants?

- **LMWH** (low molecular weight heparin), e.g. Enoxaparin 1 mg/kg SC every 12 hours or Tinzaparin 175 U/kg SC once daily or the pentasaccharide factor Xa inhibitor **Fondaparinux** are the heparins of choice for most patients [16].
- **UFH** 80 U/kg IV bolus followed by 18U/kg/hr IV in patients with normal aPTT [68] is recommended for patients:
  - in whom primary reperfusion is being considered, i.e. intermediate-high risk patients (see below)
  - with renal impairment (GFR < 30 ml/min)
  - with severe obesity [16].
  - with a high risk of bleeding given that UFH can be more easily reversed with protamine and has a shorter half-life than LMWH [68]
- **Warfarin**, when chosen as oral anticoagulant, should be added to heparin therapy as soon as possible. [16] The recommended starting doses are:
  - Warfarin 10 mg PO x 1 in patients < 60 years who are otherwise healthy outpatients.
  - Warfarin 5 mg PO x 1 in older patients and in those who are hospitalized.
- **NOACS** (new oral anticoagulants) are another option. Trials suggest that they are as effective as the heparin/warfarin regimen and possibly safer (less major bleeding) [16]. Regimens include:
  - Rivaroxaban 15 mg twice daily (with food) for 3 weeks, followed by 20 mg once daily (with food); not recommended in individuals with a creatinine clearance <30 mL/min or significant hepatic impairment
  - Apixaban 10 mg twice daily for 7 days, followed by 5 mg twice daily.
  - Dabigatran 150 mg twice daily, or 110 mg twice daily for patients >80 years of age or those under concomitant verapamil treatment, following acute phase parenteral anticoagulation.
- **Isolated subsegmental** PE management is controversial. The ESC suggests carrying out compression ultrasound in the setting of isolated subsegmental PE and, in the absence of DVT, taking clinical probability and bleeding risk into account when deciding on whether treatment is warranted [16]. If the following criteria are met, withholding anticoagulation for patients with isolated subsegmental PE is justifiable [68]:
  - no evidence of DVT
  - no signs of cardiopulmonary stress
  - no ongoing major risk for thrombosis (e.g. active malignancy)

7. Admission?

- Low-risk patients can be considered for early discharge [16].
- Intermediate-low and intermediate-high patients should be admitted [16]. No single imaging study or examination accurately predicts the likelihood of decompensation from PE [69]. Right ventricular failure is the thought to be the main factor causing death from

pulmonary embolism, hence the prognostic value of echocardiographic assessment of the right ventricle looking for dysfucntion and dilatation [2].

- Patients with positive troponin should be monitored, even in the absence of signs of RV dysfunction on echocardiography or CT [16].

CENTRAL NERVOUS SYSTEM DIAGNOSES

SUBARACHNOID HEMORRHAGE

DEFINITIONS & PATHOPHYSIOLOGY

Subarachnoid hemorrhage (SAH) refers to bleeding into the CSF-filled space between the pia mater and the arachnoid mater, two of the three meninges surrounding the brain. Non-traumatic SAH is caused by [1]:

- ruptured aneurysm (85%)
- idiopathic perimesencephalic subarachnoid hemorrhage (10%)
- rare conditions including intracranial arterial dissection, brain and spinal vascular malformations, tumours, angiitis (5%)

PRESENTING SYMPTOMS

Non-traumatic SAH may present as any of the following problems, alone or in combination:

- **Headache**; 70% of patients with SAH present primarily with headache [2]. At the most, 1% of headache patients in the ED have SAH [3]. "Thunderclap headache" is defined as a severe (≥ VAS 7) headache reaching maximal intensity within 60 seconds of onset [2]. Roughly 40% of patients with SAH present with a thunderclap headache and no other symptoms / problems [4]. Up to 8% of patients with SAH present **without** thunderclap headache [5].
- **Syncope**; transient loss of consciousness occurs in around 17% of cases [6].
- **Decreased level of consciousness** may be present, but coma is unusual [7].
- **Neurological deficit;** SAH accounts for 10% of strokes [7].
- **Seizures** during the first 24 hours occurs in < 10% of cases [7].
- **Cardiac arrest**, as a rule with PEA or asystole as the initial rhythm [8, 9].

EPIDEMIOLOGY

A	• **54 years** is the approximate mean age [6, 10].
G	• **No gender difference** was seen in a cohort study of patients presenting to the ED with headache [6].
H	• **SAH in a first- or second-degree relative** OR 4.0 [11].

BACKGROUND

M	• **Cocaine use** is a risk factor for SAH.
P	• **Hypertension** RR 2.5; OR 2.6 [12]. • **Prior SAH** is a risk factor for SAH. • **Adult-onset polycystic kidney disease** is a risk factor for SAH.
E	• **Moderate-heavy alcohol consumption** RR 2.1; OR 1.5 [12].
S	• **Smoking** RR 2.2; OR 3.1; HR 2.4 [12].

HISTORY

O	• The headache of patients with **aneurysmal SAH** reached maximal intensity [13]
	  o almost instantaneously in 50% of patients
	  o within 2-60 seconds in 24% of patients
	  o within 1-5 minutes in 19% of patients
	• **Mean time from onset to peak was 3.4 minutes** in a Canadian cohort study of 1999 patients (130 with SAH) [6]; in 14 of 130 cases, the time from onset to peak was > 5 minutes, in 11 cases > 15 minutes and in 1 case 1 hour [14].
	• **Sudden + severe headache**: one study reported a 25% prevalence of SAH among 148 patients presenting with sudden and severe headache [15].
	• **Onset of headache over > 1 hour** argued against SAH LR 0.06 (0-0.95) [16].
	• **Exertion** at onset SN 29%; SP 87%; LR+ 1.70 (1.37-2.10); LR- 0.88 (0.78-0.99) [16].
	• **Sexual activity** at onset SN 7%; SP 94%; LR+ 1.20 (0.79-1.82); LR- 1.00 (0.97-1.03) [16].
	• **Sleep** during onset SN 11%; SP 82%; LR+ 0.63 (0.45-0.89); LR- 1.09 (1.04-1.14) [16].

P	• **Unilateral** SN 30% [17]? [7]. • **Bilateral** SN 70% [17]? • **Occipital** neck-pain is the most common location • **Radiation along the spine** may occur as a result of blood-induced meningeal irritation [17]?
Q	• Typically described as a **new type** of headache which the patient has not experienced previously • **Burst or explode** at onset: SN 58%; SP 50%; LR+ 1.34 (1.08-1.66); LR- 0.74 (0.50 - 1.11) [16].
R	•
S	• **"Worst ever"** headache SN 89%; SP 26%; LR+ 1.25 (1.13-1.39); LR- 0.24 (0.02 - 3.55)[16]. • **Mean severity at peak 9.3/10** [6].
T	• **Relief or disappearance** of the headache (with or without analgesia) does not rule out SAH. • **Sentinel headache**: roughly 25% of patients with major SAH report a sudden, severe headache (so-called "sentinel" headache) 6-20 days prior to the SAH [7].
+	• **Loss of consciousness** SN 16%; SP 95%; LR+ 1.87 (0.72-4.86); LR- 0.91 (0.83-1.00) [16]. • **Neck stiffness** SN 33%; SP 95%; LR+ 4.12 (2.24-7.59); LR- 0.73 (0.66-0.80)[16]. May lead to a misdiagnosis as torticollis. Symptoms of meningeal irritation may appear 3-12 hours after the onset of headache [18]. • **Vomiting** SN 65%; SP 72%; LR+ 1.92 (1.48-2.48); LR- 0.52 (0.45-0.61) [16]; may lead to a misdiagnosis as gastroenteritis. • **Seizures** during the first 24 hours occur in < 10% of cases [7]. • **Lumbar pain** may lead to a misdiagnosis of lumbago. • **Visual symptoms**: double vision, photophobia; patients might complain of "large brown blobs" obscuring their vision. [1]. • **Blurred vision** SN 11%; SP 95%; LR+ 3.14 (0.31-31.43); LR- 0.85 (0.44 - 1.63) [16]. • **Photophobia** SN 38% SP 58% LR+ 1.07 (0.67-1.71); LR- 1.05 (0.87-1.27) [16].

PHYSICAL EXAMINATION

VS	• **Low-grade fever** may be present and lead, in conjunction with neck stiffness, to a misdiagnosis of viral meningitis.
NS	• **Normal neurological examination** in patients presenting with aneurysmal SAH SN 40-50% [19]. • **Altered mental status** SN 25%; SP 91%; LR+ 2.18 (1.33-3.56); LR- 0.87 (0.78-0.98) [16]. • **Cranial nerve III palsy** with a unilaterally enlarged pupil suggests an aneurysm in the posterior communicating artery [20]. One study reported that 14% of patients with oculomotor palsy resulting from an aneurysm at or near the junction of the internal carotid-posterior communicating artery had normal pupils [21]. • **Cranial nerve VI palsy** may occur as a result of increased intracranial pressure [20]. • **Focal neurological deficit** SN 31%; SP 93%; LR+ 3.26 (1.93-5.52); LR- 0.81 (0.67-0.97) [16].
H&N	• **Neck stiffness** SN 29%; SP 96%; LR+ 6.59 (3.95-11.00); LR- 0.78 (0.68-0.90) [16]. One study defined limited neck flexion on physical exam as "inability to touch chin to chest or raise the head 8 cm off the bed if supine" [22].
Eye	• **Intraocular hemorrhages** and/or **subhyloid linear/flame-shape streaks of blood** in the preretinal layer usually near the optic disc may be seen on fundoscopy. These findings result from retinal vein rupture secondary to the sudden rise in intracranial pressure (Terson's syndrome).

BEDSIDE TESTS

Electrocardiogram

- The EKG may show signs of suggestive of an acute coronary syndrome [23].

DIAGNOSIS

1. Might the patient have a subarachnoid hemorrhage?

Around 5% of patients with a non-traumatic SAH are initially misdiagnosed in the ED [24]. Patients with mild or atypical symptoms are at greatest risk for misdiagnosis [24]. Ironically, such patients are those who have most to gain from a correct diagnosis [25]. Mortality if untreated 50% at 6 months.

Ottawa SAH Rule

The Ottawa SAH rule [22] applies to:

- Adults patients (≥ 16 years)
- Nontraumatic headache that reached maximal intensity within 1 hour
- Alert and oriented (Glasgow Coma Scale score of 15)
- Had not sustained a fall or direct head trauma in the previous 7 days
- Presenting to the ED within 14 days of headache onset

It does NOT apply to the patients with:

- new neurologic deficits (e.g. isolated cranial nerve palsies, limb weakness)
- papilledema on fundoscopic examination (as determined by the treating physician)
- previous diagnosis of cerebral aneurysm, SAH, brain neoplasm, or hydrocephalus
- history of recurrent headaches (≥ 3 episodes of the same character and intensity over the course of ≥ 6 mo)

- returned for reassessment of the same headache if already investigated with both CT and lumbar puncture

The rule recommends investigating for SAH if ≥ 1 high-risk variable present (SN 100%, SP 15.3%, LR+ 1.17, LR- 0.024):
- Age ≥ 40 y
- Neck pain or stiffness
- Witnessed loss of consciousness
- Onset during exertion
- Thunderclap headache (defined as instantly peaking pain)
- Limited neck flexion on examination (defined as inability to touch chin to chest or raise the head 8 cm off the bed if supine)

The rule was derivered from 1999 patienter (130 med SAH) [6] and validated on 2131 patienter (132 med SAH) [22]. The Ottawa SAH rule had the following test characteristics for SAH: SN 100% (97.2 - 100%); SP 15.3% (13.8 - 16.9); LR+ 1.17; LR- 0.024 [22].

If none of the 6 variables are present, consider SAH ruled-out. Otherwise, proceed to step 2.

2. Head CT?
- The sensitivity of non-contrast CT decreases with time: SN 95% within the first 24 hours but SN of only 60% 5 days after SAH. One study reported that a negative CT carried out < 12 hrs was associated with a LR of 0.02, negative CT < 24 h LR 0.07, and negative CT at > 24 hrs LR 0.18 [26].
- A prospective cohort study of > 3,000 neurologically intact patients seeking care in the ED for a headache peaking within 1 hour showed that a third generation CT, carried out within 6 hours of headache onset and read by either general radiologists and neuroradiologists, had SN 100% (97-100%), SP 100% (99.5 – 100%), NPV 100% and PPV 100% for SAH [14].
- A retrospective study of 137 patients suspicious of SAH and a normal level of consciousness showed that a CT carried out within 6 hours and interpreted by experienced neuroradiologists, had SN, SP, PPV and NPV values of 100% when atypical presentations without headache (but with isolated neck pain) were excluded [27].
- A retrospective, matched case-control study including 55 patients with subarachnoid hemorrhage as determined by lumbar puncture after a negative cranial CT found that 11 of 55 subarachnoid hemorrhage cases (20%) had their CT performed within 6 hours of headache onset [28]. However, the author speculates in the correspondence section that CT within 6 hours is roughly 99.6% sensitive [29].
- Another retrospective study [30].
- A systematic review and meta-analysis reported that a modern CT scan performed within 6 hours of headache onset among patients with a normal neurological examination has SN 98.7% (97.1 - 99.4%) for aneurysmal subarachnoid hemorrhage [31]. A meta-analysis reported that a pooled sensitivity for CT within the first 6 hours of symptom onset of 100% (98-100%) and LR- 0.01 (0.00 - 0.04) [16]. Beyond 6 hours the pooled sensitivity of CT is 89% (83-93%) and LR- 0.07 (0.01 - 0.61) [16]

Given the safety, sensitivity and specificity of CT, head CT is indicated if SAH is clinically suspect. One study argues that a head CT performed within 6 hours of symptom onset is indicated if the pretest probability of SAH is between 0.7% and 50%, while a head CT performed beyond 6 hours from symptom onset is indicated if the pretest probability of SAH

is between 0.8% and 13% [16]. CT angiography, MR angiography or angiogram may be considered in the following circumstances:

- very high pretest probability for SAH
- patient presents > 2 weeks from symptom onset

However, these investigations may lead to the diagnosis of asymptomatic aneuryms.

Clinical Decision Rule

A negative head CT scan is sufficient to rule-out a nontraumatic SAH if the following criteria are met [31]:

- Isolated thunderclap headache presentation (i.e. not patients presenting with atypical features such as primary neck pain, syncope or seizure at onset)
- Clear time of onset.
- CT is performed within 6 hours of headache onset
- Normal neurological examination
- Modern CT scan
- Interpretation by an attending radiologist

In this setting, the post-test probability of a SAH is < 0.15%.

3. Lumbar Puncture?

The decision to carry out an lumbar puncture (LP) in the setting of a negative CT depends on the pretest (pre-LP) probability for SAH and the CT's test characteristics. According to one study, a pre-CT probability for SAH of > 70% (based on history and physical) is required to make LP post CT carried out within 6 hours in the patient's interest, whereas a pre-CT proability for SAH of > 20% is required to make LP post CT carried out beyond 6 hours in the patient's interest [16]. Another study argues that a negative CT carried out within < 12 hrs (and associated with a LR of 0.02) would lower a low pre-test probability of SAH (5%) to 0.1%. In this setting, 1000 lumbar punctures would have to be performed to detect one subarachnoid hemorrhage [26]. Factoring in the risks, sensitivity and specificity of LP, the authors of one study argue that performing an LP is of no value to a patient with a pre-LP probability of SAH below 1-2% [16]. Another study concluded that LP is indicated after a negative CT unless
the pre-CT probability of SAH was low (<1.6%) or the sensitivity of the initial non-contrast CT for blood was high (> 99.6%, i.e. third generation scanner and scanning within 6 hours of symptom onset) [3].

CSF can be analyzed for red blood cell (RBC) count. One meta-analysis reported the following test characteristics for a threshold of RBC 1000 x 10^6/L in the final CSF sample: SN 76%; SP 88%; LR+ 5.66 (1.38-23.27); LR- 0.21 (0.03-1.66) [16]. According to this study, carrying out an LP to analyze RBC count is of value if the pre-LP probability of SAH is roughly between 2 and 4% [16].

CSF may also be analyzed for xanthochromia, suggesting break-down of hemoglobin in the CSF. Xanthochromia may be detected visually or via spectrophotometry. One meta-analysis reported the following test characteristics for spectrophotometric xanthochromia: SN 100%; SP 95%; LR+ 15.23 (1.58-147); LR- 0.13 (0.02-0.83) [16], while the test characteristics for visible xanthochromia were SN 71%, SP 93%; LR+ 12.56 (2.03-77.67); LR- 0.30 (0.09 - 1.06). According to this study, carrying out an LP to detect visible xanthochromia is of value if the pre-LP probability of SAH is roughly between 2 and 8% [16]. The authors do not provide similar values regarding spectrophotometric xanthochromia.

The study argues that the range of pre-LP SAH probability where LP benefits the patient is narrow (if xanthochromia cannot be measured spectrophotometrically and if an RBC count of 1000 x 10^6/L is used). Should SAH not be deemed ruled-out after a negative head CT, the implications of this study would be to forgo LP and proceed directly to CT angiogram, should the probability of SAH exceed 10%. This study does not take into account the potential diagnostic value of LP in regards to other causes of severe, sudden headache, nor the value of using a different RBC cut-off in the final CSF sample or using spectrophotometric xanthochromia. CT angiogram does not rule out subarachnoid blood, and the detection of an aneurysm with CT angiogram does not confirm that the patient has had a SAH [3].

Xanthochromia takes up to 12 hours to develop [16], and some sources recommended waiting until 6 (ideally 12) hours have elapsed since symptom onset prior to performing the lumbal puncture. The sensitivity for bilirubin produced in vivo is close to 100% when the LP is performed between 12 hours and 2 weeks after subarachnoid hemorrhage [1]. Yet some authors do not recommend delaying lumbar puncture until 12 hours since symptom onset [2].

A decrease in the number of red blood cells between tube #1 and tube #4 is not sufficient to rule out SAH. One study reported that SAH can be rule-out if the red cell count in the last tube at least ≤ 5 x 10^6 RBCs/L [32].

MANAGEMENT

1. Contact the neurosurgeon