TEACHING MATERIALS

Intensive International Educational Program

„Medical Emergency Activities”

Jan Kochanowski University in Kielce

Selected issues related to the management of patients with difficult airways.

Introduction and Definitions

Securing the airway is one of the most critical procedures in anesthesiology, intensive care, and emergency medicine. **Difficult intubation** is a clinical situation in which the insertion of an endotracheal tube into a patient's trachea requires a high degree of skill from an experienced physician, multiple attempts, or the use of non-standard equipment. Historically (e.g., in the 1993 guidelines), it was defined as the need to perform more than three attempts or a maneuver duration exceeding 10 minutes. Currently, the emphasis is on rapid identification of the problem and smooth transition to subsequent stages of the algorithm to avoid patient hypoxia.

The most dangerous scenario is the **CICO (Can't Intubate, Can't Oxygenate)** situation. It requires the immediate implementation of emergency surgical procedures (FONA - Front of Neck Access).

Preoperative Airway Assessment

The key to avoiding unexpected difficulties is a thorough assessment of the patient before the induction of anesthesia. Standardized scales and acronyms are used for this purpose.

LEMON Acronym

LEMON is a commonly used tool for predicting difficult intubation, particularly useful in the Emergency Department (ED) setting:

L - Look externally: Searching for features that complicate intubation, such as obesity, short neck, receding mandible, large incisors, facial hair (complicates mask ventilation), maxillofacial trauma.

E - Evaluate 3-3-2 (3-3-2 Rule): Assessment of airway geometry using the patient's fingers. 3 fingers between the incisors (mouth opening), 3 fingers from the mentum to the hyoid bone (submandibular space), 2 fingers from the hyoid bone to the thyroid cartilage (laryngeal position).

M - Mallampati score: Assessment of the visibility of pharyngeal structures (described in detail below).

O - Obstruction: Assessment of the presence of tumors, abscesses, foreign bodies, glottic edema (e.g., in epiglottitis).

N - Neck mobility: Limitation of neck extension (e.g., in rheumatoid arthritis, after cervical spine injuries, wearing an orthopedic collar) prevents assuming the optimal "sniffing position".

Mallampati Score

Introduced in 1985 by S. Rao Mallampati, a four-point scale assessing the mutual relationships of the uvula, fauces, and soft palate in a sitting patient, with maximal mouth opening and tongue protrusion (without phonation).

Class I: Soft palate, uvula, fauces, and tonsillar pillars visible.

Class II: Soft palate and uvula visible.

Class III: Soft palate and base of the uvula visible.

Class IV: Soft palate not visible (only hard palate visible).

Classes III and IV are strong predictors of difficult intubation.

Management Algorithms (DAS 2025 and ASA 2022)

Difficult airway management is based on strict adherence to algorithms. The most globally recognized are the guidelines of the British Difficult Airway Society (DAS) and the American Society of Anesthesiologists (ASA).

DAS Guidelines

DAS guidelines are based on a sequential strategy (Plans A-D), which aims to prevent task fixation and minimize airway trauma.

Plan A (Tracheal intubation): Maximum of 3 intubation attempts (plus one additional by an experienced clinician). Between attempts, the technique should be changed (e.g., changing head position, using a videolaryngoscope, using a Bougie introducer).

Plan B (Maintaining oxygenation - SAD): If Plan A fails, oxygenation becomes the priority. A Supraglottic Airway Device (SAD) should be inserted, e.g., a laryngeal mask airway (LMA) or laryngeal tube (LT). Maximum of 3 attempts.

Plan C (Facemask ventilation): If SAD fails, an attempt should be made to ventilate via a facemask using an oropharyngeal (Guedel) airway and possibly reverse the anesthesia (wake the patient up) if possible.

Plan D (CICO - Emergency front of neck access): When mask ventilation fails and the patient becomes hypoxic, a CICO situation is declared, and a cricothyroidotomy (FONA) is performed immediately.

ASA 2022 Guidelines

The 2022 ASA guidelines place a huge emphasis on continuous oxygen delivery throughout the entire airway management process and on the use of capnography to confirm ventilation. The ASA algorithm introduces a clear decision tree between awake intubation and intubation after induction of anesthesia, depending on the anticipated risk.

Advanced Equipment and Techniques

Videolaryngoscopy (VL)

Videolaryngoscopes have revolutionized airway management. They work via a camera and light source integrated into the blade, transmitting a real-time image to a screen. This allows for visualization of the vocal cords without the need for a direct line of sight (alignment of the airway axes).

There are two main types:

SGVL (Standard Geometry Video Laryngoscopes): Traditional (Macintosh) shaped blades. They allow for both direct (line-of-sight) and video-assisted intubation.

HAVL (Hyper-angulated Video Laryngoscopes): Highly curved blades (e.g., GlideScope). They provide an excellent view (often Cormack-Lehane grade 1), but tube insertion can be difficult and requires the use of a rigid introducer (stylet) shaped to the blade's curve.

Bougie Introducer (Eschmann Tracheal Tube Introducer)

The Bougie introducer is a flexible but shape-retaining rod (usually 60 cm long and 15 Ch in diameter) with an angled tip (the so-called coudé tip at a 35-40 degree angle). It is an indispensable tool in cases of difficulty visualizing the glottis (Cormack-Lehane 2b and 3).

Technique of use: The Bougie is inserted under laryngoscopic guidance. The angled tip allows one to "feel"; the tracheal rings (characteristic clicking) or resistance at the level of the carina (hold-up sign), which confirms correct placement. Then, an assistant railroads the endotracheal tube over the introducer (Seldinger technique). If the tube gets caught on the arytenoids, it should be rotated 90 degrees to the left (counterclockwise).

For a single operator, the "Kiwi grip" technique is useful, where the Bougie is curled and pre-loaded with the endotracheal tube.

Supraglottic Airway Devices (SAD)

When intubation fails, SADs serve as a "Lifeline". The most popular include:

Laryngeal mask airway (LMA / i-gel): Seals around the laryngeal inlet. Intubating versions (e.g., iLTS-D, Fastrach) allow for the insertion of an endotracheal tube through the lumen of the mask.

Laryngeal Tube (LT): Equipped with two cuffs (pharyngeal and esophageal). Ventilation occurs through an opening between them. It is easy to insert "blindly" and provides good protection against aspiration.

CICO Situation and Emergency Cricothyroidotomy

The CICO (Can't Intubate, Can't Oxygenate) situation occurs with a frequency of about 1 in 10,000 anesthetics, but in the ED setting, this rate may be higher. It requires an immediate transition to emergency surgical access.

Vortex Approach

The "Vortex" model developed by Dr. Nick Chrimes assumes the existence of three upper airway "Lifelines": Endotracheal tube, SAD, and Facemask. After making a "best effort" for each of them and failing to improve oxygenation, the team must unhesitatingly move to the central zone of the vortex – emergency front of neck access (CICO Rescue).

Surgical Cricothyroidotomy (Scalpel-Finger-Bougie Technique)

According to DAS guidelines and studies (e.g., the NAP4 audit in the UK), the surgical technique using a scalpel is preferred in adults over needle (cannula) techniques, which have a high failure rate (approx. 60%).

Steps of the procedure (Laryngeal handshake & Scalpel-Bougie):

1. Identification: Extension of the patient's neck. Palpable identification of the cricothyroid membrane (between the thyroid and cricoid cartilages). Stabilization of the larynx with the non-dominant hand.

2. Incision: Making a transverse incision of the cricothyroid membrane with a scalpel (blade no. 10). In cases of difficult anatomy (obesity), a vertical skin incision (approx. 4 cm) is made first.

3. Dilatation and Bougie: Rotating the scalpel 90 degrees or inserting the little finger into the opening to maintain patency. Insertion of the Bougie introducer into the trachea alongside the finger/scalpel.

4. Intubation: Railroading a cuffed endotracheal tube (size 6.0) over the Bougie into the airway. Removal of the Bougie, inflation of the cuff, and initiation of ventilation.

Commercial kits (e.g., PaCric, ScalpelCric) contain all the necessary elements: scalpel, bougie, 6.0 tube, and syringe, which significantly reduces reaction time under stress.

Summary

Management of difficult airways requires not only theoretical knowledge but above all equipment preparation, familiarity with algorithms (DAS, ASA), and regular simulation training. The key to success is early recognition of the problem (LEMON, Mallampati scales), avoiding multiple, traumatizing intubation attempts, and readiness to immediately implement emergency procedures (SAD, cricothyroidotomy) when the patient's oxygenation is compromised.

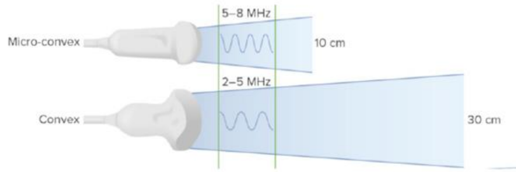
Performing ultrasound examinations in the prehospital setting in accordance with the principles of POCUS (Point-of-Care Ultrasound).

Basics of Ultrasonography

- Ultrasonography is the use of ultrasound waves to present an object in the form of an image.
- Wave frequency is the number of cycles per second—the higher the frequency, the better the resolution, but the shorter the wavelength.

PROBES

CONVEX Probe



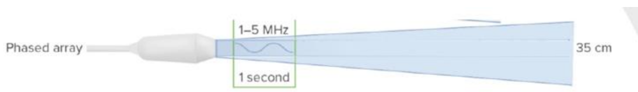
- The most popular probe in POCUS ultrasonography.
- Curved, slightly rounded probe face (a sector of a circle).
- It is a low-frequency probe (most often 2–6 MHz).
- Use: examination of the abdomen, pelvis, and lungs.

LINEAR Probe

- A high-frequency (4–12 MHz), high-resolution probe.
- Flat probe face.
- Accurate imaging of superficially located structures (usually up to 6 cm depth).
- Use: vessels, pleura.

SECTOR (Phased-Array) Probe

- A low-frequency (1–5 MHz) probe, with lower resolution and high beam penetration depth.
- Beam shape: triangular.



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- Use: cardiac examination.

Machine settings

Depth (DEPTH) – imaging depth.

Gain (GAIN) – amplification of the returning echo intensity.

ECHOGENICITY

Anechoic (black)

The term “anechoic” in ultrasonography means that no internal echoes are produced and the image is completely black. This is most often seen in fluid-filled structures because ultrasound waves pass through fluid without reflecting echoes back to the ultrasound machine.

HYPERechoic (bright/white)

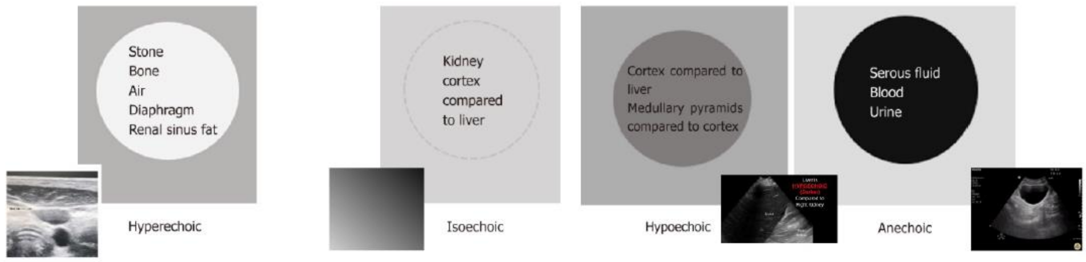
The term “hyperechoic” in ultrasonography means that a given structure produces MORE echoes
relative to the surrounding structures, resulting in a brighter/whiter appearance.

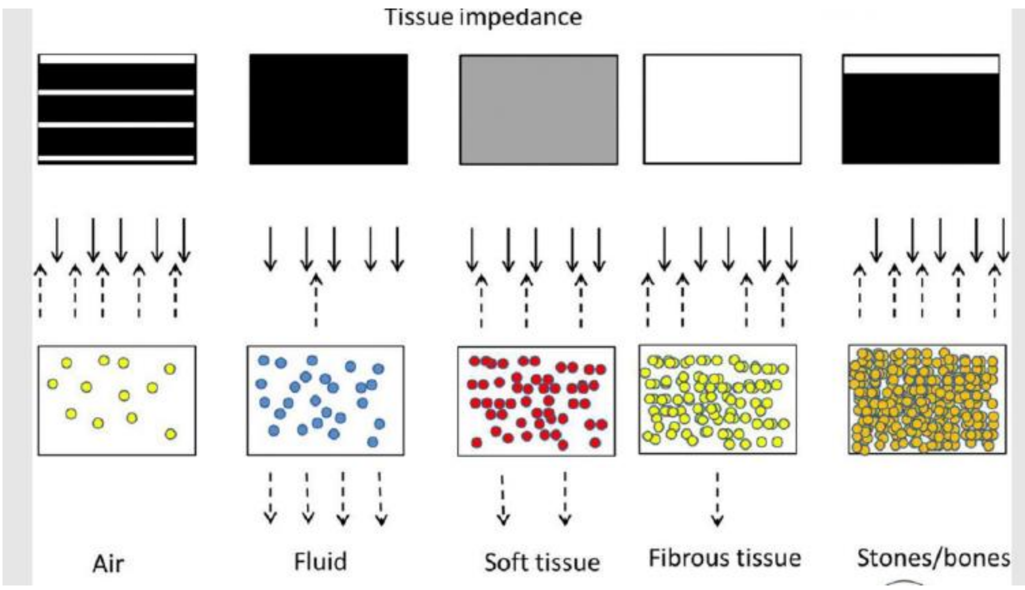
HYPOechoic (darker/gray)

The term “hypoechoic” in ultrasonography means that a given structure produces FEWER echoes
relative to the surrounding structures, resulting in a darker or more gray appearance.

<u>ISOechoic (similar)</u>

The term “isoechoic” in ultrasonography means that a given structure produces echoes similar
to another structure on the ultrasound screen. For example, one may say that the renal cortex is isoechoic relative to the splenic parenchyma.





MODES

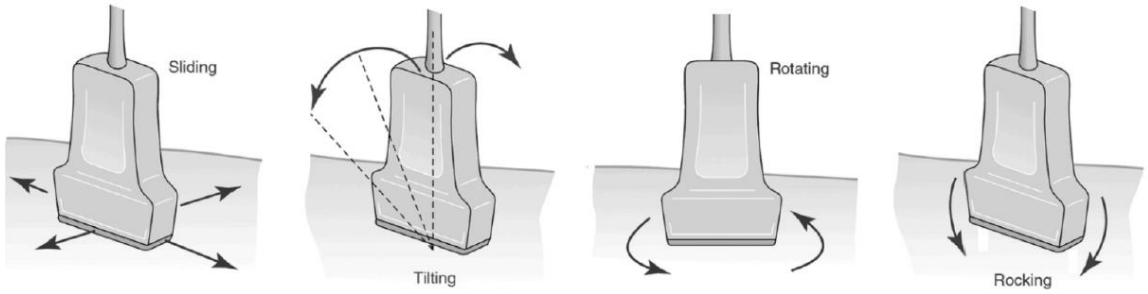
B-mode (brightness mode)

B-mode in ultrasound is a setting that creates a two-dimensional (2D) grayscale image on the ultrasound screen and is the most commonly used mode. It is also commonly called 2D mode.

M-mode (motion mode)

Ultrasound M-mode is defined as displaying motion as a function of time for a B-mode ultrasound image along a selected line. Motion is represented on the Y-axis and time on the X-axis. You can use M-mode in lung ultrasound to assess lung sliding and rule out pneumothorax.

Probe movements



ARTIFACTS

Mirror-image artifact

A mirror-image artifact in ultrasound occurs when ultrasound waves encounter a strongly reflecting surface adjacent to air.

Acoustic shadowing artifact

Acoustic shadowing occurs when ultrasound waves encounter a structure with a high attenuation coefficient. Acoustic shadowing artifacts are most commonly encountered in the following structures: bones, ribs, and gallstones.

Multiple reflection artifact (reverberations)

In the presence of strongly reflective surfaces, echoes can bounce back and forth between the reflecting surface and the ultrasound probe. This can cause the ultrasound screen to register and display multiple echoes on the screen.

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Ultrasound in trauma – eFAST protocol.

eFAST is a rapid, bedside ultrasound examination in a trauma patient, aimed at detecting fluid or air in body cavities that may pose an immediate threat to life.

Key elements to confirm:

- free fluid in the peritoneal cavity (hemoperitoneum),
- fluid in the pericardial sac (tamponade – pericardial fluid preventing the right ventricle from working),
- fluid in the pleural cavities (hemothorax),
- pneumothorax

eFAST is not an "abdominal ultrasound". It is a protocol focused on quick answers to questions such as:

<u>"Is there bleeding? Is there tamponade? Is there pneumothorax/hemothorax in the pleural space?"</u>

In practice, eFAST:

- is particularly useful in hemodynamic instability after trauma,
- can accelerate decisions about laparotomy, pericardiocentesis/surgery,
- is repeatable (you can perform it serially and monitor dynamics).

Equipment, settings, and general principles.

Probe:

- Most often: convex

Settings

- **Depth:** so that you can see the target organ + the potential space for fluid (15–20 cm)
- **Gain:** not too bright (fluid should be black/anechoic).

Set the focal zone (focus) at the level of the space of interest

Interpretation principle

You look for fluid in typical "recesses". Post-trauma fluid is most often blood, but ultrasound does not distinguish what the fluid is!

Important: a negative eFAST does not exclude injury (e.g., bowel rupture, early low-volume bleeding, bleeding from the upper or lower GI tract).

Order of windows in eFAST.

A commonly used order (may vary depending on the situation):

1. Heart (pericardium) – because tamponade kills quickly.
2. RUQ (right upper quadrant) – Morrison's pouch
3. LUQ (left upper quadrant) – splenorenal
4. Pelvis – pouch of Douglas / bladder area
5. Pleura: fluid (hemothorax) – right/left lung
6. Pleura: pneumothorax – right/left lung

1. Cardiac window – pericardium (tamponade).

Goal: is there fluid in the pericardial sac and signs of tamponade?

Most common windows:

- Subxiphoid (subcostal): the marker usually toward the patient's right shoulder; place the probe under the xiphoid process and direct the beam under the costal margin toward the heart.

What do you see?

- Pericardial fluid = a black rim around the heart (often first posteriorly).
- Tamponade when you see right ventricular collapse in diastole + the clinical picture of shock

2. RUQ – right upper quadrant (Morrison).

Goal: detect fluid in:

- the hepatorenal recess (Morrison's pouch),
- beneath the right hemidiaphragm,
- around the lower pole of the kidney.

Technique:

- Probe in the mid-axillary line, usually between the ribs, "looking" at the kidney and liver.
- Look for a black triangle/pocket between the liver and the kidney.

3. LUQ – left upper quadrant (splenorenal).

Goal: fluid in:

- the splenorenal recess,
- beneath the left hemidiaphragm.

Technique:

- Place the probe more posteriorly than on the right (the spleen is more "posterior").

4. Pelvis – bladder area (pouch of Douglas / space behind the bladder).

Goal: fluid in the lowest peritoneal space:

- in men: the space behind the bladder,
- in women: the pouch of Douglas (behind the uterus).

Technique:

- Best with at least a partially filled bladder (acts as an "acoustic window").
- Scan in two planes: transverse and longitudinal.

5. The "extended" part – chest (fluid + pneumothorax).

Hemothorax – fluid in the pleural cavity

Where to look?

- Most often posterolaterally, but in eFAST (patient supine) fluid layers posteriorly — look at the diaphragmatic window.

Technique (practically):

- Use the RUQ and LUQ windows: "slide" the view upward to the diaphragm.
- Pleural fluid = a black layer above the diaphragm

Pneumothorax – air in the pleural space

Where to scan?

- In a supine patient: air collects anterosuperiorly. Typical points: 2nd–4th intercostal space in the midclavicular line and the anterior axillary line.

What do you assess? (B-mode and M-mode)

1. **Lung sliding – movement of the visceral pleura over the parietal pleura.**
   - If sliding is present at that location, there is no pneumothorax.
2. **B-lines (vertical artifacts)**
   - The presence of B-lines practically excludes pneumothorax at the examined location.
3. **M-mode: seashore sign vs barcode/stratosphere sign**
   - "Seashore" (beach) = sliding present.
   - "Barcode/stratosphere" = no sliding (suspected pneumothorax, but there are differentials).
4. **Lung point – the transition point between sliding and no sliding**
   - Highly specific for pneumothorax and may approximate its size.

eFAST REPORT

- Heart: pericardial fluid YES/NO
- RUQ: free fluid YES/NO
- LUQ: free fluid YES/NO
- Pelvis: free fluid YES/NO
- Right/left pleura: fluid YES/NO
- Right/left pneumothorax: suspected YES/NO

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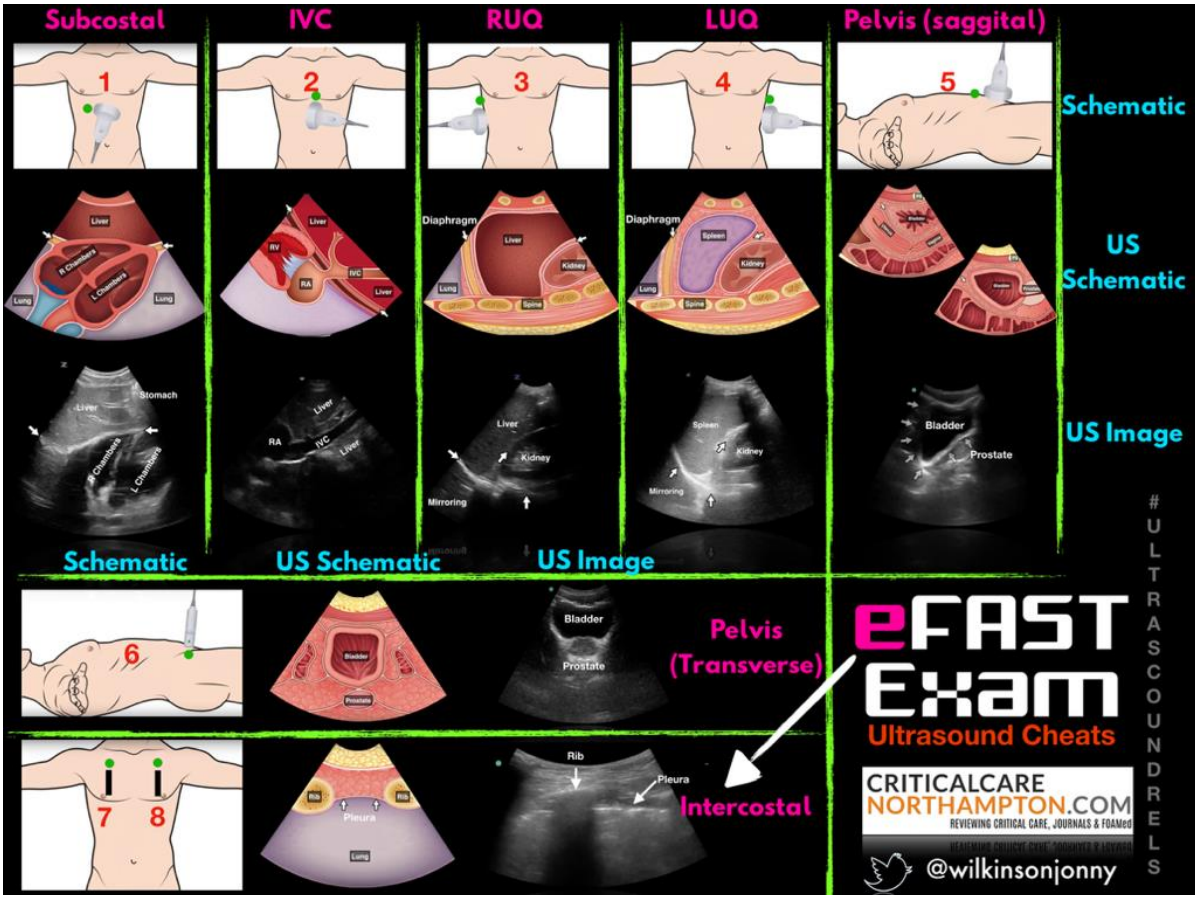

Pain management in patients in accordance with the principles of multimodal analgesia.

Introduction to Multimodal Analgesia

Multimodal analgesia is a modern pain management strategy that involves the simultaneous use of medications with different mechanisms of action (as well as non-pharmacological techniques). This approach allows for achieving an optimal analgesic effect while simultaneously reducing the doses of individual agents. According to current medical knowledge, such an approach minimizes the risk of adverse effects that frequently accompany high-dose monotherapy, particularly with opioids [Source].

In the context of Emergency Medical Services (EMS), the implementation of combination therapy is of crucial importance. The use of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) in combination therapy with paracetamol or opioids allows for a reduction in opioid doses by approximately 30–50% [Source]. Drugs from different classes (e.g., paracetamol, metamizole, NSAIDs, opioids) can be safely combined, utilizing their synergistic and additive effects.

Important note for EMS: According to the "Good Practices in Pain Management" guidelines, the administration of analgesics via intramuscular (IM) and rectal (PR) routes is not recommended in pre-hospital care. Medications administered via these routes are characterized by a long and unpredictable latency period (time to onset of effect) [Source]. The preferred routes are intravenous (IV), intraosseous (IO), or intranasal (IN) access.

Pain Assessment and Management Protocols

The key to proper treatment is the assessment of pain intensity using the NRS (Numerical Rating Scale, 0-10 pts). EMS teams should aim to reduce pain intensity by a minimum of 50%. The management depends on the etiology (traumatic vs. non-traumatic) and the intensity of the pain.

Management Scheme according to "Good Practices in Pain Management"

Pain Intensity (NRS)	Pain of non-traumatic etiology (e.g., abdomen, chest)	Pain of traumatic etiology (injuries, burns)
Mild (1-4 pts)	Ibuprofen 800 mg PO and/or Paracetamol 1000 mg PO (+ optionally	Paracetamol 1000 mg PO

	Drotaverine 80 mg IV for abdominal pain)	
Moderate (5-7 pts)	Ibuprofen 800 mg PO and/or Metamizole 2.5 g IV or Ketoprofen 100 mg IV	Metamizole 2.5 g IV and/or Ketoprofen 100 mg IV
Severe (8-10 pts)	Metamizole 2.5 g IV + Fentanyl (1.0 µg/kg IV/IO) or Morphine (0.1-0.2 mg/kg IV/IO)	Metamizole 2.5 g IV + Fentanyl (1.0 µg/kg IV/IO) or Morphine (0.1-0.2 mg/kg IV/IO)

Characteristics of Analgesic Drugs in EMS

Non-Opioid Analgesics

Paracetamol

A drug with analgesic and antipyretic properties, lacking an anti-inflammatory component. It acts by inhibiting cyclooxygenase in the central nervous system. It does not damage the gastric mucosa and does not affect blood coagulation. After intravenous (IV) administration, it begins to act within 5–10 minutes, and the effect lasts for 4–6 hours [Source].

Adult dosage: 500–1000 mg as a single dose. The maximum daily dose is 4 g.

Pediatric dosage: 10–15 mg/kg of body weight as a single dose (maximum 4 doses per day, max 60 mg/kg/day).

Limitations: It is not effective for inflammatory pain or pain localized in the abdominal cavity. Overdose poses a risk of severe liver failure (antidote: N-acetylcysteine).

Metamizole

A pyrazolone derivative with strong analgesic, antipyretic, and spasmolytic (smooth muscle relaxing) effects. It is the drug of choice for severe visceral pain (e.g., colic) and high fever resistant to other medications.

Adult dosage: 0.5–1 g (EMS protocols allow up to 2.5 g IV for severe pain). The maximum daily dose is 4 g.

Pediatric dosage: 8–16 mg/kg of body weight (in cases of life-threatening fever, typically 10 mg/kg of body weight).

Adverse effects: Intravenous administration that is too rapid can cause hypotension. Long-term use is associated with the risk of agranulocytosis (bone marrow damage) [Source].

Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

These drugs inhibit the activity of cyclooxygenase (COX), reducing the synthesis of prostaglandins. They exhibit analgesic, anti-inflammatory, and antipyretic effects. In EMS, Ibuprofen (PO) and Ketoprofen (IV) are most commonly used.

Ketoprofen: Dose of 100 mg IV (often administered as a slow infusion in 100 ml of 0.9% NaCl). It is worth noting that the intravenous administration of ketoprofen in EMS for trauma patients is often an off-label use (outside of registered indications, which mainly include postoperative pain); however, this practice is consistent with current medical knowledge [Source].

Interactions: NSAIDs can be combined with acetylsalicylic acid (ASA), but caution must be exercised not to reverse the antiplatelet effect of ASA. Drugs such as ibuprofen or ketoprofen have a short half-life and are preferred in such combinations [Source].

Opioid Analgesics

The primary drugs for managing severe pain (NRS 8-10). They act by stimulating opioid receptors (mainly μ) in the central nervous system.

Fentanyl

A synthetic opioid acting approximately 100 times stronger than morphine. It is characterized by a very rapid onset of action (approx. 2 minutes after IV administration) and a short duration of effect (approx. 30 minutes).

Advantages in EMS: Unlike morphine, fentanyl does not cause histamine release, making it a safer choice for hemodynamically unstable patients (it does not cause a drop in blood pressure) and for patients with chest injuries [Source].

Dosage: 1-2 μg/kg of body weight IV. Intranasal (IN) administration is also possible at a dose of 1.5 μg/kg of body weight, which allows for achieving an effect within 10 minutes without the need to establish vascular access.

Morphine

A classic opium alkaloid. It acts slower than fentanyl (onset after approx. 5-10 minutes IV), but its effect lasts significantly longer (up to 4 hours).

Indications: Preferred for chronic pain (e.g., cancer pain), myocardial infarctions (reduces cardiac preload), and during long transports.

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Dosage: 0.1 - 0.2 mg/kg of body weight IV (usually fractionated in 2-5 mg increments until the desired effect is achieved).

Adverse effects: Respiratory center depression, histamine release (risk of hypotension and bronchospasm), nausea, vomiting.

Co-analgesics and Anti-hyperalgesic Drugs

Ketamine

An NMDA receptor antagonist. In subdissociative doses (0.1 - 0.3 mg/kg), it exhibits strong analgesic and, crucially in trauma, anti-hyperalgesic effects. It prevents the "wind-up" phenomenon in the spinal cord, protecting the central nervous system from the consequences of a severe pain stimulus [Source]. In anesthetic doses (1-2 mg/kg IV), it is used for the induction of anesthesia. Unlike opioids, ketamine stimulates the cardiovascular system (increase in blood pressure and heart rate) and preserves the patient's own respiratory drive.

Summary

Effective pain management in EMS requires a shift from monotherapy towards multimodal analgesia. Combining drugs such as Paracetamol with Metamizole, or NSAIDs with Opioids, allows for faster and safer relief of patient suffering. It should be remembered that the administration of analgesics in the pre-hospital phase does not "mask" the clinical picture (e.g., in acute abdominal pain) and does not hinder diagnostics in the Emergency Department (ED), while significantly improving the patient's prognosis and comfort.

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Obtaining vascular access under ultrasound guidance.

Vascular access (venous and arterial) is one of the most common procedures in medicine. The problems with the classic "landmark" technique include anatomical variability, multiple puncture attempts, and the resulting complications. The recommendations emphasize that multiple puncture attempts correlate with a higher number of complications and greater patient discomfort.

Ultrasound has three key roles in vascular cannulation:

1. Pre-cannulation assessment (precannulation vessel assessment) – selecting the best vessel and puncture site, assessing patency.
2. Real-time guidance – monitoring the needle/needle tip during puncture.
3. Detection of local complications – hematoma, pneumothorax, thrombosis,

What does ultrasound provide in practice?

- a higher success rate (first-pass and overall),
- shorter time to obtain access,
- fewer attempts and fewer mechanical complications (e.g., arterial puncture, hematoma).

Ultrasound equipment and settings

Probes and frequency:

- Linear probe
- 2D (B-mode): basic imaging of the vessel wall and lumen, and relationships with adjacent structures.
- Color Flow Doppler (CFD): confirmation of flow presence and direction.
- Spectral Doppler (PWD): the character of flow (arterial vs venous) and its variability.

Image optimization:

- set the depth so that the vessel is in the center of the screen,
- adjust the gain so that the vessel lumen is anechoic and the wall and tissues are clearly visible,
- set the focal zone at the level of the vessel,
- remember: too much probe pressure can collapse the vein and it may "disappear".

How to distinguish a vein from an artery on ultrasound?

2D (B-mode) features:

Veins: usually larger, thin-walled, may have valves, easily compressible, change diameter with respiration and patient position.

Arteries: smaller, more round, thicker wall, no valves, less compressible, usually pulsatile.

Doppler:

Artery: pulsatile flow, systolic predominance.

Vein: slower, more continuous flow;

Ultrasound-guided cannulation technique

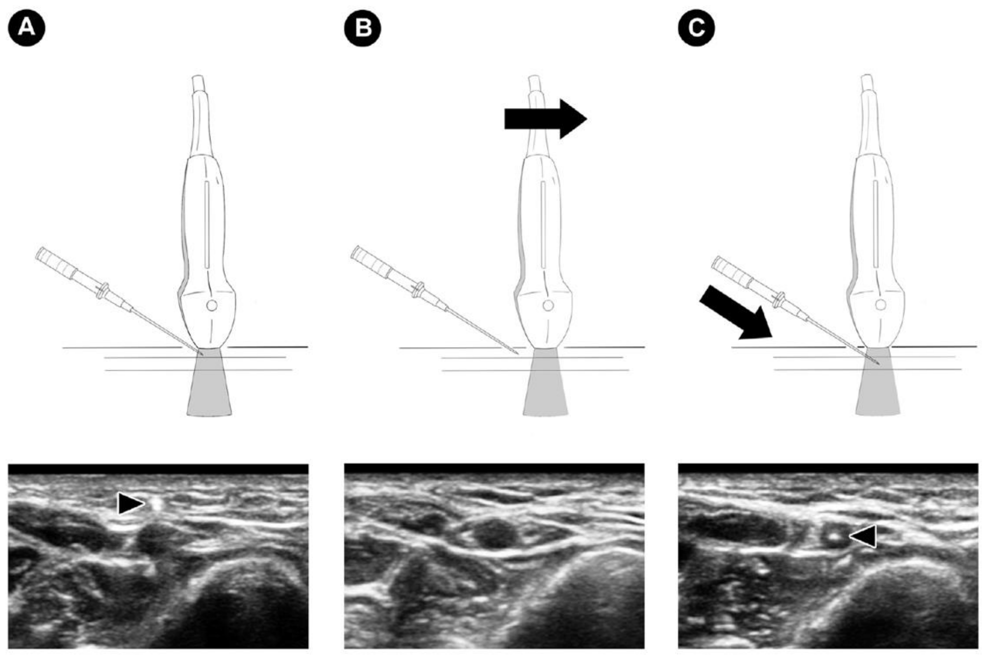
Pre-puncture assessment (always!):

- Identify the target vein in SAX (short-axis, transverse) and, if possible, in LAX (long-axis, longitudinal).
- Assess: depth, diameter, patency, thrombosis, tortuosity, relation to the artery and vulnerable structures.
- Choose a puncture site that provides the simplest needle path to the lumen and minimizes the risk of puncturing adjacent structures.

“Out-of-plane” (SAX) and “in-plane” (LAX) approaches:

Out-of-plane in SAX: you see the vessel “in a circle” and the needle as a bright dot—continuous tracking of the tip is more difficult. To address this, the DNTP (dynamic needle tip positioning) technique is described: you “catch” the needle tip, slide the probe until it disappears, advance the needle until it appears again—step by step until entry into the lumen.

In-plane in LAX: ideally allows visualization of the entire needle path and tip in real time, but requires very good alignment with the vessel axis (sometimes difficult with large vessels and a narrow probe).



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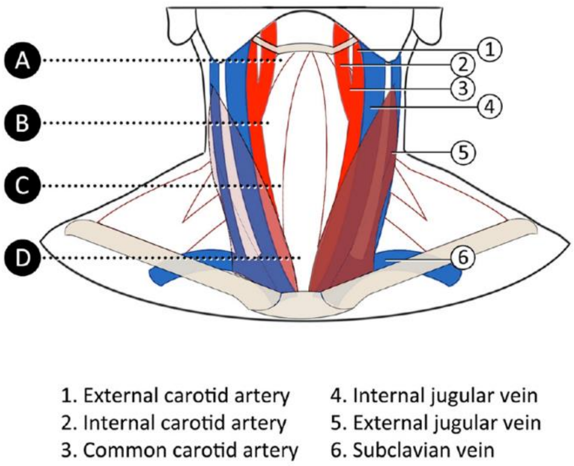
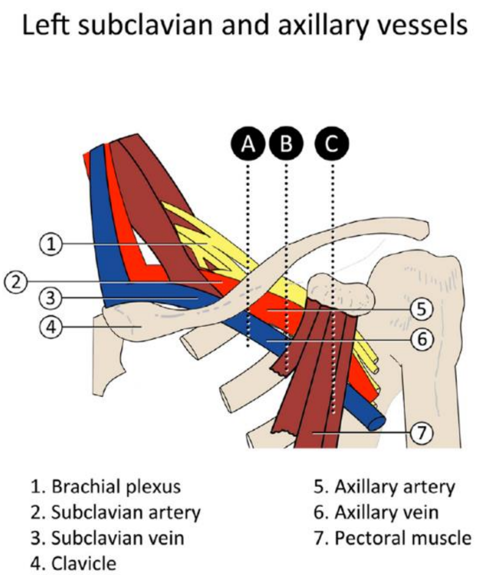
Key ultrasound-guided venous access sites (adults)

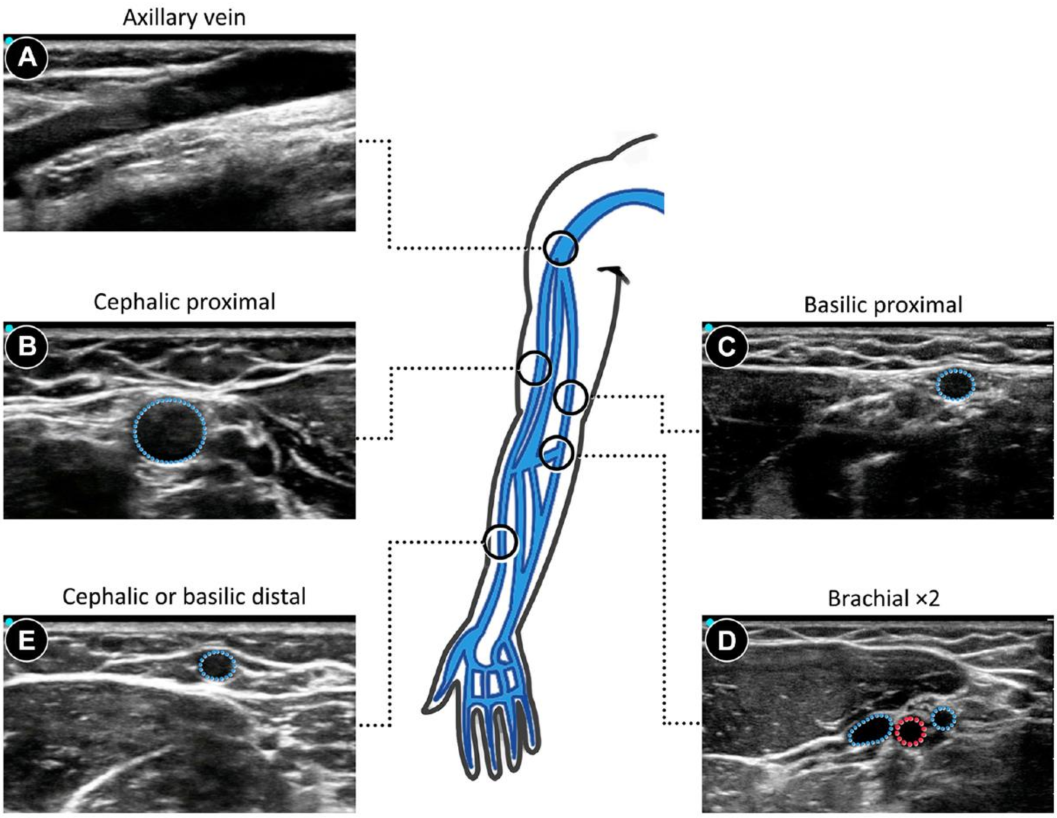
Internal jugular vein – IJV (internal jugular vein)



Subclavian vein



Peripheral access



Mini-checklist

A. Before puncture (US assessment):

- identify the vein and artery (B-mode + compression ± Doppler)
- assess patency (compression, flow)
- choose puncture site and needle path (safety margin)
- optimize machine settings

B. Puncture (real-time US):

- selected technique: out-of-plane (SAX) / in-plane (LAX) / DNTP
- needle tip visible
- control angle and depth

C. After puncture:

- confirm the guidewire within the lumen of the correct vessel
- dilation and catheter insertion
- assess complications depending on the location

D. Patency assessment

- Flush the cannula with 10 mL of 0.9% NaCl

Establishing intraosseous access.

What is intraosseous access?

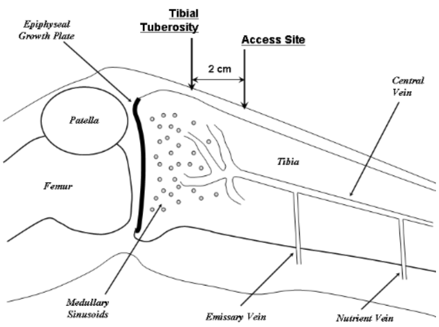
Intraosseous (IO) access involves inserting a needle into the medullary cavity of a bone in order to obtain rapid access to the circulatory system. The medullary cavity is highly vascularized, and through the network of marrow sinusoids, medications and fluids enter directly into the central circulation. The pharmacokinetics of drugs administered intraosseously are practically the same as with intravenous administration.

Intraosseous access is used primarily in emergency situations when obtaining intravenous access is impossible or significantly delays treatment. In emergency medicine it is considered an alternative method to IV access, particularly in cardiac arrest, severe shock, major trauma, or in patients with poorly visible peripheral veins.

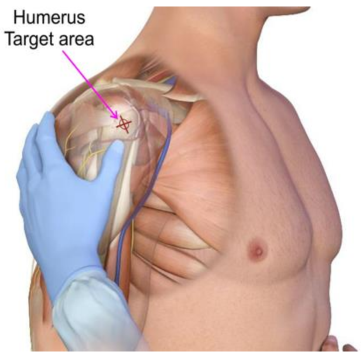
According to current resuscitation guidelines, intraosseous access should be established quickly if attempts to obtain intravenous access are unsuccessful or may delay treatment.

Sites for intraosseous access.

The most commonly used sites for intraosseous access are long bones with a well-developed medullary cavity and a thin cortical layer. The most important anatomical landmarks include the proximal tibia, proximal humerus, and the sternum (in selected systems).



The most commonly used site is the proximal tibia. The insertion point is located approximately two centimeters below the tibial tuberosity and one to two centimeters medially. This site is easy to identify even in critically ill patients because the tibial tuberosity serves as a clear anatomical landmark.



The second very good insertion site is the proximal humerus. The insertion point is located in the region of the greater tubercle of the humerus. Access in this location provides very rapid drug delivery to the central circulation because the medullary cavity of this bone is directly connected to the circulation of the shoulder girdle.

In some systems the sternum is also used; however, this requires specialized equipment and experience and is therefore used less frequently.

In children, the distal tibia is also commonly used, several centimeters above the medial malleolus.

Equipment used

Special high-strength needles are used to obtain intraosseous access. These needles are capable of penetrating the cortical layer of the bone and introducing a cannula into the medullary cavity.

The most commonly used system in emergency medicine is an automatic drill-based system (e.g., EZ-IO), which allows rapid and safe insertion of the needle into the bone. Alternatively, manual needles are used and inserted using a rotational motion.

The basic kit for performing intraosseous access includes:

- an intraosseous needle of appropriate length
- an insertion device (manual or automatic)
- a syringe with normal saline for flushing the line
- an infusion set
- disinfectants
- gloves
- a stabilization dressing

Selecting the correct needle length is very important. The needle must pass through the layer of subcutaneous tissue and the bone cortex, while its tip must ultimately reach the medullary cavity.

Technique of Placement

The technique of establishing intraosseous access must be performed according to a structured sequence of actions. Correct identification of the anatomical landmark, stabilization of the limb, and verification of needle placement after insertion are of key importance. The procedure should be performed as quickly as possible while maintaining strict aseptic technique.

Procedure

1. Identification of indications and insertion site

- selection of an appropriate bone (most commonly the proximal tibia or proximal humerus)
- identification of anatomical landmarks
- assessment of contraindications at the selected site

2. Equipment preparation

- intraosseous needle of appropriate length
- insertion device (e.g., powered drill system)
- syringe with 0.9% NaCl
- infusion set
- antiseptic solution
- gloves
- stabilizing dressing

3. Preparation of the insertion site

- skin disinfection
- stabilization of the limb
- local anesthesia in conscious patients if necessary

4. Needle positioning

- the needle should be positioned perpendicular (approximately 90°) to the surface of the bone
- the tip of the needle should be placed precisely over the selected anatomical landmark

5. Needle insertion into the bone

- in automated systems, the insertion device is activated
- in manual systems, the needle is advanced with a rotational motion and pressure
- penetration through the cortical layer of the bone is usually felt as a sudden decrease in resistance

6. Removal of the stylet

- once the needle is correctly inserted, the stylet is removed
- the cannula remains in the medullary cavity

7. Confirmation of correct placement

- aspiration of bone marrow (not always possible)
- easy administration of fluids
- absence of swelling at the insertion site
- stability of the needle within the bone

8. Flushing the access

- rapid administration of 0.9% NaCl
- in adults usually approximately 10 ml under pressure

9. Connection of the infusion set

- attachment of an extension line or infusion set
- initiation of fluid or medication administration

10. Stabilization of the access

Medications

Almost all medications used in resuscitation and emergency medicine can be administered via intraosseous access. These include adrenaline, amiodarone, analgesics, sedatives, and infusion fluids. Drug dosing is the same as for the intravenous route.

Each medication administration should be preceded by flushing the access with normal saline to ensure that the cannula remains patent. After the drug has been administered, the access should be flushed again to facilitate transport of the medication into the central circulation.

In conscious patients, infusion into the medullary cavity may cause significant pain. Therefore, before starting fluid administration, lidocaine should be administered intraosseously to significantly reduce pain.

Most commonly administered medications via intraosseous access:

- adrenaline
- amiodarone
- lidocaine
- atropine
- magnesium sulfate
- fentanyl
- morphine
- ketamine
- midazolam
- propofol
- lidocaine (for analgesia prior to intraosseous infusion)
- crystalloids (0.9% NaCl, balanced electrolyte solutions)
- blood products

Complications

Intraosseous access is a safe procedure; however, complications may occur. The most common complication is extravasation of fluid into the surrounding soft tissues, which may lead to compartment syndrome. Less frequently, infections, osteomyelitis, or damage to the growth plate in children may occur.

Proper insertion technique and accurate identification of anatomical landmarks significantly reduce the risk of complications.

Duration of Use

Intraosseous access is considered a temporary solution. Once stable intravenous or central venous access has been obtained, the intraosseous needle should be removed. Most guidelines recommend that IO access should not remain in the bone for longer than approximately twenty-four hours.

Analysis of critical parameters.

RKZ (acid-base balance)

RKZ is a state in which the body maintains a constant pH of body fluids (especially blood)
within a narrow range thanks to the cooperation of:

- **buffers** (act immediately – bind/release H^+ ions),
- **lungs** (regulate the amount of CO_2 via ventilation within minutes),
- **kidneys** (regulate HCO_3^- and H^+ excretion over hours–days).

The goal of RKZ is to ensure proper functioning of enzymes, cells, and organs.

The body maintains blood pH within a narrow range of approx. 7.35–7.45, because pH affects:

- enzyme activity,
- cardiac muscle contractility,
- neuromuscular excitability,
- oxygen binding by hemoglobin (Bohr effect),
- electrolyte distribution (especially potassium).

In physiology, the "main acid" is, in practice, CO_2, because:

CO_2 diffuses into the blood and, in the presence of water, forms the system:

$$\mathbf{CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-}$$

Buffer system

A buffer is a system that limits pH fluctuations by binding or releasing H^+ ions.

Buffers act immediately, before the lungs and kidneys respond.

The most important buffers in the body

A) Bicarbonate buffer (HCO_3^-/CO_2) – the most important in blood

Henderson–Hasselbalch equation

- pH depends on the ratio of HCO_3^- / $PaCO_2$

This explains why:

- hypoventilation (CO_2↑) rapidly lowers pH,
- hyperventilation (CO_2↓) rapidly raises pH.

B) Hemoglobin buffer (Hb/HbH) – key in red blood cells

Hemoglobin binds H^+ (especially in the deoxygenated form).

C) Protein buffer (plasma proteins)

Albumin and other proteins have groups capable of binding H^+.

D) Phosphate buffer ($H_2PO_4^-/HPO_4^{2-}$)

Three lines of pH defense: buffers → lungs → kidneys

1) Buffers (seconds)

They immediately "dampen" the pH change, but do not remove the cause.

2) Lungs (minutes)

Ventilation regulates CO_2:

- acidosis → the body increases ventilation (CO_2↓) = compensation,
- alkalosis → decreases ventilation (CO_2↑) = compensation

3) Kidneys (hours–days)

Kidneys:

- reabsorb almost all filtered HCO_3^-,
- produce "new" HCO_3^- by excreting H^+

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Acid-base balance

- **Normal pH: 7.35–7.45**
- **Normal ($PaCO_2$): 35–45 mmHg (≈ 4.7–6.0 kPa)**
- **Normal HCO_3^- (bicarbonate): 22–26 mmol/L**
- **Normal PaO2: 80–100 mmHg**

Example of RKZ

RADIOMETER ABL 800 FLEX

ABL837 ITM Strona B
RAPORT PACJENTA   Strzykawka - S 250uL   16:01 Próbka #   2022-03-13 8996

Identyfikacja

Numer dostepu	
Nazwisko pacjenta	MATLAK
Imie pacjenta	
Data urodzenia	
Typ próbki	Tętnicza
FO2(I)	30,0 %
T	37,0 °C
Operator	Anonimowo

Wartości gazometrii			
pH 1	7,399		[7,350 - 7,450]
pCO2 2	42,3	mmHg	[-]
pO2 3	83,5	mmHg	[83.0 - 108]
Wartości oksymetrii			
ctHb	10,5	g/dL	[-]
Hct,c	32,5	%	[-]
sO2	96,1	%	[95,0 - 99,0]
FO2Hb	94,5	%	[94,0 - 99,0]
FCOHb	0,8	%	[0,5 - 1,5]
FMetHb	0,9	%	[0,0 - 1,5]
FHHb	3,8	%	
Wartości elektrolitów			
cK+	4,3	meq/L	[3,5 - 5,0]
cNa+	139	meq/L	[136 - 146]
cCa2+	1,19	mmol/L	[1,15 - 1,29]
↑ cCl-	106	meq/L	[98 - 106]
Wartości metabolitu			
↑ cGlu	7,2	mmol/L	[3,9 - 5,8]
? cLac	1,0	mmol/L	[0,5 - 1,6]
↑ cCrea	135	µmol/L	[44 - 124]
ctBil	8	µmol/L	[1 - 17]
Poprawione wartości temperatury			
? pH(T)	7,399		
pCO2(T)	42,3	mmHg	
pO2(T)	83,5	mmHg	
Status tlenu			
ctO2,c	14,1	Vol%	[-]
? p50,c	26,55	mmHg	[-]
Status kwas/zasad.			
? SBE,c 4	1,3	mmol/L	[-]
? cHCO3-(P,st),c 5	25,4	mmol/L	[-]
Wartości przeliczone			
?↓ Luka anionowa,c	7,5	meq/L	[8,0 - 16,0]

Quick algorithm for interpreting blood gas analysis

1. **What is the patient's condition?**
2. **Assess oxygenation (Is the patient hypoxic?)**
3. **Determine pH (Is the patient in acidosis or alkalosis?)**
4. **Assess the respiratory component**

- $PaCO_2$ ↑ → "moves toward respiratory acidosis"
- $PaCO_2$ ↓ → "moves toward respiratory alkalosis"

5. **Assess the metabolic component**

- HCO_3^- ↓ → "moves toward metabolic acidosis"
- HCO_3^- ↑ → "moves toward metabolic alkalosis"

6. **Assess: lactate + glucose + ketones + creatinine**

DISORDERS:

Metabolic acidosis

Acidosis with an increased anion gap

Main causes:

- **lactic: shock, hypoxia, sepsis, seizures, severe anemia, CO poisoning, etc.**
- **ketoacidosis: DKA (diabetic), alcoholic, starvation**
- **uremic: advanced renal failure**
- **toxic: methanol, ethylene glycol, salicylates (often mixed disorders here)**

Metabolic acidosis with a normal AG

Most often:

- diarrhea (HCO_3^- loss)
- renal tubular acidosis (RTA)
- iatrogenic after large volumes of 0.9% NaCl (hyperchloremia)

Metabolic alkalosis

Typically: loss of H^+ / Cl^- and volume depletion

- vomiting / gastric content aspiration
- loop/thiazide diuretics
- hypokalemia (often coexists)

Respiratory acidosis (hypoventilation)

Causes:

- respiratory depression (opioids, sedation)
- COPD/asthma with ventilatory failure
- neuromuscular diseases
- severe pneumonia, pulmonary edema (often mixed with metabolic)

Respiratory alkalosis (hyperventilation)

Causes:

- pain, anxiety, fever, (early) sepsis, hypoxia, pulmonary embolism

Electrolytes in the ED

Potassium (K^+)

Hyperkalemia

When is it dangerous?

- usually ≥ 6.0 mmol/L or
- a rapid rise or
- **ECG changes (this is a red flag regardless of the number)**

ECG: peaked T waves, widened QRS, prolonged PR, loss of P, "sine wave".

Hypokalemia

Dangerous because it is arrhythmogenic (especially with hypomagnesemia).

- mild: 3.0–3.5
- severe: < 3.0 (especially with symptoms)

ECG: flattened T wave, U-wave, prolonged QT, ventricular arrhythmias.

Sodium (Na^+)

Hyponatremia

Risk depends on:

- **neurologic symptoms (seizures, altered consciousness),**
- the rate of decline.

Biggest pitfall: correcting chronic hyponatremia too quickly → risk of osmotic demyelination syndrome (ODS). Therefore, correction must be controlled.

Hypernatremia

Most often "too little water": dehydration, osmotic diuresis, impaired thirst.
ED:

- if shock/hypovolemia → first isotonic fluids for stabilization, then replace free water (carefully).
- also do not correct too quickly (risk of cerebral edema in chronic cases).

Calcium (Ca^{2+})

Hypocalcemia

Symptoms: paresthesias, tetany, laryngospasm, seizures, QT prolongation.
ED:

- symptomatic/severe → i.v. calcium.
- check Mg^{2+}, albumin (total vs ionized Ca), causes (after transfusions: citrate, sepsis, acute pancreatitis, hypoparathyroidism).

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Hypercalcemia

Symptoms: dehydration, altered consciousness, QT shortening, arrhythmias.
ED:

- the cornerstone is i.v. hydration (usually 0.9% NaCl) and treatment of the cause
- further treatment (bisphosphonates, calcitonin) depending on etiology and consultation.

Management of a patient with hypothermia.

Definitions and Clinical Epidemiology

Definition

Accidental hypothermia is defined as an unintentional drop in core body temperature below 35°C (95°F).

Primary vs. Secondary Hypothermia

Primary hypothermia

Caused primarily by environmental exposure (e.g., mountain incidents, immersion, homelessness, loss of heating).

Secondary hypothermia

Occurs due to underlying medical conditions or intoxication (e.g., sepsis, hypoglycemia, stroke, trauma, alcohol, sedatives, endocrine disorders).

Frequently encountered in urban EMS and emergency departments.

Clinical Importance in EMS and ED

Hypothermia is associated with coagulopathy, hemodynamic instability, and increased susceptibility to arrhythmias and cardiac arrest. Severe hypothermia may allow good neurological outcomes even after prolonged resuscitation if appropriate rewarming (including ECLS/ECMO when indicated) is provided.

Thermoregulation and Pathophysiology

Mechanisms of Heat Loss

Heat is lost through the following mechanisms:

Radiation (often the largest component in typical exposure).

Convection (wind, air movement).

Conduction (contact with cold surfaces, wet clothing).

Evaporation (wet skin/clothing, perspiration, respiration).

Physiological Response to Cold

The progression of hypothermia commonly follows:

Peripheral vasoconstriction leading to centralization of circulation.

Shivering with increased metabolic heat production.

Exhaustion of compensatory mechanisms (fatigue, glycogen depletion, hypoglycemia).

Central nervous system depression and slowing of conduction.

Bradycardia and progressive myocardial instability.

Increased risk of ventricular arrhythmias and cardiac arrest.

Organ System Effects Relevant to EMS

Cardiovascular

Bradycardia and reduced cardiac output.

Prolonged conduction intervals and increased susceptibility to ventricular fibrillation, especially with rough handling.

Respiratory

Hypoventilation and reduced respiratory drive in severe hypothermia.

Increased risk of aspiration due to depressed protective reflexes.

Neurological

Slowed cognition, ataxia, altered mental status; paradoxical undressing may occur.

Coma and apparent death-like presentation in severe hypothermia.

Coagulation

Hypothermia impairs coagulation pathways and platelet function.

In trauma, hypothermia contributes to the lethal diamond (hypothermia, acidosis, coagulopathy, hypocalcemia).

Assessment of the Hypothermic Patient in EMS

Safety and the Minimal Handling Principle

Patients with moderate to severe hypothermia should be managed with gentle handling, horizontal positioning, avoidance of sudden movements, and avoidance of unnecessary manipulation. These measures reduce the risk of ventricular arrhythmias and rescue collapse.

ABCDE Approach – Practical Modifications

A – Airway

Assess airway patency and aspiration risk. Airway interventions should minimize heat loss.

B – Breathing

Assess respiratory rate and oxygen saturation. Provide oxygen when clinically indicated. Warmed, humidified oxygen may support internal rewarming if available.

C – Circulation

Bradycardia is common. Pulse checks may require prolonged assessment. Continuous ECG monitoring is recommended; be prepared for hemodynamic deterioration.

D – Disability

Evaluate AVPU/GCS and measure blood glucose. Consider secondary causes (e.g., intoxication, stroke, sepsis).

E – Exposure / Environment

Immediately stop further heat loss: insulate from the ground, protect from wind and moisture, remove wet layers when possible, and apply layered insulation.

Core Temperature Measurement

Treatment decisions in severe hypothermia depend on core temperature rather than peripheral temperature. Preferred methods depend on context and availability:

Esophageal probe (intubated patients).

Bladder probe (with temperature-capable catheter).

Rectal probe (may lag during dynamic changes and may be affected by afterdrop).

Tympanic measurement only with appropriate devices and technique.

When reliable core measurement is not available, clinical staging and risk assessment remain essential for decision-making.

Classification of Hypothermia – The Swiss Staging System

The Swiss staging system is a clinical classification used particularly in prehospital environments when core temperature measurement is unavailable. It correlates clinical presentation with approximate temperature ranges, but individual variability is significant; staging should primarily guide risk assessment and logistics rather than precise temperature estimation.

Swiss Hypothermia Stages (HT I–HT IV)

Stage	Clinical Presentation	Approx. Core Temperature	Cardiac Arrest Risk
HT I	Conscious; shivering typically present	35–32°C	Low
HT II	Impaired consciousness; shivering reduced/absent	32–28°C	Increased
HT III	Unconscious; vital signs present	28–24°C	High
HT IV	Apparent death / cardiac arrest	<24°C	Present

Recent recommendations (e.g., ICAR MedCom) emphasize assessment of responsiveness and cardiac arrest risk rather than temperature approximation alone.

Afterdrop and Rewarming Shock

Afterdrop

Afterdrop is a continued decline in core temperature after rewarming or evacuation has begun.

Mechanisms:

Return of cold peripheral blood to the core during vasodilation and reperfusion.

Heat transfer from the warm core to the cold periphery (thermal gradient).

Clinical consequences:

Further core cooling despite initiated care.

Increased risk of arrhythmias and hemodynamic deterioration in moderate to severe hypothermia.

Practical risk factors:

Aggressive limb warming without simultaneous trunk warming.

Excessive movement, ambulation, or sudden verticalization.

Massage of cold extremities.

Insufficient insulation during transport.

Prevention (prehospital):

Prioritize trunk rewarming.

Minimize handling; transport horizontally when feasible.

Avoid isolated limb warming in moderate to severe hypothermia.

Rewarming Shock

Rewarming shock refers to hemodynamic collapse during or shortly after rewarming. Clinically, it may present as hypotension, worsening perfusion, and arrhythmias.

Mechanisms (clinical model):

Peripheral vasodilation leading to relative hypovolemia (vascular capacitance increase).

Redistribution of blood from central to peripheral circulation.

Combined effects of afterdrop and an irritable hypothermic myocardium.

Coexisting dehydration, infection, intoxication, or trauma.

Prehospital implications:

Monitor blood pressure and ECG continuously in moderate to severe hypothermia.

Use warmed IV fluids when indicated for shock/hypovolemia (not as a sole rewarming method).

Avoid rapid peripheral warming; focus on trunk warming and insulation.

Plan early transport to an appropriate facility.

Prehospital Management Algorithm

Immediate Priorities

Stop further heat loss (wind, moisture, cold ground).

Minimal handling and horizontal positioning in HT II–IV.

ABCDE assessment with blood glucose measurement.

Continuous ECG monitoring.

Classify clinically (Swiss staging) and determine cardiac arrest risk.

Early transport decision, including consideration of ECLS/ECMO centers for severe cases.

Insulation and Packaging

A practical layered approach:

Remove wet clothing when feasible; replace with dry layers.

Apply insulating layers (blankets, sleeping bag, thermal wraps).

Add a windproof/waterproof vapor barrier layer.

Insulate from the ground (mat, vacuum mattress, improvised insulation).

Apply heat sources to the trunk (chest/back/axillae), not primarily to the limbs.

Rewarming Strategies

Mild hypothermia (HT I)

Passive rewarming: dry clothing, insulation, warm environment.

Warm, sweet oral fluids if fully conscious and low aspiration risk.

Active trunk warming when available.

Moderate to severe hypothermia (HT II–III)

Active external trunk rewarming (e.g., forced-air warming, heat packs on the trunk).

Oxygen as indicated; warmed, humidified oxygen if available.

Warmed IV fluids when indicated for shock/hypovolemia.

Continuous ECG monitoring and readiness for cardiac arrest.

Cardiac arrest (HT IV)

Start resuscitation according to special circumstance guidelines.

Continue insulation and trunk warming during CPR.

When feasible, transport to a center capable of extracorporeal rewarming (ECLS/ECMO).

Common Prehospital Errors

Forcing ambulation or aggressive activity in HT II/III.

Aggressive limb warming without trunk warming.

Inadequate insulation during procedures and transport.

Neglecting blood glucose measurement and evaluation for secondary causes.

Premature declaration of death without appropriate assessment in suspected severe hypothermia.

Take-Home Messages

Stop heat loss first: insulation, wind and moisture protection, and removal of wet layers when feasible.

Handle gently and keep the patient horizontal in moderate to severe hypothermia.

Warm the trunk rather than focusing on extremities.

Anticipate afterdrop; avoid excessive movement and isolated limb warming.

Monitor for rewarming shock and treat shock with warmed fluids when indicated.

Consider extracorporeal rewarming pathways for severe cases, depending on system capabilities.

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Management of trauma patients based on the ITLS guidelines.

Introduction

Assessment of the scene and rescuer safety constitute the first step in trauma care. During the approach to the scene, rescuers should analyze potential hazards and plan the operational strategy of the emergency medical team.
Information provided by the dispatcher may assist in planning the response; however, such information is often incomplete or inaccurate.
Therefore, upon arrival, rescuers must independently assess the situation.

The first operational decision should be the selection of a safe location to park the ambulance.
The vehicle should be positioned as close as possible to the incident while maintaining a distance that allows safe scene assessment without exposing the team to additional hazards.
Whenever possible, the ambulance should be positioned facing away from the scene to allow rapid patient loading and immediate departure if the situation deteriorates.

Scene Safety

Before exiting the vehicle, rescuers should perform a preliminary scene survey through the windshield, commonly referred to as a "windshield survey."
This allows identification of obvious hazards before approaching the patient.

Potential hazards include:

• fire or presence of toxic substances
• risk of electrical injury
• unstable structures or surfaces (e.g., ice, slopes, damaged buildings)
• oxygen-deficient environments or toxic gases

Particularly dangerous environments include sewers, silos, cargo holds, and confined tanks where oxygen deficiency or toxic atmospheres may occur.
Rescuers should not enter such environments without appropriate protective equipment and specialized support teams.

Mechanism of Injury

Mechanism of injury describes the process by which energy is transferred to the patient's body.
Understanding the mechanism of injury helps predict potential internal injuries and guides diagnostic and therapeutic decisions.

The primary factor responsible for tissue damage is kinetic energy, which is proportional to the mass of the object and the square of its velocity.
Consequently, increases in velocity have a much greater impact on injury severity than increases in mass.

Two major categories of trauma are recognized:

• blunt trauma
• penetrating trauma

In many real-world incidents, both mechanisms may occur simultaneously.

Blunt Trauma

Blunt trauma occurs when force is applied to the body without disruption of the skin.
These injuries often result from rapid deceleration forces that cause internal organs to continue moving within the body cavity after the body has stopped moving.

Penetrating Trauma

Penetrating trauma occurs when an object pierces the skin and underlying tissues.
Common causes include violence, accidents, or firearm injuries.

Typical penetrating injuries include:

• stab wounds
• gunshot wounds
• injuries caused by high-velocity fragments such as metal or glass

Primary Survey

Modern trauma management follows the CABCDE approach:

C – control of massive hemorrhage
A – airway management
B – breathing assessment
C – circulation assessment
D – disability / neurological status
E – exposure and prevention of hypothermia

The purpose of the primary survey is the rapid identification and immediate treatment of life-threatening conditions.

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Rapid Trauma Assessment

Rapid trauma assessment is a systematic examination of the patient designed to identify potential injuries.

Head and neck assessment includes evaluation for wounds, jugular venous distension, and tracheal deviation.

Chest examination focuses on symmetry of respiratory movement, paradoxical motion, bruising, wounds, tenderness, instability, and crepitus.
Breath sounds and heart sounds should also be assessed.

Abdominal examination includes evaluation for bruising, wounds, evisceration, tenderness, guarding, or abdominal distension.

Pelvic assessment focuses on pain, deformity, and instability.

Extremities should be assessed for deformities, swelling, distal sensation, and motor function.

Reassessment

Reassessment is the ongoing evaluation of the patient's condition and the effectiveness of treatment interventions.

It should be performed repeatedly during patient transport.

Recommended frequency:

- **every 5 minutes in unstable patients**
- **every 15 minutes in stable patients**

Reassessment should also be performed after any intervention, patient movement, or change in clinical condition.

Vital signs that should be monitored include:

• heart rate
• respiratory rate
• blood pressure
• oxygen saturation (SpO_2)
• ECG monitoring
• end-tidal CO_2 ($ETCO_2$)
• body temperature

SHOCK AND HEMORRHAGE CONTROL

Introduction

Management of shock has been the subject of extensive research over recent decades. As a result, recommendations regarding prehospital trauma care have evolved, particularly in the management of hemorrhagic shock.
Experience gained during military conflicts, including operations in Iraq and Afghanistan, has significantly influenced modern strategies for the management of massive bleeding.

Shock is defined as a state of tissue hypoxia resulting from one or more of the following mechanisms:

- decreased oxygen delivery to tissues
- increased oxygen consumption
- impaired cellular utilization of oxygen

In most cases, shock results from circulatory system failure leading to inadequate organ perfusion.
Initially, shock may be reversible; however, rapid recognition and immediate treatment are essential to prevent progression to irreversible organ failure.

Stages of Shock

The progression of shock is typically divided into three stages:

- compensated shock
- decompensated shock
- irreversible shock

Early recognition during the compensated stage significantly improves patient outcomes.

Requirements for Adequate Tissue Perfusion

Adequate tissue perfusion depends on several key physiological factors:

1. Adequate circulating blood volume
2. Efficient pulmonary gas exchange
3. Intact vascular system capable of maintaining blood flow
4. Effective cardiac pump function

Disturbance of any of these elements may result in the development of shock.

Classification of Shock

Based on the underlying cause, shock is commonly divided into four major categories:

- **Hypovolemic shock** – caused by loss of circulating blood volume
- **Distributive shock** – caused by abnormal vasodilation and maldistribution of blood

flow
• **Obstructive shock** – caused by mechanical obstruction of blood circulation
• **Cardiogenic shock** – caused by failure of the heart as a pump

Hypovolemic Shock

Hypovolemic shock results from an absolute loss of intravascular volume, most commonly due to bleeding or fluid loss.

Common causes include:

• external hemorrhage
• internal hemorrhage
• severe vomiting or diarrhea
• fluid shifts into the "third space"
• burns
• peritonitis

Compensatory Mechanisms

The body activates several compensatory mechanisms in an attempt to maintain perfusion of vital organs such as the brain and heart.

These mechanisms include:

• activation of the sympathetic nervous system
• release of catecholamines
• peripheral vasoconstriction
• redistribution of blood flow toward critical organs

These responses often maintain normal blood pressure during early stages of blood loss.

Early Signs of Shock

Clinical manifestations during the compensated stage result from the body's compensatory responses.

Common early signs include:

- dizziness
- weakness
- increased thirst
- pale skin
- tachycardia
- tachypnea
- cool, clammy skin
- decreased urine output
- weak peripheral pulses

Late Signs of Shock

When compensatory mechanisms fail, the patient progresses to decompensated shock.

Typical late manifestations include:

- hypotension
- altered mental status
- confusion or agitation
- decreased level of consciousness
- coma
- cardiac arrest

Hemorrhage Control

Immediate control of bleeding is the first priority in trauma care.

Methods of hemorrhage control include:

- direct pressure
- pressure dressing
- tourniquet application when other methods fail

These interventions should be implemented during the primary survey when life-threatening bleeding is identified.

Fluid Therapy

If signs of shock persist despite hemorrhage control, additional resuscitation measures should be initiated.

Prehospital management includes:

• positioning the patient supine
• administration of high-flow oxygen
• rapid transport to an appropriate hospital
• establishing large-bore intravenous access
• initiation of crystalloid fluid therapy

Recommended initial fluid bolus:

Adult: 500 mL crystalloid bolus
Child: 20 mL/kg crystalloid bolus

The primary goal of resuscitation is restoration of tissue perfusion rather than normalization of blood pressure.

Internal Bleeding

When internal bleeding is suspected, rapid transport to a trauma center is essential.

Prehospital management focuses on:

• rapid transport
• oxygen therapy
• intravenous access
• cautious fluid administration to maintain perfusion
• continuous monitoring of vital signs
• repeated trauma reassessment

Excessive fluid administration may worsen bleeding by increasing blood pressure and disrupting clot formation.

Hemostatic Agents

If bleeding cannot be controlled with direct pressure or a tourniquet, hemostatic agents may be used as an adjunctive measure.

These agents promote clot formation at the bleeding site but should not replace mechanical hemorrhage control.

Tranexamic Acid (TXA)

Tranexamic acid is an antifibrinolytic medication that inhibits the breakdown of blood clots.

Clinical studies have demonstrated that early administration of TXA in trauma patients with significant hemorrhage reduces mortality due to bleeding.

Maximum benefit occurs when TXA is administered within the first 3 hours after injury.

Recommended dosing regimen:

Initial dose: 1 g administered over 10 minutes
Maintenance dose: 1 g infused over 8 hours

CHEST TRAUMA AND SPINE TRAUMA

Significance of Chest Trauma

The chest contains several organs essential for life, including the lungs, heart, and major blood vessels.
Injuries to these structures may rapidly lead to life-threatening conditions. Early recognition and prompt management are therefore critical in trauma care.

Severe chest injuries most commonly result from:

• motor vehicle collisions
• falls from height
• penetrating trauma such as gunshot or stab wounds
• blunt trauma including crush injuries

Thoracic trauma is frequently associated with multisystem injuries and is responsible for approximately 20–25% of trauma-related deaths.

Thoracic Anatomy

The thoracic cage consists of twelve pairs of ribs extending from the thoracic vertebrae to the sternum.
These ribs protect the organs located within the chest cavity.

The chest wall includes:

• skin
• subcutaneous tissue
• muscles
• ribs
• neurovascular bundles

Neurovascular bundles run along the inferior border of each rib.
This anatomical feature is important when performing procedures such as needle decompression of the chest.

Pleural Space and Mediastinum

The lungs are covered by a thin membrane known as the pleura.

Two layers are distinguished:

• visceral pleura – covering the lung surface
• parietal pleura – lining the inner surface of the chest wall

The potential space between these layers is called the pleural cavity.

Air, blood, or fluid may accumulate in this space, resulting in:

• pneumothorax (air)
• hemothorax (blood)
• pleural effusion (fluid)

The mediastinum lies between the lungs and contains the heart, aorta, vena cava, trachea, main bronchi, and esophagus.

Tension Pneumothorax

Tension pneumothorax occurs when air enters the pleural cavity but cannot escape. This results in progressive accumulation of pressure within the thoracic cavity.

Increasing intrathoracic pressure leads to:

• collapse of the affected lung
• mediastinal shift toward the opposite side
• compression of major venous structures
• decreased venous return to the heart
• development of obstructive shock

Clinical signs may include dyspnea, tachypnea, tachycardia, hypotension, jugular venous distension, and unilateral absence of breath sounds.

Management of Tension Pneumothorax

Prehospital management includes:

• ensuring airway patency
• administration of high-flow oxygen
• emergency needle decompression when indicated
• rapid transport to an appropriate trauma center

Needle decompression is a temporary but life-saving intervention until definitive chest drainage can be performed in the hospital setting.

Open Pneumothorax

Open pneumothorax occurs when a penetrating injury creates a direct communication between the pleural cavity and the external environment.

Air enters the chest through the wound during inspiration, leading to lung collapse and impaired ventilation.

Management includes:

• airway management
• administration of oxygen
• sealing the wound with an occlusive dressing
• rapid transport to a trauma center

Cardiac Tamponade

Cardiac tamponade results from accumulation of blood or fluid within the pericardial sac surrounding the heart.
This accumulation compresses the heart and prevents adequate ventricular filling.

The classic Beck's triad includes:

• hypotension
• distended neck veins
• muffled heart sounds

Prehospital treatment focuses primarily on rapid transport to definitive care.

Cardiac Contusion

Cardiac contusion is a consequence of blunt chest trauma, commonly seen in motor vehicle collisions or high-energy impacts to the chest.

Clinical manifestations may resemble myocardial infarction and include:

• chest pain
• arrhythmias
• signs of heart failure

Diagnosis often relies on electrocardiographic abnormalities and clinical suspicion.

Massive Hemothorax

Massive hemothorax refers to significant accumulation of blood within the pleural cavity, typically exceeding 1000 mL.

Signs may include:

- hypotension
- tachycardia
- dyspnea
- diminished breath sounds on the affected side

Prehospital care focuses on airway management, oxygen therapy, treatment of shock, and rapid transport to a trauma center.

Flail Chest

Flail chest occurs when at least two adjacent ribs are fractured in two places, creating a free-floating segment of the chest wall.

The characteristic finding is paradoxical chest movement:

- during inspiration – the flail segment moves inward
- during expiration – the segment moves outward

Management includes oxygen therapy, adequate analgesia, and ventilatory support when necessary.

Tracheobronchial Injuries

Injuries to the trachea or main bronchi may result from penetrating trauma or severe blunt force.

Clinical manifestations may include:

- respiratory distress
- subcutaneous emphysema
- pneumothorax
- hemothorax

Diagnosis in the prehospital setting is challenging and requires a high index of suspicion.

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Aortic Injury

Traumatic rupture of the thoracic aorta is one of the most lethal complications of chest trauma.

It most commonly results from rapid deceleration injuries such as high-speed motor vehicle collisions or falls from height.

Typical symptoms include severe chest pain, interscapular pain, and differences in blood pressure between the upper extremities.

Spine Trauma

The vertebral column consists of 33 vertebrae divided into five regions:

- cervical – 7 vertebrae
- thoracic – 12 vertebrae
- lumbar – 5 vertebrae
- sacral – 5 fused vertebrae
- coccygeal – 4 fused vertebrae

The spinal cord runs within the vertebral canal and is responsible for transmission of nerve impulses between the brain and the rest of the body.

Spinal Cord Injury

Damage to the spinal cord may result in:

- loss of sensation
- motor deficits or paralysis
- spinal shock

Common mechanisms of spinal injury include hyperflexion, hyperextension, rotation, and axial compression.

Spinal Motion Restriction (SMR)

Modern trauma care emphasizes selective spinal motion restriction rather than routine full immobilization.

The goal of SMR is to minimize spinal movement while maintaining patient comfort and avoiding complications associated with rigid immobilization.

Common methods include:

• vacuum mattress stretcher
• stretcher with head blocks and straps
• careful patient positioning

Rigid spine boards are now primarily used for short-distance extrication rather than prolonged transport.

Selected issues in disaster medicine

Theoretical Introduction

Disaster medicine is a field of medicine focused on the organization and management of medical response in situations where the number of casualties exceeds the available resources of the emergency response system. Its primary objective is to reduce mortality through the efficient use of personnel and resources in conditions characterized by chaos, time pressure, and shortages of staff, equipment, and medications. Unlike emergency medicine, which focuses on the individual patient, disaster medicine concentrates on the population, aiming to save the greatest possible number of lives with limited resources.

A key component of disaster response is medical triage, defined as the rapid assessment of casualties and their assignment to categories of treatment or evacuation priority. The purpose of triage is to achieve the best possible outcomes for the largest number of people through optimal allocation of available resources. Disaster medicine encompasses planning, preparedness, response, and recovery following an incident. It requires cooperation among medical services, rescue organizations, and administrative authorities. Its role is not limited to providing medical care but also includes ensuring the continuity of healthcare system functioning during crisis situations. Disaster medicine therefore constitutes an essential component of national health security and an integral element of crisis management.

The most widely known and commonly used triage system in the United States is the START system (Simple Triage and Rapid Treatment). It is simple and rapid and is based on four criteria: ability to walk, respiration, pulse, and mental status. Individuals who are able to walk are classified as green (minor). Those who do not breathe after airway opening are assigned the black category (deceased/expectant). Patients with a respiratory rate greater than 30 breaths per minute or without a palpable radial pulse are classified as red (immediate). The remaining patients with moderate injuries are categorized as yellow (delayed).

The advantage of the START system is its simplicity, which allows it to be used not only by medical personnel but also by firefighters, police officers, and trained volunteers. A version adapted to European conditions is the mSTART system, which incorporates slightly different assessment thresholds and introduces a more detailed evaluation of perfusion and neurological status. Currently, numerous modifications of the START system are used worldwide, which will be discussed in detail during the lectures.

The SALT system (Sort, Assess, Lifesaving interventions, Treatment/Transport), developed in the United States, adds the element of early life-saving interventions during the triage process itself. This allows responders to initiate immediate actions, such as hemorrhage control, even before the entire triage process has been completed.

In the United Kingdom, the Triage Sieve system is used, as well as other triage systems developed within the National Health Service (NHS) and used mainly by emergency services and the military. The system is extremely simple and is based primarily on the assessment of respiration and circulation. After the initial Triage Sieve assessment, medical personnel perform a more detailed Triage SORT, which utilizes the Revised Trauma Score (RTS) to assign appropriate treatment priorities.

The CareFlight system, widely used in Australia, follows a similar principle but introduces assessment of the patient's ability to walk and pulse presence, enabling faster triage in field conditions.

In Poland, there is no single triage system mandated by legislation; however, the most commonly applied approach is a model based on a modification of the START system.

Disaster medicine includes not only actions taken during the incident but also preparation and system recovery afterward. During the preparedness phase, crisis response plans are developed, training sessions and simulations are conducted, and equipment supplies are accumulated. In the response phase, the activities of emergency services are coordinated, priorities are established, and the evacuation of casualties is carried out. In the recovery phase, the response is analyzed, conclusions are drawn, and systemic errors are corrected.

An important component of this discipline involves ethical considerations. During disasters, medical professionals often face difficult decisions regarding whom to treat first and whom, despite severe condition, cannot receive full treatment due to limited resources. In such situations, the traditional principles of medical ethics may be superseded by the central principle of disaster medicine: "do the greatest good for the greatest number of people."

International organizations such as the World Health Organization (WHO), the International Red Cross, the European Union, and NATO cooperate in disaster response and preparedness. Poland participates in the European Civil Protection Mechanism and continues to develop its national emergency medical services system and crisis management structures. Specialized response teams such as the Polish Emergency Medical Team (EMT) take part in humanitarian missions worldwide, supporting rescue operations following earthquakes, floods, and other disasters. The COVID-19 pandemic represented a contemporary example of a global health crisis in which elements of disaster medicine played a crucial role in resource planning, patient evacuation, and prioritization of care.

CBRNE Incidents in Disaster Medicine

The acronym CBRNE refers to five categories of threats:

C – Chemical

B – Biological

R – Radiological

N – Nuclear

E – Explosive

CBRNE incidents are characterized by a high potential to cause mass casualties and major disruptions to healthcare systems. Unlike conventional mass casualty incidents, where injuries are primarily mechanical, CBRNE events may result in contamination, infectious disease outbreaks, radiation exposure, or explosive injuries, requiring specialized medical and logistical preparedness.

In disaster medicine, CBRNE incidents are considered high-risk mass casualty situations that require detailed planning, rapid response, and integration of multiple services, including medical, chemical, biological, military, and civilian organizations. Any CBRNE event may have global consequences, affecting populations, the environment, and economic stability.

Chemical threats primarily involve chemical warfare agents, industrial chemicals, and organic toxins. The biological (B) category includes pathogenic microorganisms and toxins capable of causing epidemics. Radiological and nuclear (R/N) threats involve the release of radioactive materials or the consequences of a nuclear explosion. Explosive (E) threats include improvised explosive devices (IEDs), industrial explosions, and transport-related accidents. Medical management in such events differs significantly from standard emergency response procedures, and response algorithms must be appropriately adapted.

Basic Definitions

Disaster medicine – a field of medicine concerned with the preparation, organization, and delivery of medical care in situations where the number of casualties exceeds the capacity of local emergency services and healthcare systems. *(WHO definition)*

Multiple casualty incident – an event involving more than one casualty but not exceeding the operational capacity of a single emergency team.

Mass casualty incident – an event in which the number of casualties exceeds the capabilities of the responding team at the scene.

Medical disaster – a situation in which the number of individuals requiring medical assistance significantly exceeds the available resources of emergency medical services and hospitals, necessitating the application of disaster medicine principles and medical triage.

Primary triage (initial triage) – an assessment performed at the incident scene by the first responding emergency services.

Secondary triage – reassessment performed at a medical point, during transport, or in the hospital.

Dynamic triage – a repeated assessment process performed as the patient's condition changes.

Active shooter – a situation in which the threat posed by an attacker has not been neutralized and there remains a risk from an armed assailant.

CBRNE – incidents involving chemical, biological, radiological, nuclear, and explosive hazards.

MASCAL (Mass Casualty Situation) – an incident involving a large number of casualties.

EMS team (ZRM – Emergency Medical Team) – a prehospital emergency medical response unit.

Medical Incident Commander (KAM) – the person responsible for coordinating medical operations at the scene.

Incident Commander (KDR) – the person responsible for coordinating overall rescue operations.

PSP – State Fire Service (Państwowa Straż Pożarna).

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Selected TRIAGE Systems

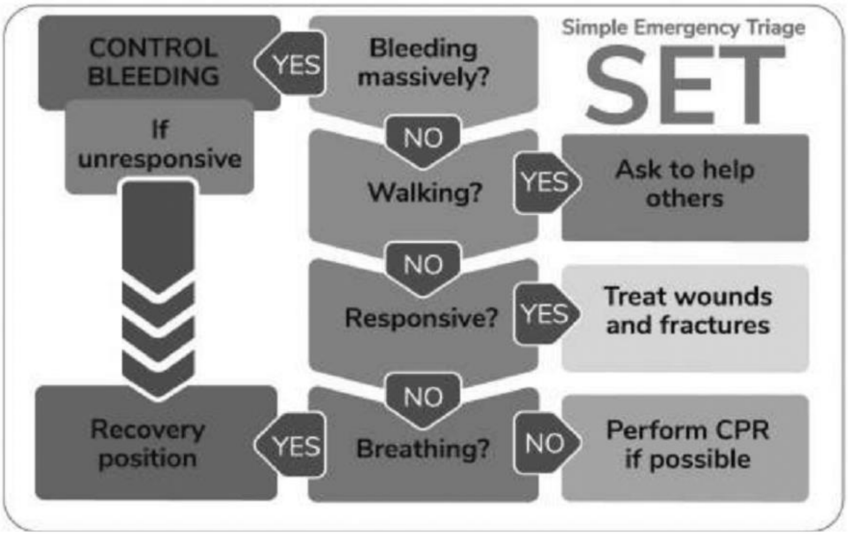

Figure 1Jaskuła J. et. al. Simple Emergency Triage (SET) - the new perspective on mass casualty incident triage. https://www.researchgate.net/publication/344729314_Simple_Emergency_Triage_SET_-_the_new_perspective_on_mass_casualty_incident_triage

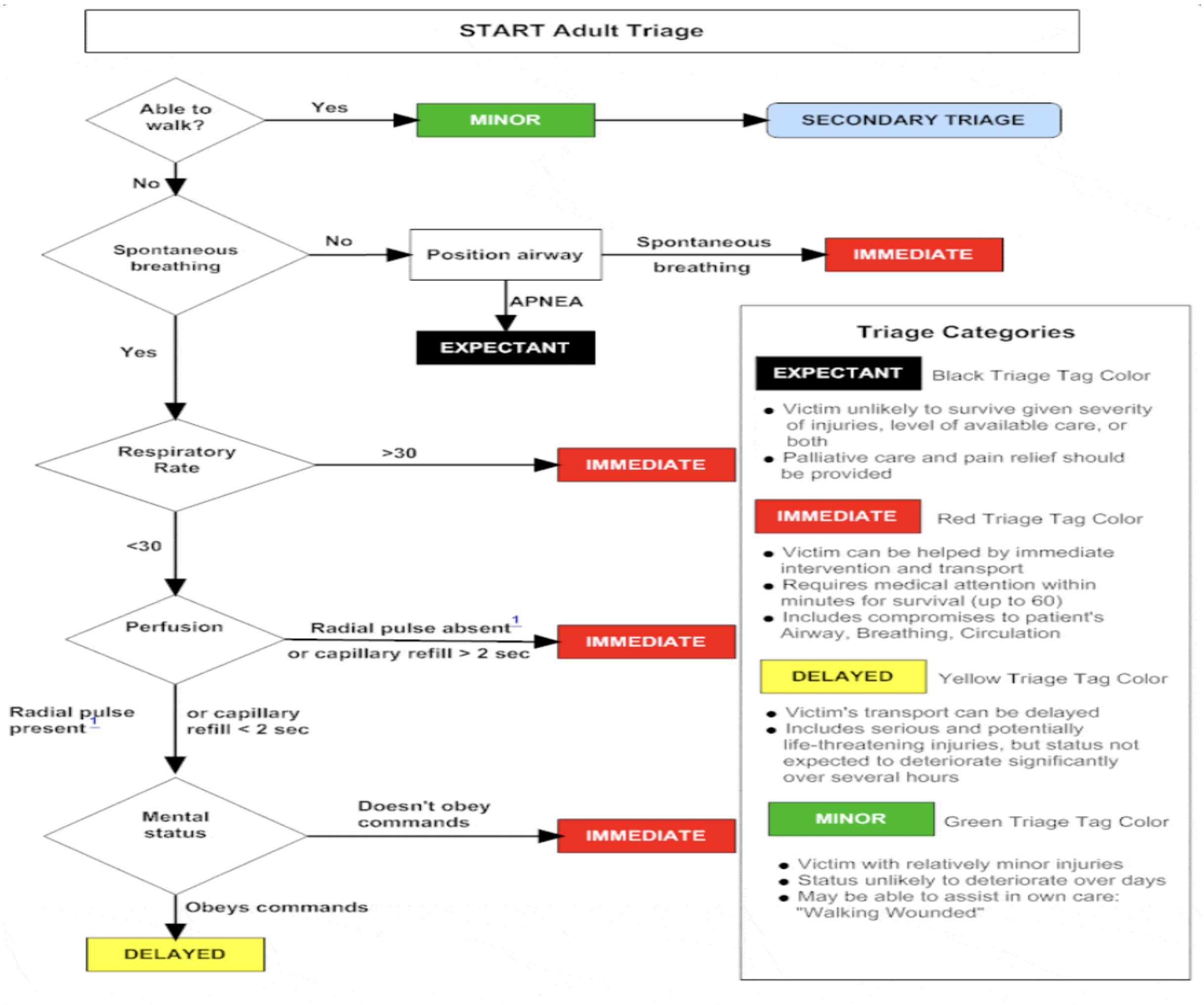

Figure 2 https://www.crisis-medicine.com/start-salt-and-ramp-triage-in-a-mass-casualty-event/

SALT Mass Casualty Triage Algorithm (Sort, Assess, Lifesaving Interventions, Treatment/Transport)

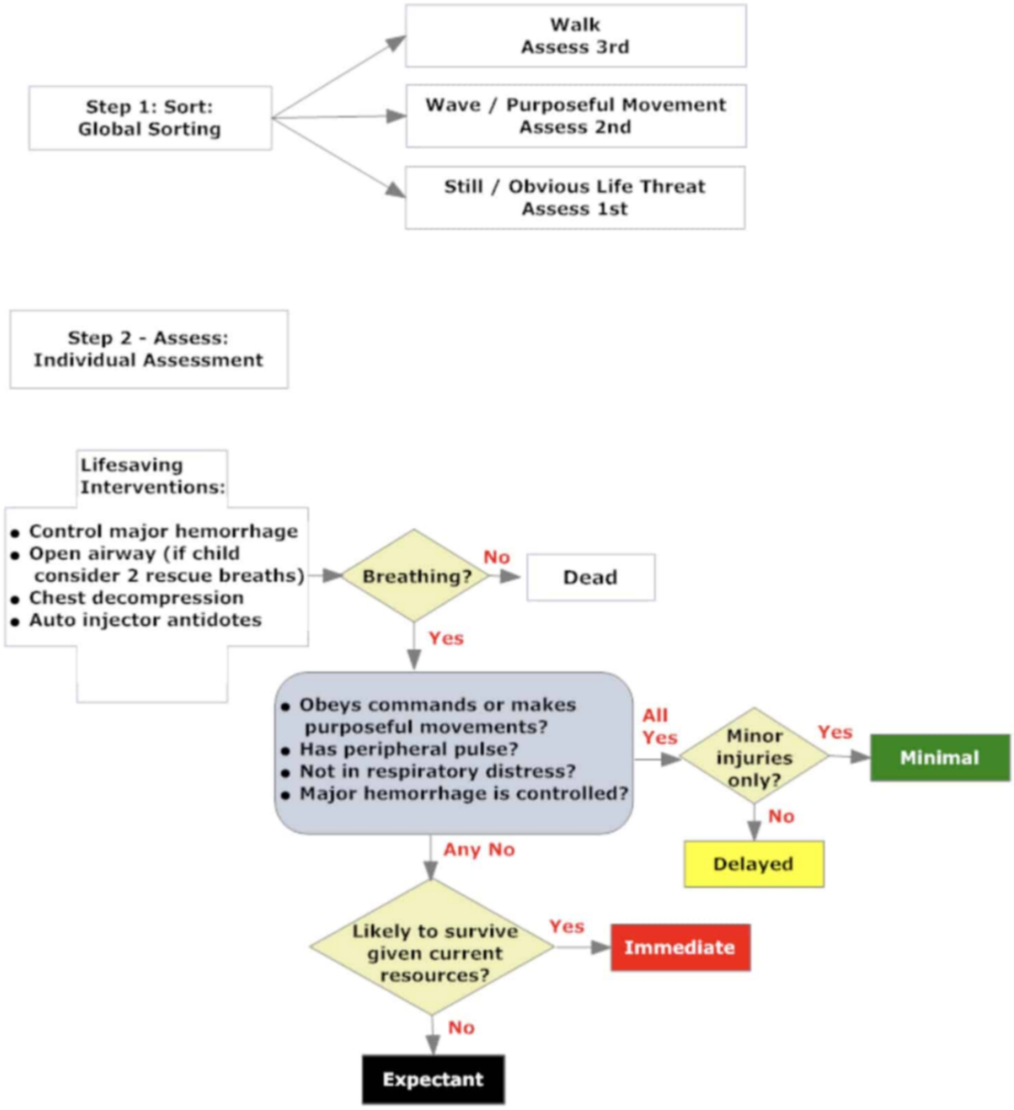

Figure 3 https://www.crisis-medicine.com/start-salt-and-ramp-triage-in-a-mass-casualty-event/

NHS Major Incident Triage Tool (MITT)

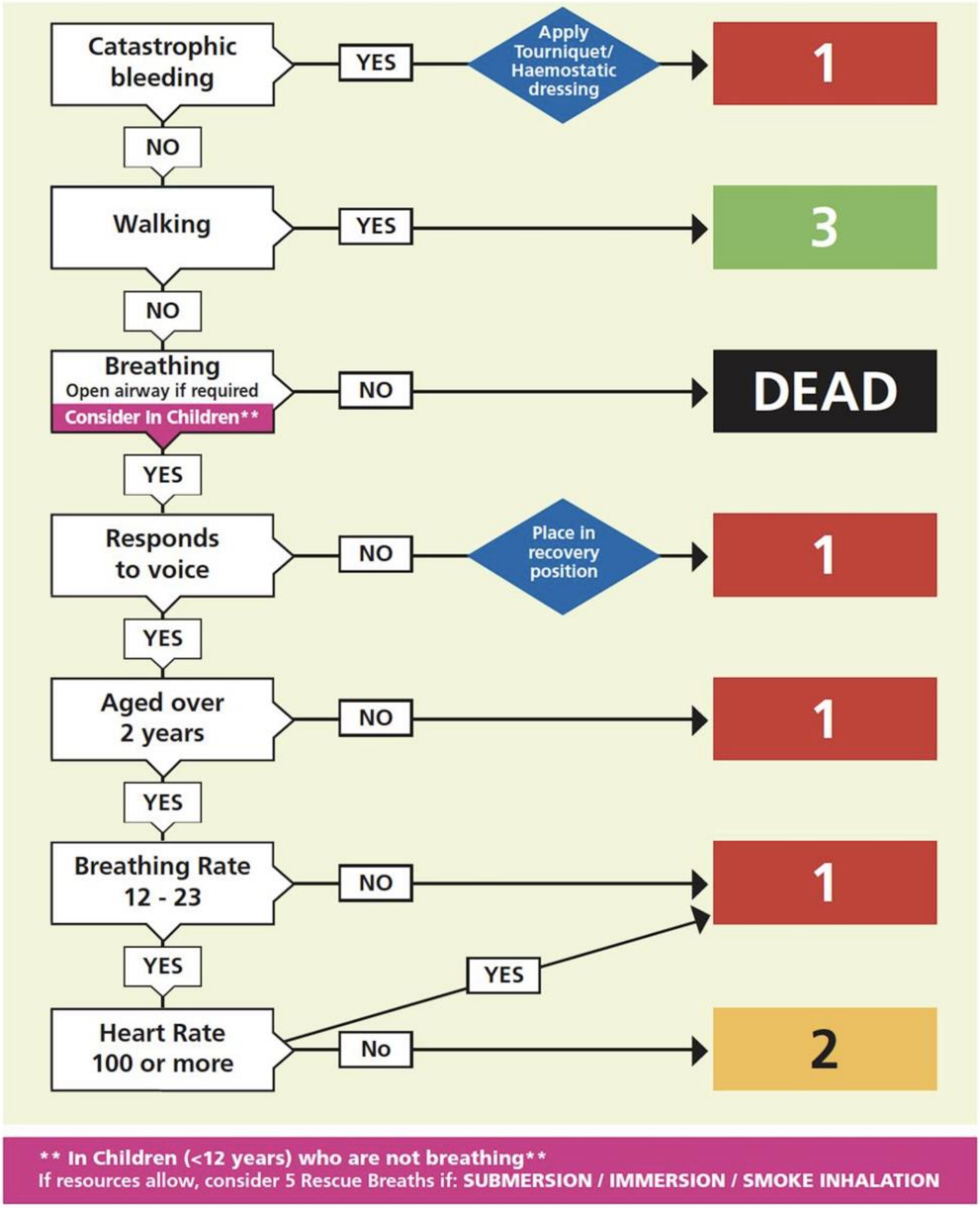

Figure 4 https://emj.bmj.com/content/39/11/800

Objectives of Medical Triage

- Rapid identification of individuals requiring immediate medical assistance.
- Rational allocation of resources (personnel, equipment, and transport).
- Ensuring continuity of care across different phases of the response.
- Reducing chaos and improving communication between responding services.

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