Prehospital Care and In-Hospital Initial Trauma Management

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Key Points

- More than half of trauma-related deaths occur within the first 24 h after the primary injury. Thus, the early phases are crucial in the management of the trauma patient.
- The timely delivery of a functioning prehospital emergency trauma care is a key challenge, potentially impacting the survival of trauma victims.
- The emergency medical service (EMS) can be divided into three broad categories: (1) basic life support (BLS) EMS system, (2) advanced life support (ALS) EMS system, and (3) physician-led ALS (MD-ALS) system.
- In the prehospital emergency assistance of traumatized patients, two main strategies can be pursued: "Stay & Play" and "Scoop & Run."
- A brief assessment of the surrounding trauma scene is conducted prior to evaluating an individual patient. Next, the "primary survey" is performed, to identify life-threatening conditions prompting immediate support therapy.
- Endotracheal intubation is the key intervention for securing the airway, thus preserving ventilation and oxygenation. It is an advanced technical skill, potentially lifesaving, but not free from risks.
- Controversy exists on the role of intravenous crystalloids to compensate shock in the out-of-hospital setting. A preliminary issue is the difficult evaluation of the shock entity and the subsequent determination of the potential benefit associated with an intravenous fluid bolus.
- The allocation of the right medical resource for each trauma patient is based on the limited information provided by first responders on the scene; for this reason prehospital trauma triage is a challenging task.
- The development of a quick, safe, and effective triage algorithm is of critical importance, contributing to both patients' outcome and optimal resource allocation.
- Major trauma management requires several different procedures, which must be performed in the shortest time possible, often concomitantly. A team-based approach is mandatory. Shared institutional protocols should be established, where any team member is assigned to specific tasks.
- The purpose of the primary evaluation is to recognize patients who need emergent endotracheal intubation, fluid resuscitation, and/or resuscitation maneuvers for treatment of imminent threats to life (e.g., decompression of a tension pneumothorax, relief of cardiac tamponade, drainage of massive hemothorax).

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- Once the ABCDE and resuscitation algorithms have been carried out, a secondary survey is performed with the aim of obtaining the list of the patient's injuries and establishing therapeutic priorities.
- The principles of damage control resuscitation are avoiding/reversing hypothermia, delaying complete volume resuscitation until definitive hemostasis is achieved, minimizing crystalloid administration, applying massive transfusion protocols, minimizing delays in surgical or angiographic interventions, use of functional coagulation point-of-care tests to guide ongoing resuscitation, and administration of tranexamic acid to aid hemostasis.

8.1 The Trauma System

More than half of trauma-related deaths occur within the first 24 h after the primary injury. Thus, the early phases are crucial in the management of the trauma patient. Prehospital and in-hospital emergent care are the two necessary elements of a healthcare system whose aims include the treatment of major traumatic injuries.

Nevertheless, a true consensus about the overall standards in trauma care is far from being reached, due to the significant heterogeneity in terms of clinical approaches and logistics, typical of each country's emergency care system. The available high-quality evidence is, therefore, scarce, with several, still unresolved, controversies.

Overall, effective teamwork, the development of shared local guidelines, and multidisciplinary algorithms are recognized as the cornerstones of a functioning "trauma system."

The aim of this chapter is to outline the different phases of early trauma management, in both the pre- and in-hospital settings.

8.2 Prehospital Trauma Care

The timely delivery of a functioning prehospital emergency trauma care is a key challenge, potentially impacting the survival of trauma victims [1]. The main goals are to:

1. Ensure a prompt dispatch.
2. Detect and treat all life-threatening injuries (if possible).
3. Identify the most appropriate hospital for each patient, avoiding under-triage and over-triage.
4. Effectively communicate with the destination facility.
5. Minimize the delay of potentially definitive care.

However, due to clear logistic and ethical limitations, few randomized controlled trials have been carried out on prehospital trauma care. Moreover, several dissimilarities must be considered among the different countries, including cultural, geographical, and economical aspects, as well as the existing regional policies [1].

8.2.1 Prehospital Trauma Care: "Who?"

In general, a structured approach should be adopted in the treatment of acute trauma [2]. Among western countries, several different models of prehospital trauma care can be identified. At present, no system can be considered better performing in terms of clinical outcome [3]. Generally speaking, the emergency medical service (EMS) can be divided into three broad categories:

1. *Basic life support (BLS) EMS system*
   A BLS team provides noninvasive support care. Systems including this first-level rescue team provide trained volunteers or technicians. In the trauma scenario, their aim is to rapidly transport patients to a medical care facility.
2. *Advanced life support (ALS) EMS system*
   The team is staffed with paramedics, healthcare professionals working as emergency medical technicians in the out-of-hospital setting. They perform invasive procedures, such as tracheal intubation and intravenous fluid therapy.
3. *Physician-led ALS (MD-ALS) system*
   A medical doctor is part of the first-responder emergency team, which usually also include a technician and nurse with specific emergency care training. The dispatch of such a highly specialized team is generally considered according to a pre-specified protocol, based on the available information coming from the trauma scene.

In 2007, Roudsari et al. conducted an international study to compare these three main EMS staffing philosophies. The authors reported substantial heterogeneity in the performance according to the team composition, even within the same prehospital trauma care system. Particularly, the early trauma fatality rate was significantly lower in MD-ALS EMS systems compared with ALS EMS systems. Nevertheless, the incidence of shock in the emergency department did not vary significantly [4, 5]. There is no convincing evidence that, in the urban setting of western countries, compared to BLS, the use of prehospital ALS teams provides any benefit to injured patients in terms of either morbidity or mortality [6]. This is likely due to the proximity of the scene to an available trauma center and the prevalent role of time in the management of acute trauma. Recently, Garner et al. designed a randomized controlled trial to evaluate the impact of prehospital physician intervention in the setting of severe traumatic brain injury. Although, unfortunately, the study was discontinued early, intention-to-treat analysis showed no significant difference in 30-day mortality. The sensitivity analyses suggest a clinically significant mortality reduction in patients with GCS < 9 receiving physician prehospital care [7]. In a recent systematic review, Wilson et al. analyzed whether prehospital management by doctors affects outcomes in major trauma when compared to management by other advanced life support providers. Data shows insufficient evidence to conclude that prehospital management by doctors improves outcomes in patients with major trauma [8].

8.2.2 Prehospital Trauma Care: "How?"

In the prehospital emergency assistance of traumatized patients, two main strategies can be pursued:

1. *Stay & Play*: as much as possible, the patient is stabilized at the scene and then transported to the hospital.
2. *Scoop & Run*: the team reaches the closest available trauma center as soon as possible, without any medical intervention being performed to stabilize the patient.

The *Stay & Play* strategy is usually preferred in European countries, while North American systems favor a *Scoop & Run* approach.

In order to *Stay & Play*, the appropriate advanced equipment and trained personnel must timely reach the patient at the scene. Stabilization includes, after a systematic assessment, at least the capability to perform (a) endotracheal intubation, (b) tube thoracostomy, and (c) ensuring an intravenous line to start the fluid resuscitation therapy. Conversely, the *Scoop & Run* strategy involves the shortest possible arrival to the trauma center, while managing the immediately life-threatening injuries during transportation. A few emergency medical systems try to combine the two approaches. The principle of the fastest possible arrival to a trauma referral center is constantly preserved. However, limited therapeutic interventions are quickly performed at the scene, to allow for more secure transportation. Other necessary lifesaving maneuvers can also be carried out in the ambulance, on the way to the hospital.

The appropriateness of invasive maneuvers being performed on-site, relatively to their impact on patients' outcomes, is currently debated, thus questioning the validity of either approach. Clearly, there is a close relationship between the composition of the emergency team dispatched on site (BLS vs. ALS vs. MD-ALS), the choice to whether or not perform rescue interventions, and the time needed to complete them successfully.

8.2.3 Prehospital Trauma Care: "What?"

Unnecessary interventions performed at the scene of major traumatic injuries are inevitably associated with an increased mortality rate [9]. For this reason, the identification of recommended vs. potentially detrimental maneuvers to be performed out of the hospital is of capital importance.

First, regardless of the training and education of the first responder, a schematic evaluation should guide further management of the injured patient in the prehospital phase (Fig. 8.1). Generally speaking, the classic American College of Surgeons' Advance Trauma Life Support approach is always valid.

A brief assessment of the surrounding trauma scene is conducted prior to evaluating an individual patient. Next, the

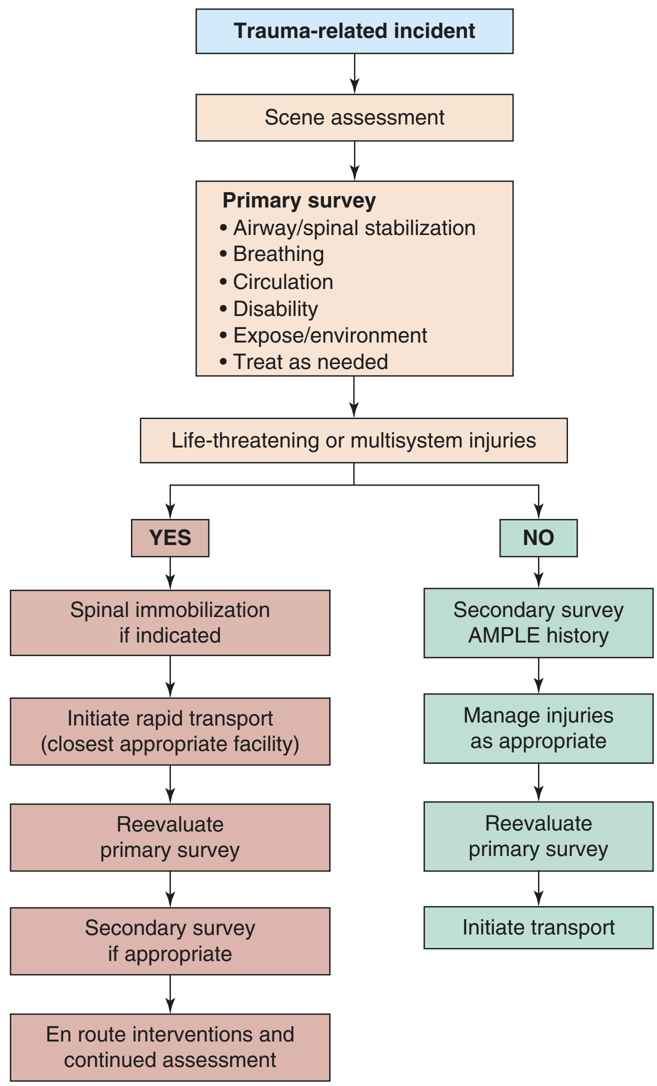

Fig. 8.1 Flowchart of the general on-scene approach to major trauma (Reproduced with permission from Salomone JP, Pons PT, McSwain NE, eds. PHTLS: Prehospital Trauma Life Support. 7th ed. St. Louis: Mosby; 2011:429. Copyright © Elsevier)

"primary survey" is performed, to identify life-threatening conditions prompting immediate support therapy, although uncertainty remains about which exact maneuver should be considered "lifesaving" in such setting. After the completion of the primary survey, the patient with identified life-threatening, or potentially life-threatening, injuries is rapidly prepared for transport to the closest available facility [10].

8.2.3.1 Endotracheal Intubation

Provided the integrity of the respiratory system, endotracheal intubation is the key intervention for securing the airway, thus preserving ventilation and oxygenation. It is an advanced technical skill, potentially lifesaving, but not free from risks (Fig. 8.2). The rationale for on-scene intubation is the maintenance of airway patency and oxygenation, both potentially altered, either primarily or secondarily, by the injury. Several studies report worse outcomes with out-of-hospital endotracheal intubation. While a common procedure in major traumas, only a few studies have actually demonstrated an improved outcome [11]. Again, the limitations of inadequate research design are important, with the literature currently mainly relying on observational studies with significant bias. Prehospital endotracheal intubation takes time and can be associated with factors leading to an adverse outcome such as inadvertent hyperventilation, transient hypoxia, bradycardia, and adverse events related to the maneuver itself [12]. Overall, it must be considered that untoward effects may counterweigh the potential benefit of emergent endotracheal intubation [11]. The literature is also inconclusive relatively to the optimal sedation and/or paralysis strategy to pursue in order to achieve optimal and safe conditions for laryngoscopy, with no clear advantage of a rapid sequence intubation (RSI) protocol, although, clinically, this is usually the preferred approach [13]. The placement of a tube within the trachea out of the hospital and in the trauma setting is particularly difficult. Also considering the potential instability of the patient due to the traumatic lesions, and the importance of time, unsuccessful intubation attempts pose significant risks. Alternative dedicated devices, such as the Combitube® double-lumen endotracheal tube, or laryngeal mask airway devices, can also be used. Such devices can be blindly introduced into the patient's supraglottic space. Concerns remain related to the potential adverse effects and limitations of these devices. To date, no definitive data are available regarding their safety and effectiveness. At present, they should be considered either second-tier alternatives, particularly if no member of the onsite team is adequately trained for the proper placement of an endotracheal tube, or rescue devices, in case of failed intubation.

Indications for endotracheal intubation include:

- Inability of the patient to maintain a patent airway due to altered (or rapidly decaying) neurological status (Glasgow Coma Scale score ≤ 8)
- At-risk airway (e.g., non-readily resolving airway obstruction, major burns, neck hematomas, etc.)

Once an endotracheal tube has been placed, confirmation of the exact positioning within the trachea must be sought. This is based, first, on clinical data. Particularly, first, at laryngoscopy, the operator should be able to directly see the tube passing through the vocal cords. Then, bilateral breath sounds must be heard at ventilation, with no gastric inflation. The chest rising and tube fogging complete the clinical assessment. Furthermore, the visualization of CO_2, either through capnography or rapid colorimetric detectors, further confirms the correct tube placement within the airway. Finally, the tube is appropriately secured.

8.2.3.2 Intravenous Fluid Therapy

The rationale for placing an intravenous line to start fluid infusion is based on the perceived aim of rapidly stabilizing the hemodynamics of the trauma patient. The purpose is maintaining adequate perfusion pressures, thus avoiding further tissue damage. Again, controversy exists on the role of intravenous crystalloids to compensate shock in the out-of-hospital setting.

A preliminary issue is the difficult evaluation of the shock entity and the subsequent determination of the potential benefit associated with an intravenous fluid bolus. Although clinically useful, the validity of standard ATLS classification of shock (Table 8.1) has been recently put under scrutiny [14, 15]. New classifications, based on a more pathophysiological approach, have been proposed [16]. However, at present, no globally accepted evidence-based method has been established as a reference for the estimation of blood loss and fluid requirements in trauma patients. As a result, ATLS classification is still widely used, both clinically, and as a literature benchmark.

The role of fluid resuscitation itself also remains controversial. Most authors agree on the detrimental effect of an excessive increase in intravascular volume through an aggressive fluid resuscitation strategy, before the source of bleeding is effectively controlled. Forced hemodilution, due to a disproportionate infusion of crystalloids in hypovolemic hemorrhagic trauma patients, would ultimately lead to a decrease in distal organ perfusion. The three natural physiological defense mechanisms of hemostasis (arterial retraction/spasm, hypotension, and clotting) would be compromised. An increased risk of bleeding may result, with decreased arterial pressure [16]. No published study has ever demonstrated an improvement in survival associated with the prehospital administration of fluids. The most recent Cochrane systematic review on this topic gathered data from six prospective interventional RCTs. The authors found no conclusive evidence for, or against, earlier, or

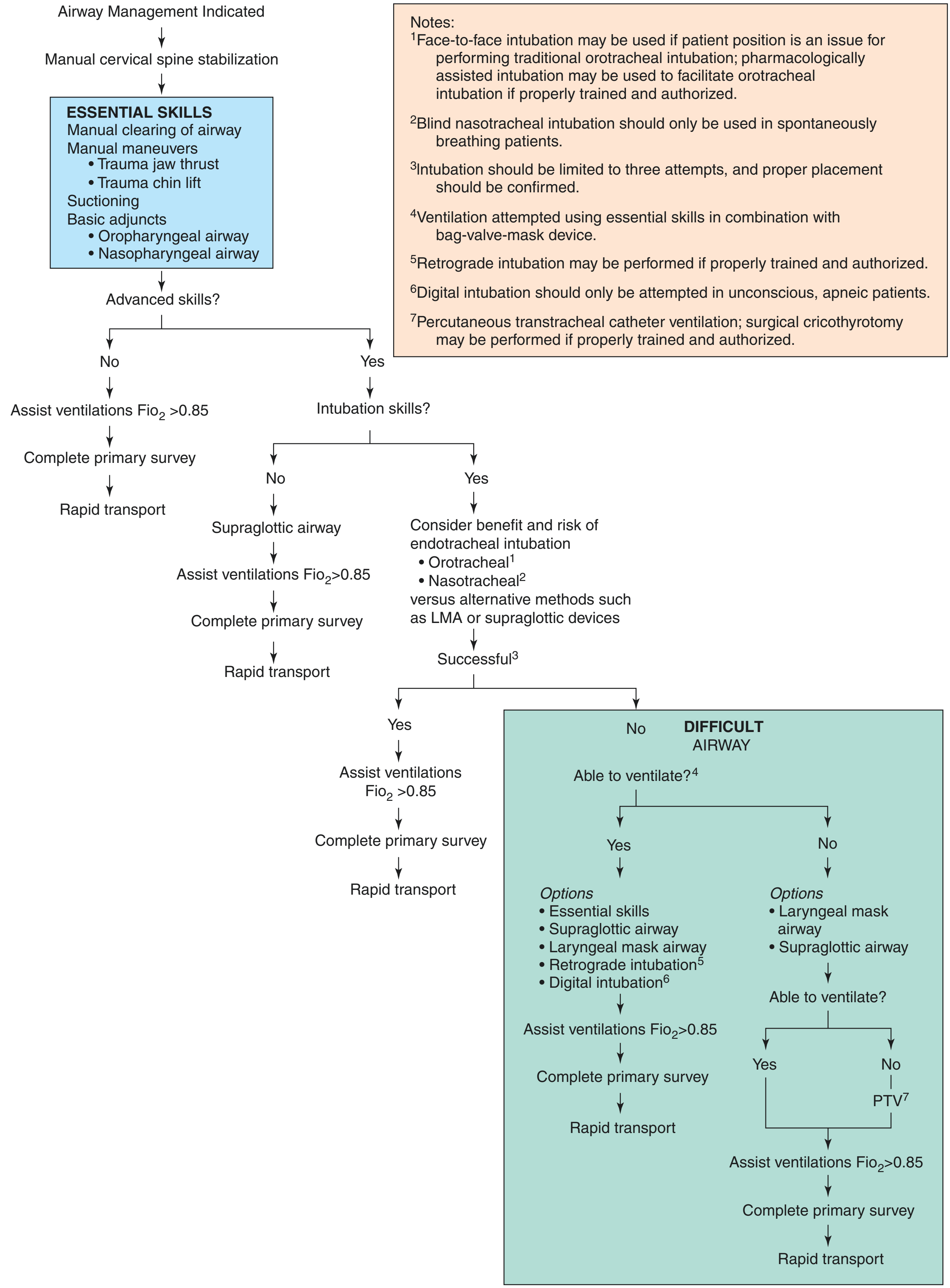

Fig. 8.2 Flowchart: prehospital airway management (Reproduced with permission from Salomone JP, Pons PT, McSwain NE, eds. PHTLS: Prehospital Trauma Life Support. 7th ed. St. Louis): Mosby; 2011:140. Copyright © Elsevier)

Table 8.1 Class of hemorrhagic shock—ATLS classification

	I	II	III	IV
Blood loss (mL)	Up to 750	750–1500	1500–2000	>2000
Blood loss (% of volume)	Up to 15	15–30	30–40	>40
Heart rate (bpm)	<100	100–120	120–140	>140
Respiratory rate (bpm)	14–20	20–30	30–40	>35
Urine output (mL/h)	>30	20–30	5–15	Negligible
Central nervous system/mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargic

larger-volume, intravenous fluid administration in uncontrolled hemorrhage [17].

In the absence of clear recommendations and lack of convincing evidence, in our opinion, trauma fluid resuscitation in the prehospital setting must be based on the available clinical data, collected after the on-scene primary assessment. Three general principles could be highlighted:

- If the patient shows signs of uncontrolled hemorrhage, with no evidence of traumatic brain injury (TBI), fluids can be infused, titrated to maintain systolic blood pressure (SBP) in the range of 80–90 mmHg.
- If TBI is suspected, in the context of multiple injuries, intravenous fluids should be administered at a rate sufficient to maintain a SBP of 90 mmHg.
- In case of isolated TBI, a SBP higher than 100 mmHg should be targeted.

En route to the destination hospital, the EMS providers should ideally obtain two large bore (14 or 16 gauge) intravenous catheters. If possible, lactated Ringer should be warmed (102 °F/38.8 °C) prior to administration. The time required to secure an IV access and start the infusion on the scene is also debated, with authors reporting minimum time intervals ranging between 2 and 12 min or more [18–20]. Although further studies are needed to clarify this issue, EMS providers should never delay transport just to initiate intravenous therapy. Moreover, fluids must be administered only to the extent they help reaching the SBP goal [1]. There is also uncertainty about the best kind of fluid to be infused in a bleeding trauma patient. Further randomized controlled trials are needed in this area.

8.2.4 Prehospital Trauma Care: "When?"

8.2.4.1 Trauma Triage

Triaging trauma patients means developing a pre-established method, leading to the prioritization of treatment, built on the baseline available information. Purpose of field triage is to select patients in order to appropriately allocate medical resources to those most likely to benefit. First and foremost, an effective triage should result in severely injured patients (even potential ones) being addressed to tertiary hospitals equipped with the staff, expertise, and facilities to adequately treat them, namely, "trauma centers." Statistically, only 7–15% of trauma patients actually require this higher level of assistance [1]. However, the allocation of the right medical resource for each trauma patient is based on the limited information provided by first responders on the scene. Prehospital trauma triage is, therefore, a true challenge. Several issues must be taken into account, such as (1) the time restraint of the situation; (2) the paucity of information available from the scene, whose reliability depends on the level of training of the first responder; (3) the unpredictable availability of hospitals to actually accept candidate patients; and (4) the variable geography of the area and its impact on the time needed for transport. Depending on the characteristics of the controlled area, emergency medical service dispatch centers continuously manage multiple trauma calls and perform triage on several, often concomitant, trauma cases. The development of a quick, safe, and effective triage algorithm is of critical importance, contributing to both patients' outcome and optimal resource allocation.

Once the patient has been directed to the selected treatment center, information about the patient's state is usually transmitted to the receiving facility. The availability of a clear and concise prehospital report allows the hospital team to anticipate emergent equipment and personnel needs.

Another issue is the definition of "major trauma victim." While easy to intellectualize, its exact quantification is complicated. The use of a precise classification is important, in order to standardize and compare triage systems, treatment protocols, and outcomes.

The Injury Severity Score (ISS) is an anatomical scoring system. An Abbreviated Injury Scale (AIS) score (1–6, "minor" to "unsurvivable") is assigned to the worst injury in each body system (head, face, chest, abdomen, extremities—including pelvis—external). The ISS is then computed as the sum of squares of the AIS scores in the three most injured regions. A maximum value of 75 is automatically assigned if an AIS 6 is present in any system [21].

The ISS is a useful tool to retrospectively classify major trauma victims, whereas an ISS > 15 usually is an accepted threshold.

The American College of Surgeons Committee on Trauma and the Centers for Disease Control and Prevention's 2011 Guidelines for Field Triage of Injured Patients outline anatomical, mechanical, and particular patient's conditions that raise suspicion of severe trauma.

Table 8.2 Markers of severe traumatic injury

Clinical indicators	Anatomical indicators	Mechanical indicators	Special considerations
GCS < 13	Penetrating injuries to the head, neck, torso, and extremities proximal to the elbow or knee	Falls >6 m (adults) >3 m (children)	Older adults (>55 years of age)
SBP < 90 mmHg	Chest wall instability or deformity	High-risk automobile crash	Pregnancy >20 weeks
RR >29 or <10 or altered respiratory mechanics or prehospital intubation	Two or more proximal long bone fractures	Car deformity with intrusion of the car body (including the roof) of >30 cm at the occupant site or >45 cm at any site	Anticoagulants
	Crushed, degloved, mangled, or pulseless extremity	Ejection (partial or complete) from automobile	Burns
	Amputation proximal to the wrist or ankle	Death in same passenger compartment	EMS team judgment
	Pelvic fractures	Vehicle telemetry data consistent with high risk of injury	
	Open or depressed skull fractures	Auto versus pedestrian (bicyclist thrown, run-over, or with significant (e.g 30 km/h) impact)	
	Paralysis	Motorcycle crash >30 km/h	

GCS Glasgow Coma Scale, *SBP* systolic blood pressure, *RR* respiratory rate, *EMS* emergency medical service

The ACS Field Triage System is a more complete, advanced triage scoring method. Indications are included for patient referral to a trauma center based on specific physiology and anatomy of the injury. The mechanism of injury and comorbid factors are considered as well. Interestingly, the EMS team judgment about the severity of the injury is also taken into consideration (Table 8.2 and Fig. 8.3) [1].

Conversely, several European countries do not have a national mandatory triage scale. Evidence is lacking about the usefulness of a trauma field triage system, nor comparisons about different systems, or the applicability of the same system within different nations, are currently available [22]. However, the absence of robust evidence on the effect of any particular prehospital triage algorithm, while a significant limitation, does not mean such systems should not be implemented. On the contrary, further research is needed in this critical aspect of the emergency and acute care medicine discipline.

A known indicator of the trauma center performance is the rate of under-triage and over-triage. Under-triage is defined as the misclassification of a patient as not in need of a higher level of care (mainly, the destination to a trauma center), when in fact he/she does. Under-triage is a medical problem that may easily result in a poor patient outcome, since the receiving medical facility may not be ready or adequate for the management of an unexpected major trauma victim.

On the other hand, over-triage is the incorrect classification of a patient as requiring admission to a trauma center, whenever such high-level resources were indeed not needed. An over-triaging system errs on the side of patient safety. However, it inevitably results in a poorer allocation of financial and human resources.

The American College of Surgeons Committee on Trauma (ACS-COT) recommends mature trauma systems to strive in order to achieve rates of <5% under-triage. Conversely, the ACS-COT defines as "acceptable" an over-triage rate of 25–50% [23].

8.2.4.2 Time vs. Outcome

The "golden hour" is a well-known key principle of trauma care, attributed to R. Adams Cowley, founder of Baltimore's renowned Shock Trauma Institute [9]. It is defined as the post-injury time interval when resuscitation and stabilization are expected to be the most beneficial for the trauma victim [6]. While a useful paradigm to stress the importance of time limitations in trauma care, the evidence supporting the "golden hour" concept is actually scarce. The 1-h cutoff has not been scientifically replicated, and its usefulness in the management of EMS systems has repeatedly been called into question [24]. Again, there is no large RCT conducted in the civilian population that either strongly supports or rejects the hypothesis that faster is universally better in trauma care [25]. A recent large systematic review conducted by Harmsen et al. showed a decreased mortality risk with shorter response time and transfer time. However, longer on-scene time and total prehospital time were associated with increased odds of survival [26]. Moreover, according to the authors, a swift transport does seem beneficial for patients suffering penetrating trauma, particularly if hemodynamically unstable and/or with associated TBI. According to other reports, longer prehospital time in patients with ISS > 15 was associated with an increased length of stay and complications, but not with increased mortality [27]. In conclusion, the "golden hour" seems to better apply to specific subgroups of patients, but there is no evidence favoring the

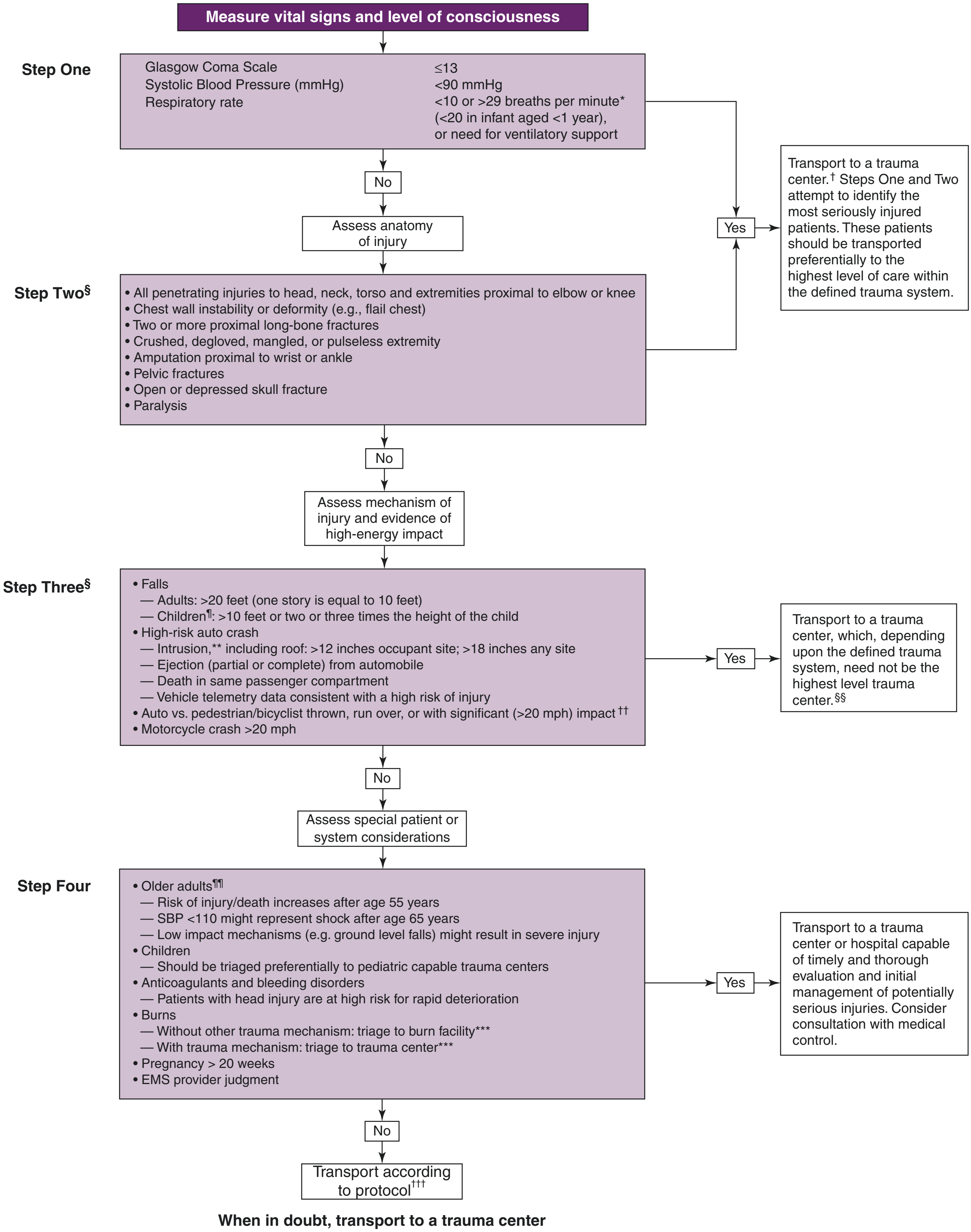

Fig. 8.3 2011 American College of Surgeons Guidelines for field triage of injured patients (reproduced with permission)

widespread application for every trauma. A much stronger factor favoring survival seems to be the referral of major trauma patients from the field directly to a specialized trauma center [28].

8.3 In-Hospital Initial Trauma Care

The emergency room is the place where, bypassing waiting rooms, the patient is rushed once arrived at the destination hospital. The availability, in modern emergency departments, of dedicated specialized rooms for the management of major traumas (e.g., "shock room," "trauma bay," Fig. 8.4) significantly facilitates the management of such cases. Patient's priorities are thereby established. In order to achieve this goal, similarly to the field approach, a strict protocol of evaluation and treatment should be observed. A primary and a secondary evaluation are planned. The aim of the primary evaluation is to recognize and treat immediately life-threatening conditions. The ATLS Airways, Breathing, Circulation, Deficit, and Exposure (ABCDE) systematic assessment is typically adopted. A secondary evaluation subsequently follows, including a head-to-toe physical examination, monitoring, imaging, and laboratory tests. Of note, the completion of the planned diagnostic and treatment course could be delayed in case of patient's instability. In that case, it is crucial to minimize the time elapsing from admission to operating room (OR) or interventional radiology (IR) transfer.

Early control of bleeding is mandatory for improving outcome. It is important to establish priorities and to identify patients who would benefit from early damage control surgery or IR. The patient's assessment should be coupled with a damage control resuscitation strategy whose aim is to prevent the lethal triad of (1) hypothermia, (2) acidosis, and (3) coagulopathy, as well as to identify patients for whom the activation of a massive blood transfusion protocol is needed.

Damage control resuscitation is currently the cornerstone of the management of major trauma patients. At the same time, damage control surgery aims at controlling early hemorrhage and minimizing operative time, by delaying definitive repair to the moment the patient will be stabilized.

8.3.1 The "Trauma Team"

Major trauma management requires several different procedures, which must be performed in the shortest time possible, often concomitantly. A team-based approach is mandatory. Shared institutional protocols should be established, where any team member is assigned to specific tasks.

The composition of the trauma team varies based on each institution's practice. However, the core of the team requires five to eight members.

The team leader is in charge, with direct responsibility on, mainly, (1) emergency room logistics, (2) the decision-making process about diagnostic and therapeutic priorities, and (3) communication, both within the team and with the

Fig. 8.4 Representative emergency department "shock room" for the comprehensive management of major trauma patients. The facility is a large space, fully equipped with all the necessary material for the emergency management and evaluation of traumatic injuries without the patient, nor the team, leaving the area (airway, IV access, ultrasound, X-ray tube, mechanical ventilation, monitoring, point-of-care testing, blood transfusion, body and fluids warming, spine and pelvis immobilization, etc.). If needed, emergent damage control surgical procedures (e.g., tube thoracostomy, extraperitoneal pelvic packing, emergency thoracotomy) can be performed

patient's relatives. The leader should be coordinating the team, without being involved in a specific clinical task. The role of team leader does not require specific training, but it is usually fulfilled by a physician, most often a surgeon. Intensivists, or emergency physician, can also act as team leaders, depending on the institutional setup.

An anesthesiologist/intensivist/emergency physician is the member of the team dedicated to airway management, central vascular accesses, volume resuscitation, and sedation/analgesia.

A surgeon is generally responsible for emergency chest decompression and chest tube placement, surgical management of bleeding, and head-to-toe physical examination of the victim.

At least two nurses should be part of the team, one assisting the airway expert, the other helping the surgeon. Peripheral vascular access, gastric tube placement, blood draw, and urethral catheter placement are usually performed by nurses, as well.

The presence of a radiologist, an orthopedic, and/or a neurosurgeon is often necessary in the emergency room for the first phases of severe trauma victim management.

Much emphasis should be put on communication and coordination among team members. It is well recognized that effective teamwork in severe trauma management can be lifesaving.

8.3.2 Primary Evaluation

During the primary evaluation, all immediately life-threatening conditions are detected, in a very short time frame (i.e., few minutes), and treated. The cornerstone of primary evaluation is the ABCDE assessment. ABCDE and resuscitation procedures should be carried out simultaneously, and the effect of any therapeutical intervention should be reassessed in a timely fashion. Complete primary evaluation and treatment must be carried out before proceeding with subsequent trauma protocol steps. The ABCDE should be reassessed periodically and/or whenever patient's conditions change.

The purpose of the primary evaluation is to recognize patients who need emergent endotracheal intubation, fluid resuscitation, and/or resuscitation maneuvers for treatment of imminent threats to life (e.g., decompression of a tension pneumothorax, relief of cardiac tamponade, drainage of massive hemothorax) [29].

8.3.2.1 Airway and Cervical Spine

Spine Protection

It is mandatory to minimize movement of the cervical spine during airway management. Neck immobilizing devices should be kept in place until cervical spine injury has been ruled out by imaging (CT scan being the gold standard technique, even though, in some cases, MRI is required). If immobilizing devices have to be removed, the head must be kept in neutral in-line position with manual immobilization by a member of the trauma team [29].

Endotracheal Intubation

Whenever the patient has already been intubated out-of-hospital, its correct placement should be checked by bilateral chest auscultation and capnography. If the tube is found in the esophagus, it should be kept in place until a definitive airway has been secured, as tube removal may elicit vomit.

In the trauma setting, several conditions may threaten airway integrity, such as foreign bodies, avulsed teeth or dentures, blood, vomit, expanding hematoma, edema, direct airway or circumferential neck burns, etc. Any such situation must be promptly detected. In general, a GCS < 8 is likely associated with loss of protective airway reflexes, increasing the risk of aspiration of gastric contents. Endotracheal intubation is generally indicated. Suction must always be in place and ready for use, being an essential device for safe airway management.

Ventilatory problems in the trauma patient include apnea/bradypnea due to unconsciousness or neuromuscular paralysis (e.g., spinal cord lesion above C5 level) or inadequate respiratory efforts. Hypoxia (defined as an SpO2 $< 90\%$ in reservoir bag mask) and acidosis (pH < 7.2) are commonly used parameters.

Combative patients may need sedation and intubation in order to carry out diagnostic and therapeutic procedures. Agitation could also be due to substance abuse, or even hypoxia.

The choice of the intubation technique is based upon the circumstances and the operator's skills. Intubation is often a challenging maneuver in the trauma victim. Equipment for the management of the difficult airway, including a surgical one, must be available and ready for use, in case conventional attemps fail. In the awake, spontaneously breathing patient, intubation with a "rapid sequence induction" is the most common approach. It allows to minimize the risk of aspiration by avoiding mask ventilation [29].

Advanced Airway Management

Videolaryngoscopy is an option, given the frequent limitation to neck hyperextension. Awake nasal or orotracheal intubation assisted by fiberoptic bronchoscopy also is a possibility, but it requires trained personnel and an awake, collaborative patient.

A supraglottic device (e.g., laryngeal mask) can be placed temporarily if intubation fails, in order to ensure ventilation. Notably, supraglottic devices do not protect from aspiration.

Cricothyroidotomy of tracheostomy may be the only way of securing the airway of patients with severe facial or laryngeal trauma.

8.3.2.2 Breathing

Prevention of hypoxemia is recommended in the severe trauma setting. Supplemental oxygen (at least 10 L/min with bag mask) should be provided to all spontaneously breathing patients with major trauma, in order to maintain an SpO_2 of 95% or higher.

Assessment

A focused physical examination can often lead to detect severe respiratory conditions requiring immediate intervention:

- A respiratory rate < 10/min indicates hypoventilation, likely associated with hypercapnia.
- A respiratory rate > 29/min suggests inadequate respiratory efforts.
- Symmetry of respiration should be assessed with both inspection and auscultation.
- Subcutaneous emphysema raises a high suspicion of pneumothorax, laryngeal, or tracheobronchial trauma.
- Central cyanosis is assessed by inspecting the color of lips or mucosae, keeping in mind that, in order to be observed, cyanosis requires at least 5 g/dL of unoxygenated hemoglobin (may not be evident with concomitant severe anemia).
- Diagnosis of tension pneumothorax should be clinical. The affected side is often elevated compared to the contralateral, its excursion is impaired, and the jugular tone can be increased. Reduced breath sounds and hyperresonance on percussion are characteristic features but may be difficult to assess in a noisy environment.
- In case of massive hemothorax, dyspnea is usually evident; limitation of excursion and reduced breath sounds also aid the diagnosis.
- Flail chest is detected by inspection and suggests underlying pulmonary contusion.

Treatment

Tension pneumothorax and massive hemothorax should be drained even before imaging is obtained, in case of a severe cardiovascular or respiratory derangement. Emergent treatment of tension pneumothorax is performed by needle decompression, placing a large bore IV cannula in the second intercostal space, just above the rib, on the midclavicular line. A chest drain tube should then be placed as soon as possible, possibly before positive-pressure mechanical ventilation is initiated. Treatment of massive hemothorax is by chest tube drainage. The amount of blood drained should be strictly monitored. Penetrating chest injuries may lead to open pneumothorax if the defect of the chest wall is wide enough. In this case, an occlusive dressing should be placed upon the wound, and a chest tube should be inserted in a different site. Invasive or noninvasive mechanical ventilation should be considered in case of flail chest.

Mechanical Ventilation

Mechanical ventilation in the trauma victim can be challenging. In the first phases of trauma management, positive-pressure ventilation can aggravate hypotension, decreasing venous return, especially in already hypovolemic patients. On the other hand, the risk of hypoxia due to alveolar de-recruitment is concrete. Moreover, for the overall management of the trauma case, it is important to keep a SpO_2 of at least 95% for adequate oxygen delivery. A protective ventilation strategy should be early adopted to prevent ventilation-induced lung injury. Protective ventilation includes the use of low tidal volumes (6–8 mL/Kg predicted body weight) and moderate positive end-expiratory pressure (PEEP), targeting a plateau airway pressure below 30 cmH_2O. Respiratory rate should be titrated based on $PaCO_2$ levels, aiming at normocapnia (35–40 mmHg).

Hyperventilation, in order to keep moderate hypocapnia (30–35 mmHg), should be adopted, as a rescue therapy, only in case of imminent or ongoing cerebral herniation. The effect of PEEP on intracranial pressure has been shown to be negligible, as long as the $PaCO_2$ is controlled.

It is important to monitor respiratory mechanics and gas exchange with serial arterial blood gas analyses throughout the early phases of trauma management.

8.3.2.3 Circulation

Assessment

Circulation is first assessed by checking peripheral and central pulses, looking for signs of hypoperfusion and, most importantly, identifying potentially active sources of bleeding. The presence of a carotid pulse indicates a systolic blood pressure >40–50 mmHg, while a palpable radial pulse generally indicates a systolic pressure of at least 70 mmHg.

Heart rate, peripheral oxygen saturation (SpO_2), and non-invasive blood pressure should be assessed. Clinical signs of tissue hypoperfusion, such as augmented capillary refilling time (>3–4 s), cold extremities, and mottling, which is usually more evident around knee caps, may be present in spite of still normal blood pressure.

Jugular veins should always be inspected, as increased jugular filling and congestion of the head and neck suggest an obstructive cause of shock, such as tension pneumothorax or cardiac tamponade.

Cardiac arrest in the trauma setting is generally associated with a poor outcome, with extremely low survival rates.

Reversible causes of cardiac arrest (i.e., severe hypovolemia, or tension pneumothorax, cardiac tamponade) should immediately be detected and treated.

Cardiac tamponade diagnosis on clinical basis can be challenging. Beck's triad (jugular tension, severe hypotension, and dull heart sounds) raises the suspicion, but definitive diagnosis is made by point-of-care transthoracic echography. Needle pericardiotomy, or emergency thoracotomy, should be performed.

Treatment

At least two large bore peripheral venous catheters (best if 14 gauge) should be placed as soon as possible. If major vascular lesions are suspected, IV lines should be placed so that the potentially damaged vessel does not affect the continuity between the IV access and the right ventricle (i.e., place the IV above the diaphragm in case of abdominal injuries, below the diaphragm if superior vena cava affluent obstruction, or disruption, is suspected).

Intraosseous access is a valuable option for rapid fluid resuscitation in case an IV cannot be placed. It allows the infusion of crystalloids and blood components. The placement of central venous access and/or artery cannulation should not delay the initial trauma resuscitation. These procedures are usually carried out later on, during the secondary evaluation, or even after diagnostics have been completed.

Volume Resuscitation/Bleeding Control

Hemorrhagic shock resuscitation is based on prompt fluid replacement. Isotonic crystalloids are currently the first choice for early volume resuscitation. Despite their effectiveness in restoring intravascular volumes, synthetic colloids (starches) should be avoided, as they can impair platelet function and coagulation and increase the risk of kidney injury. Albumin is contraindicated in the presence of traumatic brain injury.

Balanced isotonic crystalloids are generally preferred, since the infusion of large volumes of normal saline may lead to hyperchloremic metabolic acidosis and impaired renal perfusion.

On the other hand, normal saline is the crystalloid of choice in patients with traumatic brain injury, in which hypotonic crystalloids must be avoided.

Controlling hemorrhage clearly is the crucial aspect of the vast majority of trauma cases.

Uncontrolled post-traumatic bleeding is the second leading cause of mortality after TBI. Trauma-related coagulopathy is a major issue in the trauma victim. Up to 30% of bleeding patients already show some degree of coagulation impairment at admission. Thus, the importance of the early recognition of active bleeding and coagulopathy is paramount for the improvement of trauma patients outcome. Hemostasis should be the first goal in the patient who is actively bleeding.

Aggressive crystalloid resuscitation in order to restore normal vital signs in the first phases of trauma care can lead to deleterious consequences, both primarily, like hypothermia and dilution coagulopathy, and secondarily, like fluid overload, abdominal compartmental syndrome, and ARDS. Moreover, a liberal fluid administration leading to an excessive elevation in arterial pressure might be detrimental, as it increases blood loss and prevents, or disrupts, the formation of clots at the bleeding site.

Mild, controlled hypotension (permissive hypotension) favors clot formation and slows bleeding rate from damaged vessels. Similarly to the prehospital setting, a SBP of 80–90 mmHg should be targeted in patients with ongoing hemorrhage, and no known TBI, until definitive bleeding control is achieved. Crystalloids should be titrated to achieve such target SPB, while overall crystalloids should be as minimized as possible, in favor of transfusing blood components whenever necessary.

For patients with active bleeding and concomitant traumatic brain or spinal cord injury, on the other hand, a higher blood pressure threshold should be observed (>100 mmHg of systolic or >80 mmHg mean arterial pressure), in order to assure adequate cerebral, or spinal cord, perfusion.

Vasopressors

Vasopressors should be considered only as a temporary measure to maintain tissue perfusion in case of severe hypotension unresponsive to volume therapy. Low-dosage norepinephrine is the most commonly used agent. Inotropes could be considered in case of suspected myocardial depression.

Patients with hemorrhagic shock and an identified source of bleeding should undergo immediate bleeding control procedures if they do not respond to the initial volume resuscitation.

Blood Transfusion

Massive transfusion protocols should be developed within each trauma center. Effective communication between the trauma team and the blood bank is extremely important in the management of the trauma victim requiring blood transfusion.

Transfusion goals should not be limited to ensure adequate oxygen delivery through hemoglobin supplementation, but should instead include adequate coagulation factors and platelet. A standard red blood cell (RBC)/fresh frozen plasma (FFP)/platelet (PLT) ratio of 1:1:1 is currently recommended.

Shock index (i.e., heart rate/systolic blood pressure ratio) is the most common trigger of massive transfusion protocol activation. Type 0 negative packed RBCs should be available as a temporary resource. A restrictive hemoglobin goal of 7 g/dL is recommended in trauma victims with no known cardiovascular disease.

Patient's hemodynamics and its responsiveness to volume resuscitation are crucial in defining further diagnostic and therapeutic paths. The stable patient can undergo accurate secondary evaluation, being addressed to CT scan, then possibly surgery or IR vs. conservative management and observation. On the other hand, the hemodynamically unstable (or the transiently responsive) patient should promptly undergo extended focus ultrasonography and bedside chest plus pelvis X-ray, in order to identify bleeding sources (usually thoracic, abdominal, or pelvic). The latter patient is likely to benefit from early damage control surgery, requiring a massive transfusion and strict coagulation monitoring.

Tranexamic Acid

The administration of tranexamic acid, an antifibrinolytic drug, is recommended within 3 h after injury (1 g should be administered in the prehospital setting, then an additional 1 g should be infused in 8 h) in order to avoid clot disruption.

Desmopressin (DDAVP) 0.3 mcg/kg could help hemostasis in patients with known von Willebrand disease or under antiplatelet drugs, together with platelets. Prothrombin complex concentrates are given to reverse the effect of vitamin K antagonist or factor Xa inhibitors. An antidote for direct thrombin inhibitor dabigatran is now available (idarucizumab) [30].

8.3.2.4 Disability

A first, rapid assessment of the level of consciousness can be obtained with the AVPU scale, which evaluates mental status defining the patient as:

- Alert
- Responsive to verbal stimuli
- Responsive to pain
- Completely unresponsive

The Glasgow Coma Scale (GCS) is the cornerstone of the assessment of the victim's state of consciousness. It evaluates three items (eye-opening, verbal, and motor response) resulting in a score from 3 to 15. In the intubated patients, always unable to speak, the motor response is crucial in defining mental status.

First neurological examination is completed assessing pupillary status: baseline diameter and response to light. Altered pupillary status is an early sign of cerebral herniation, which requires immediate treatment.

The GCS assessment should be systemically repeated, as well as the ABCDE, even after the first evaluation. Neuroworsening (defined as an impairment of two points of the GCS) should be promptly detected by periodic reassessment of GCS.

It must be noted that altered mentation in the severe trauma settings could be due not only to traumatic brain injury but also other factors like cerebral hypoxia due to shock hypoperfusion or hypoxemia, metabolics, and intoxication [10].

8.3.2.5 Exposure

Up to two-thirds of severe trauma victims presents some degree of hypothermia, which is an independent risk factor for mortality. Hypothermia has several detrimental effects on patients' outcome, mostly impairing platelets function and coagulation. Severe hypothermia (<32 °C) is associated with almost 100% mortality.

Risk factors of hypothermia include the severity of injury, CNS involvement, extremes of age, wet clothes, long extrication time, burns, large open wounds, blood loss, low environmental temperatures, and underlying medical conditions (e.g., hypothyroidism, adrenal failure, diabetes mellitus). A few iatrogenic factors may lead to increased heat loss as well, such as exposure, general anesthesia and muscle paralysis, large intravenous infusion of cold crystalloids or blood products, and lengthy (>3 h) surgery.

Since it is difficult to rewarm a patient in which considerable heat loss has occurred, any effort should be made in order to prevent hypothermia. The patient's body temperature should be periodically assessed. First-line strategies for keeping normothermia (i.e., a core temperature of 36–37 °C) should include removal of wet clothes, avoidance of cold surfaces, warm room environment, warm intravenous fluids, warm blankets, and forced-air blankets.

In case of hypothermia, active warming strategies should be implemented. Forced-air warming should be maximized, like other potentially available tools, like underbody heating pads, radiant warmer, humidified ventilation, or circulating water garment. Body cavity lavage with warm fluids during surgery is another option, although of uncertain efficacy. Of note, warming should be ceased in case the subject's temperature rose above 37 °C, as hyperthermia is associated with increased mortality as well.

Body temperature has a considerable impact on hemodynamics as well, especially in the trauma patients. Mild hypothermia stimulates sympathetic activity leading to increased heart rate and blood pressure, which can mask underlying hypovolemia. Attention should also be paid to avoid too rapid temperature shifts, particularly in patients with underlying cardiovascular disease [31].

TBI with associated intracranial hypertension could, on the other hand, benefit from mild hypothermia. As usual, pros and cons of hypothermia must be put on the balance.

8.3.3 Secondary Evaluation

Once the ABCDE and resuscitation algorithms have been carried out, a secondary survey is performed with the aim of obtaining the list of the patient's injuries and establishing therapeutic priorities.

During the secondary survey, vital signs must periodically be checked. It must be noted that this secondary evaluation is carried out only if the patient is stable or once stabilized by a successful resuscitation. In case of persisting instability, in spite of proper resuscitation maneuvers, the patient should be promptly transferred to the OR/IR for hemorrhage source control. In this case, the secondary survey is performed later on, as soon as the patient stabilizes.

The secondary assessment involves the collection of focused medical history (if feasible), a whole body physical exam, patient's monitoring, and imaging.

8.3.3.1 AMPLE

Interviewing the awake patient or, if not feasible, collecting information from the next of kin, a quick and focused past medical history can be obtained. The "AMPLE" mnemonic summarizes the most relevant medical issues to be evaluated in the trauma patient: allergies, medications, past illness, last meal, and events. Particularly, it is crucial to find out whether or not the patient is taking anticoagulant medications that might need immediate reversal.

8.3.3.2 Physical Examination

A systematic head-to-toe examination is performed, in order to detect all sites of possible injury:

- A rapid neurological exam of motor and sensory functions and cranial nerve assessment. Notably, scalp hemorrhage may lead to important blood loss, especially in children.
- Neck palpation, in order to recognize subcutaneous emphysema ("snowball crepitus"), swelling, or dislocation of structures.
- Inspection and palpation of the chest for the detection of chest wall fractures and flail chest.
- Inspection and palpation of the abdomen to exclude abdominal tenderness and/or wall tension.
- Evaluation of pelvic stability.
- Inspection of the perineum and digital rectal examination to detect bleeding and test sphincter tone.
- Evaluation of the urethral meatus.
- Examination of the extremities for fractures or misplacements; muscle palpation in order to rule out early compartment syndrome.
- Evaluation of the back with the log-roll maneuver: a group of operators rolls the patient on a side, keeping the long axis of the spine in-line, while inspection and palpation of the whole spine are performed, seeking for swelling, dislocation, or tenderness. Lifting up the scoop stretcher can be utilized in spite of log rolling for palpation of the spine in patients with suspected unstable pelvic fracture.

8.3.4 Laboratory Tests

Blood samples should be early drawn in the emergency department for point-of-care and a basic set of laboratory analyses.

An arterial blood gas analysis not only assesses pulmonary gas exchange but also the presence of metabolic acidosis, the level of hemoglobin, and the electrolytic balance. Lactate levels and base deficit are currently the standard markers of tissue perfusion. Their complete normalization within the first 24 h following injury should be the goal of resuscitation efforts. Thus, their trends should be monitored. Lactate clearance requiring more than 24 h is associated with the development of post-traumatic organ failure.

The analysis of venous blood gases, particularly from peripheral samples, cannot be considered a valid surrogate for the estimation of blood oxygenation, CO_2, and pH, but is reliable indicators of lactate levels.

Most importantly, a sample for the determination of blood type and cross-matching should always be drawn as soon as possible. A complete blood count is mandatory as well. Hemoglobin level at emergency department admission does not necessarily reflect the severity of blood loss. During hemorrhage, whole blood is lost; thus interstitial fluid shifts to restore intravascular volume, ultimately producing hemodilution, which, however, is not immediately measurable. As a consequence, normal hemoglobin levels do not rule out an ongoing bleeding. On the other hand, already low hemoglobin or hematocrit level at hospital admission must be considered an indicator of important bleeding, potentially associated with coagulopathy.

Standard coagulation tests, such as activated partial thromboplastin time (aPTT) and prothrombin time (PT), are mandatory minimum requirements for trauma care. An international normalized ratio (PT-INR) <1.5 should be sought. Nevertheless, standard coagulation tests are of limited help for the assessment of early trauma-induced coagulopathy. Thus, functional point-of-care whole blood viscoelastic coagulation tests, such as thromboelastography (TEG), should be obtained, in order to have a quicker and deeper understanding on the status of hemostasis (time of clot formation, strength of the clot, platelet aggregation, and fibrinolytic process). TEG-guided coagulation resuscitation is one of the key principles of the damage control approach. Fibrinogen levels must always be assessed together with platelet count and coagulation times, as fibrinogen is the first coagulation cascade factor to drop, due to consumption in the severe trauma bleeding patient.

Other basic laboratory studies aimed at assessing potential organ dysfunction include blood urea nitrogen, creatinine, liver enzymes, and glucose level. Baseline levels of blood muscle enzymes (creatine phosphokinase and myoglobin) should also be checked. Cardiac biomarkers can be required if cardiac contusion is suspected on the basis of dysrhythmias or echographic findings. Toxicology blood tests are often useful for both clinical and legal purposes. Finally, pregnancy status should be ruled out in all fertile-age females by testing urinary beta-hCG.

8.3.5 Monitoring

An arterial line can be placed before or after imaging, to obtain continuous invasive blood pressure and to draw blood samples for arterial blood gas analyses.

Establishing central venous access can be useful for monitoring and sampling purposes, as well as for the intraoperative and postoperative management of infusions, should surgery be needed.

A 12-lead electrocardiogram should be performed to evaluate possible cardiac injury. A nasogastric (orogastric, in case of basal skull fractures) tube is often placed.

All major trauma patients should receive urethral catheterization. If there's suspicion of perineal or pelvic injury involving the urethra or the bladder, urology consult should be sought.

8.3.6 Imaging

8.3.6.1 X-Ray and eFAST

Bedside chest and pelvis X-rays, and extended focused ultrasonography, are performed in all patients, regardless of the hemodynamic status, as they can be crucial in the prompt detection of bleeding or obstructive causes of shock. These exams are obtained directly in the emergency room.

Extended focused assessment with sonography for trauma has increasingly become an extension of physical examination. Moreover, in many protocols, emergency echocardiography for detection of cardiac tamponade or lung ultrasound for the diagnosis of pneumothorax has actually become part of ABCDE assessment itself.

Whenever an ultrasound (US) machine is available, the abdominal echographic examination has now replaced the diagnostic peritoneal lavage for the diagnosis of intra-abdominal bleeding. A positive US is very specific and accurate for detection of hemoperitoneum. On the other hand, a negative exam does not completely rule out intraperitoneal hemorrhage. In this case, further diagnostic (i.e., contrast-enhanced CT scan) might be considered.

8.3.6.2 CT Scan

Contrast medium-enhanced multislice CT assessment is the gold standard imaging exam for hemodynamically stable patients with a high-risk mechanism of injury. Ongoing bleeding with a minimum rate of 0.5 mL/min can be visualized. Trauma scan patterns often include the head, neck, chest, abdomen, and pelvis. If shock is present, CT is usually delayed, and sources of bleeding are first assessed by sonography or bedside X-ray of the chest and pelvis.

The availability, at some institutions, of CT-scan machines allowing the quick execution of the exam within the emergency room minimizes time, sometimes allowing the study to be completed even in the partially unstable patient, provided an at least initial response to resuscitation. However, the CT suite inevitably is an environment where the trauma victim is more vulnerable. Risks and benefits should be balanced by the team.

Today, emergent angiography has become an interventional, rather than diagnostic, procedure. The arterial bleeding is generally detected as a "blushing" on contrast-enhanced CT scan. If indicated, transfer to IR is prompted for the nonsurgical control of bleeding through the endovascular approach.

8.3.7 Damage Control Resuscitation and Surgery

The principles of damage control resuscitation are:

- Avoiding/reversing hypothermia
- Delaying complete volume resuscitation until definitive hemostasis is achieved
- Minimizing crystalloid administration
- Applying massive transfusion protocols
- Minimizing delays in surgical or angiographic interventions
- Use of functional coagulation point-of-care tests to guide ongoing resuscitation
- Administration of tranexamic acid to aid hemostasis

Damage control surgery essentially means a three-step approach to the severely injured patients:

1. First emergent intervention to control bleeding and contamination, which should last less than 90 min (e.g., abdominal or pelvic packing, exterior fixation of pelvis or fractured limbs)
2. Resuscitation and monitoring in the intensive care unit
3. Once resuscitation goals are achieved (usually within 12–48 h): definitive surgical repair

A damage control approach should not be used systematically in all severe trauma victims. Some of them could rather benefit from definitive surgery. Recommendations for damage control surgery include:

- Hypothermia
- Metabolic acidosis
- Presence of coagulopathy
- Hemodynamic instability
- Severe bleeding

all of which must be unresponsive to resuscitation [30, 32].

8.3.8 Pain Relief

Pain management is an often-overlooked issue in severe trauma. For patients with major trauma, intravenous morphine is a good first-line analgesic. Doses should be titrated based on the patient's response. The physician must be aware that, after the administration of opiates, the victim's adrenal response to pain is blunted, so systemic vascular resistances and cardiac output can rapidly decrease leading to sudden hypotension, due to a previously occulted hypovolemia.

Ketamine at analgesic doses is a valid option. Benzodiazepines like midazolam are often associated, in order to prevent hallucinations.

NSAIDs should be avoided in the early stages of severe trauma, due to their possible detrimental effects on platelet function and kidney perfusion.

8.3.9 Antibiotic Prophylaxis

The majority of severe trauma victims do not require any a priori antibiotic prophylaxis. Inappropriate use of antibiotics agent is responsible for selection of drug-resistant bacteria and fungi. The choice to administer antibiotic prophylaxis should be evaluated on individual basis. Specific conditions in which antibiotic prophylaxis is recommended include:

- Open traumatic brain injury
- Maxillary fractures
- Open limb fractures
- Hollow viscus injuries

Adjustment of antibiotics administration should be considered in patients undergoing massive transfusion.

Tetanus vaccination status of the patient should be assessed, and, if necessary, tetanus immunoglobulins, or vaccination refresh, should be administered.

8.4 Handover

Concisely passing thorough and correct information among healthcare professionals is particularly challenging in the trauma setting. This is due to the simultaneous involvement of several different operators, across multiple specialties and with different levels of training (technicians, nurses, physicians). Both in the prehospital and in-hospital settings, miscommunication may arise, associated with the emergency character of the situation, the multiple actions being undertaken at the same time, and the significant amount of information being passed along through the different phases of trauma care. A structured approach should be pursued in such circumstances, possibly with the aid of safety checklists.

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