4 Trauma System and Rescue Strategies

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Learning Objectives
- To know the definition of a trauma system
- To understand and discuss the impact of a trauma system on a society
- To name the components of a trauma system
- To explain the importance of an accurate prehospital triage score
- To name the subgroup of patients at risk for an "undertriage"
- To debate the "scoop and run" versus "stay and play" field tactic

4.1 Trauma Systems

4.1.1 Definition of Trauma System

A trauma system is a prearranged approach to trauma patients in a defined geographical area that provides full and optimal care. It is integrating the local or regional Emergency Medical Service (EMS) system. Regionalization is an important aspect of trauma as a system because it enables the efficient use of health care facilities within a defined geographical area. The major goal of a trauma system is to improve patients' outcomes after trauma. When comparing states with and without a regional trauma system, a significant reduction in mortality was found when a regional trauma system was present [1].

4.1.2 Trauma System Components

The key elements of a trauma system are access to care, centralized call and triage center, integrated prehospital care, trauma center certification based on need, and rehabilitation. Additional components of a trauma system are prevention, education, research, disaster medical planning, and rational financial planning.

The preclinical components of a trauma system may encompass un-trained first responders, more advanced responders, specially trained staff such as emergency medical technicians (EMTs), physicians deployed to prehospital trauma scenes or even airborne medical services. The preclinical components are discussed in larger detail below.

The administrative components of a trauma system include system oversight and legal regulation, education, monitoring, and quality manage-

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ment as core functions. System oversight and regulation often rest with authorities of the interior or government bodies attending to public health, but other governmental agencies such as the department of defense may also assume those functions. An essential component of a trauma system is to certify traumas based on patient needs. In the US, for example, where this trauma center designation based primarily on financial interest there are too many trauma centers in large urban regions and too few in remote rural regions. In more developed systems, another—and quite effective—function of the administrative component is trauma prevention. When designed well, prevention measures directly result from data collected within a trauma system and should lead to improvements measurable though the systems monitoring and quality management components. Preventive measures may include safety regulations for hazardous industries, adaption of traffic infrastructure or simple speed limits for motor vehicles. A systematic review of the published evidence regarding the effectiveness of trauma systems in North America estimated the magnitude of benefit from implementation of a trauma system was approximately 15–20% reduction in risk of death among seriously injured trauma patients [2]. This number however likely is a lower bound estimate, because it only accounts for the benefits that result from the treatment of people already injured. It neglects the effect that systematic data collection within trauma systems has informing the preventive practice within the larger society. Often overlooked is the potential for regional trauma care research, including conducting randomized multicenter studies.

4.1.3 Implementing, Monitoring, and Improving Trauma Systems

4.1.3.1 Education and Training

Training providers within a trauma system can only be as good as the adaption of the training to local needs and circumstances. Training should be adapted to the amount of time providers can dedicate to it and be specific for local circumstances. For example, where avalanches are an issue, advanced providers should be proficient in self-protection, temperature management, and know differences between wet snow and powder avalanches and its mechanisms of injury; where gunshot or stab wounds are frequent, advanced providers should receive training on specific algorithms, such as resuscitative balloon occlusion of the aorta.

Any training however should aim to strike a balance between theoretical concepts and practical application, giving priority to improving practice. For example, it is insufficient to know the debated indications and contraindications of cervical spine immobilization, if the majority of collars put on patients do not result in sufficient restrictions of cervical spine motion [3].

Whenever possible, trainers should have both prehospital trauma care experience and experience with the local health care system. Furthermore, trainers should have received didactic training by means of a faculty development or “train the trainer” course, simply because being a good trauma care provider does not suffice to become a good teacher of trauma care.

4.1.3.2 System Evaluation and Quality Management

Trauma care systems are most effective when they incorporate routine system evaluation and quality management. Both measures can affect the system directly as well as inform preventive measures occurring outside the system. Data sources can be routine provider documentation in trauma registries, direct field observations, critical incident reporting, simply listening in on current provider communication or outcome studies. Other data sources include peer review of system components, benchmarking against similar systems, death certificate statistics, and hospital claims data. The trauma system should have the authority to validate the data source, including access to the patient’s medical records.

The WHO (www.who.int) provides many useful tools to assess and manage trauma system quality, including a resource matrix for prehospital trauma care systems, a trauma system maturity index, and a trauma care checklist, similar to the team checklist used in many operating rooms around the world.

4.1.3.3 Hospital Resources

For optimizing hospital resources, external peer review is used to verify specific hospital's capabilities to deliver appropriate level of care. Trauma centers with full capabilities and resources are defined as Level I trauma centers. It serves as a regional resource for the provision of the most advanced trauma care through immediate 24-h availability of full surgical, interventional, anesthesiological, and intensive care service.

It has been shown that triaging severely injured patients to hospitals that are incapable of providing definitive care is associated with increased mortality [4]. It is of paramount importance to accurately select, at a very early stage of the chain of rescue, which trauma victim will benefit the most from the resources of a Level I trauma center. For this objective, field triage scores to identify major trauma patients are required (Table 4.1).

Table 4.1 Trauma center categorization according to the Committee on trauma of the American College of Surgeons [5]

	Definition	Elements
Level I	Comprehensive regional resource center that is a tertiary care facility central to the trauma system. Capable of providing total care for every aspect of injury—from prevention through rehabilitation.	– 24-h in-house coverage of attending trauma surgeon, and prompt availability of care in all surgical specialties, anesthesiology, emergency medicine, radiology, internal medicine, pediatric and critical care. – Referral resource for communities in nearby regions – Leadership in prevention, public education to surrounding communities. – Continuing education of the trauma team members – Comprehensive quality assessment program – Research – At least 1200 trauma patients yearly or 240 admissions with an Injury Severity Score of more than 15
Level II	Able to initiate definitive care for all injured patients	– 24-h immediate coverage by attending trauma surgeon, as well as coverage by the specialties of orthopedic surgery, neurosurgery, anesthesiology, emergency medicine, radiology, and critical care – Tertiary care needs such as cardiac surgery, hemodialysis and microvascular surgery may be referred to a Level I Trauma Center – Provides trauma prevention and continuing education programs for staff – Comprehensive quality assessment program
Level III	Able to provide prompt assessment, resuscitation, surgery, intensive care, and stabilization of injured patients and emergency operations.	– 24-h immediate coverage by emergency medicine physicians and the prompt availability of trauma surgeons and anesthesiologists. – Comprehensive quality assessment program. – Developed transfer agreements for patients requiring more comprehensive care at a Level I or Level II Trauma center. – Back-up care for rural and community hospitals. – Continued education of the nursing and allied health personnel or the trauma team. – Involvement in prevention efforts and active outreach program for its referring communities.
Level IV	Able to provide advanced trauma life support (ATLS) prior to transfer of patients to a higher level trauma center. It provides evaluation, stabilization, and diagnostic capabilities for injured patients.	– Basic emergency department facilities to implement ATLS protocols – 24-h laboratory coverage – Available trauma nurse(s) and physicians available upon patient arrival – May provide surgery and critical-care services if available. – Developed transfer agreements for patients requiring more comprehensive care at a Level I or Level II Trauma center. – Comprehensive quality assessment program – Involved with prevention efforts and active outreach program for its referring communities.

Table 4.2 Criteria for consideration of transfer from Level III centers to Level I or II centers [5]

1.	Carotid or vertebral arterial injury.
2.	Torn thoracic aorta or great vessel.
3.	Cardiac rupture.
4.	Bilateral pulmonary contusion with Pao2:Flo2 ratio less than 200.
5.	Major abdominal vascular injury.
6.	Grade IV or V liver injuries requiring transfusion of more than 6 U of red blood cells in 6 h.
7.	Unstable pelvic fracture requiring transfusion of more than 6 U of red blood cells in 6 h.
8.	Fracture or dislocation with loss of distal pulses.
9.	Penetrating injuries or open fracture of the skull.
10.	Glasgow Coma Scale score of less than 14 or lateralizing.
11.	Spinal fracture or spinal cord deficit.
12.	Complex pelvis/acetabulum fractures.
13.	More than two unilateral rib fractures or bilateral rib fractures with pulmonary contusion (if no critical-care consultation is available).
14.	Significant torso injury with advanced comorbid disease (such as coronary artery disease, chronic obstructive pulmonary).

4.1.3.4 Interhospital Transfer

The Committee on trauma of the American College of Surgeons have worked out and give recommendations on criteria for consideration of transfer trauma patients from Level III centers to Level I or II centers (Table 4.2) [5]. Close collaboration among all the hospitals in a regional trauma system is a prerequisite to the optimal interhospital transfer of patients. The development of mutually agreed upon written guidelines for the transfer of trauma patients between institutions is an essential part of a trauma system. These agreements should define which patients should be transferred and the process for doing so. Elucidating each hospital's treatment capabilities, as well as regional transportation options, is the first step. This information is then used to develop guidelines for rapid resuscitation, identification of injured patients who require a higher level of care, transportation options, and two-way communication of performance improvement and patient safety (PIPS) issues between hospitals [5].

4.2 Rescue Strategies

The delivery of high quality prehospital care is initiating the chain of rescue and therefore critical to the survival of the severely traumatized patient. Following, three different levels of prehospital trauma care are described.

4.2.1 First Tier: First Responders

The first tier of a trauma system can be established by teaching basic trauma principles to members of the public. First responders should be qualified to recognize an emergency as such call for help and provide life-saving treatment until more formally qualified staff is available.

Many developed countries train large parts of the population in half-day courses by making participation in such courses mandatory when applying for a driver's license or other regulated activities. Training typically includes a structured diagnostic approach to patients, for example, an ABC mnemonic, where A stands for assess and airway, B for breathing, and C for circulation [6]. Interventions trained often include safe positioning of unconscious but breathing victims, movements to open obstructed airways, provision of mouth-to-mouth/nose ventilation, and chest compressions. Also, techniques to stop bleedings can be included into basic training [7]. First responders typically do not carry any medical equipment and rely on public communication networks such as mobile phone coverage to communicate with other system components.

Although first responder training is short and equipment minimal to none, educating strategically selected groups of the public can have large effects for the injured. For example, between 1998 and 2000, 335 drivers of commercial vehicles such as taxis, busses, or trucks in Ghana participated in a first-aid course [8]. Before the course, most injured people arriving in hospitals were brought there by such commercial drivers, because they volunteered to transport victims of traffic accidents they drove by, or because relatives of victims paid them. A year after the course, investigators conducted follow-up interviews with the trained drivers and with hospitals [9]. Two-thirds of the drivers indicated that they had provided first aid since taking the course, and the type of aid dramatically improved. For example, 42% of the drivers indicated they had attempted bleeding control (versus 4% before the course) and 35% had used airway management techniques (opposed to 2% before). Nurses scored the first aid of trained drivers much higher than those of an un-trained control group (7 out of 10 points versus 3 out of 10). The actual cost of the course was US$ 4 per driver trained, indicating that building in existing, although informal structures can substantially and efficiently improve trauma systems in the developing world.

4.2.2 Second Tier: Basic Prehospital Trauma Care

The second level of prehospital trauma care is typically established either at the community level or on the level of larger factories or organizations. Providers are most often volunteers but have more extensive formal training than first responders. Training typically includes basic life support (BLS) including bag-mask ventilation and the use of automated external defibrillators, or advanced bandage and splinting techniques. Providers are further trained in basic scene management, field triage, and basic documentation requirements. The amount and sophistication of material available within the second tier are highly variable and can range from a small first-aid bag to dedicated vehicles. In many areas of the world, this level of prehospital trauma care is integrated with other regionally relevant services, such as mountain rescue, park rangers, or costal lifeguards.

4.2.3 Third Tier: Advanced Prehospital Trauma Care

The third tier is composed of highly trained staff, mostly working under a paid employment contract. Providers, called emergency medical technicians (EMT) or paramedics in many parts of the world, typically have received hundreds or more hours of both, formal education and supervised training on the job. In most countries of the developed world, providers at this level of trauma care are members of a regulated profession with legislation that sets their freedom of action and defines expectations towards them and the system component. For example, German legislation regulating professional preclinical trauma care sets a timeframe for system responses (for e.g., 10 min from reception of a call for help until arrival on scene of the first qualified staff.)

Entities of the third tier are often equipped with a dedicated communication system that connects them among each other, to a central coordination unit and/ or to hospitals in the proximity. Furthermore, the third tier typically uses dedicated and extensively equipped transportation units, such as ambulances or helicopters. Beyond these basic similarities—extensively trained professionals with dedicated and often extensive equipment—the design and work of third tier components are highly variable across the world. While many European systems widely employ prehospital physicians, most of the Anglo-Saxon parts of the world give priority to the use of EMTs and restrict the use of physicians outside hospitals to very special situations (such as, e.g., remote area coverage provided by the flying doctor service in Australia).

Two systems rather different with respect to the availability of prehospital physicians are the Netherlands and Germany. While Germany is known for its physician based prehospital approach to any emergency patient, with a dense network of hundreds of physician staffed ground vehicles and helicopters, in the Netherlands, prehospital care is a domain of EMTs who can call upon one of just four physician staffed mobile medical teams. A retrospective registry study compared the effect of national prehospital rescue strategies between the two countries on the status of severely injured patients at the time of admission to a trauma center [10]. Of the 12,168 patients included in the study, around 58% in the Netherlands arrived at the hospital in company of a physician, a stark contrast to the 98% observed in Germany. Patient injuries and demographics were largely comparable between the two countries, and the study found no difference in 24 h mortality. However, the mean prehospital time for patients in Germany was 15 min longer than in the Netherlands (68.7 min vs. 53.8 min) despite comparable treatment free intervals (and thus likely distance of the third tier to the scene of injury) and German patients received twice as much prehospital volume (1103 mL vs. 541 mL). The study did not assess system effectiveness, but its results raise the question whether the extensive use of prehospital physicians is indeed efficient. The expense of providing routine physician presence in the field is also a consideration, and in the US there is virtually no physicians directly involved in prehospital care.

4.2.4 "Scoop and Run" Versus "Stay and play"

As mentioned above, a victim may be initially assessed by a provider able to provide basic life support (BLS) or perhaps advanced life support (ALS). While BLS programs provide solely noninvasive maneuvers such as maintenance of spinal precautions, fracture splinting, extremity hemorrhage control, and assisted ventilation with the aid of a bag-valve-mask system, ALS programs have the capacity to provide definitive airway control with endotracheal intubation and venous access in the prehospital setting. Moreover, depending on the local circumstances, prehospital ALS interventions can be provided by EMS personnel with or without a physician. With a physician, an even much larger scope of resuscitative interventions is within the armamentarium of the preclinical team including needle chest decompression or even cricothyrotomy [11]. ALS interventions to the injured patient in the field have largely replaced programs offering BLS alone. Of note, ALS was provided to 79% of severely injured patients in the US [12].

While prehospital ALS has theoretical advantages, the evidence supporting its effectiveness and justification for widespread implementation for trauma is limited [13]. A major concern and a matter of debate are the delay to definitive care due to the administration of ALS interventions in the field—also known as the "Stay and Play" approach. This stands in contrast with the BLS principles, which is representing the "Scoop and Run" tactic. Several studies directly comparing outcomes among patients receiving ALS or BLS prehospital care have demonstrated the absence of benefit, or even the presence of harm, with ALS care, although a number of studies showed no increase in the prehospital time with field ALS interventions [14–18]. However, it is important to note that the majority of studies examining care in the prehospital environment are based on data from established regional systems, in which the decision for a field ALS or BLS response is protocolized. As a result, more critically injured patients receive ALS—which makes it difficult to assess whether the higher rates of adverse outcomes are due to ALS or occur in spite of ALS care. As a result, it may be more informative to focus on studies of individual interventions or specific injury pattern.

4.2.5 Prehospital Endotracheal Intubation

Several studies comparing bag-valve-mask ventilation with more advanced airway management found no benefit associated with prehospital intubation. In fact, a number of studies have demonstrated higher rates of mortality, with the group most likely to be affected being those patients with traumatic brain injury [19–21]. These data are particularly concerning, given the theoretical benefit of airway control in this population. Prehospital endotracheal intubation is challenging [22] and potential benefits have to be outweighed with endotracheal intubation-related complications, including multiple intubation attempts [23], improper tube placement [24, 25], prolonged scene time [26], transient desaturation [27], hyperventilation [28, 29], hypotension [30], hypertensive response to laryngoscopy and endotracheal intubation [31] which may lead to increased intracranial pressure [32], and endotracheal intubation/laryngoscopy-induced increased intracranial pressure [33].

Although the previously cited studies appear to support scoop and run, a number of methodological issues should be highlighted. More severely injured patients are more likely to undergo intubation attempts. The question is further complicated by the heterogeneity of patients and providers included in available studies. For example, many studies of prehospital intubation include patients with both blunt and penetrating injuries [20, 34], while others have focused on patients with head injuries [35, 36]. Providers include physicians and paramedics with variable training, and the frequency of intubation attempts and successful intubations clearly depend on each individual prehospital system. This has been shown by Klemen and Grmec who demonstrated decreased early mortality in patients with traumatic brain injury intubated in the field compared with those patients without definitive airway control [35]. The findings of that study, however, were confounded by the differences in training between the field physician providers, who cared for virtually all of the intubated subjects in the study, and the paramedic providers, who cared for all of the nonintubated subjects. Finally, the geographical situation needs to be taken into account. In circumstances of very long transport times, e.g., in rural environments, interventions prior to transportation to hospital might provide some advantage. For example, in the US when transport times exceed 45 min, helicopter flight nurses routinely preform ALS procedures. In an urban environment with relatively short transport times, however, there is no strong evidence supporting field endotracheal intubation [13].

4.2.6 Prehospital Fluids

For hypotensive patients with penetrating torso injuries, delay of aggressive fluid resuscitation until operative intervention has been shown to improve the outcome although the benefit was primarily in those with penetrating cardiac wound [37]. This well conducted study has stimulated many similar studies and the concept of planned hypotensive or damage control or hemostatic resuscitation has been promulgated. Nevertheless, there are still preclinical protocols that call for the provision of intravenous (IV) access with two large bore IVs followed by the rapid administration of saline or Ringers lactate if the blood pressure is below 90 mmHg systolic. However, obtaining an IV in poor conditions is difficult and is resulting in a delay to definitive treatment. In addition, running fluid into a patient without hemorrhage control is itself controversial and has the potential to harm by worsening of trauma-induced coagulopathy and hypothermia [38]. However, this controversy is further complicated by the availability of whole blood and blood products in prehospital systems, particularly in air medical transport with longer transport times. Recent studies in the US demonstrated improved outcome with plasma in air transport [39] but no benefit with ground transport [40]. Currently, studies on the impact of the administration of blood products in the prehospital setting on outcomes after trauma are ongoing. However, it is vital that the prehospital trauma care providers always consider the delay to definitive care against the potential benefit from the field treatment.

4.2.7 Field Triage Scores

Adequate prehospital trauma triage of injured patients is essential for optimal trauma care. In an inclusive trauma system, it is critical to transport patients with severe injuries to a Level I trauma center and patients without severe injuries to lower-level hospitals. Management of care of the injured trauma patient on the scene of injury remains challenging, and situations can be chaotic. After a rapid trauma assessment of clinical and physiological parameters, EMS professionals must identify patients at risk for severe injury and select the proper destination. Therefore, prehospital triage scores with a high accuracy to predict severe injury are required.

The prehospital triage scores are mainly based on physiologic and non-time-dependent factors (Table 4.3). However, even in a very advanced pre-

Table 4.3 Selection of indications for immediate transport to a trauma center

Physiologic parameters:
• Glasgow Coma Scale (GCS) ≤13
• Systolic blood pressure <90 mmHg
• Respiratory rate <10 or >29 breaths/min (or in age <1 year, respirations<20 breaths/min)
• Requiring ventilatory support
Non-time dependent factors
• Penetrating injury to head, neck, torso, or proximal extremity (above knee or above elbow)
• Two or more proximal long bone fractures
• Crushed, degloved, mangled, or pulseless extremity
• Extremity amputation proximal to the wrist or ankle
• Pelvic fracture
• Open or depressed skull fracture
• Paralysis

hospital setting, 20% of the patients with severe injuries are not transported to a Level I trauma center [41]. This is significantly higher than the benchmark level of 5%, as set by the ACS-COT [42]. This underlines the difficulties and real world challenges of prehospital evaluation of trauma victims. Of note, these undertriaged patients are at increased risk for preventable morbidity and mortality [43]. Especially elderly patients with more co-morbidities or patients with traumatic brain injury who require operative intervention are susceptible for an undertriage [44, 45]. Currently, no single field triage score has been accepted as the gold standard and there is need for improvement of the prehospital triage protocol.

Since 1986, the Centers for Disease Control and Prevention (CDC) in the US collaborated with the American College of Surgeons Committee on Trauma (ACS-COT) to provide guidance for the field triage process though its "Field Triage Decision Scheme." In 2011, the CDC reconvened the Panel to review the 2006 Guidelines and recommend any needed changes. Figure 4.1 is showing the 2011 Guidelines for field triage of injured patients [46]. Triaging a single trauma patient is guided according to the defined triage criteria for that particular regionalized trauma system. If the patient meets the criteria of a major trauma victim, her or she is transported to the nearest designated trauma center.

4.3 Conclusion

A trauma system will improve the care of polytraumatized patients on different outcome levels. Triaging polytraumatized patients to Level I trauma centers will improve outcome. No single field triage score has been accepted as the gold standard and there is need for improvement of the prehospital triage protocol because undertriaging is an ongoing problem. Reducing the delay to definitive treatment of trauma victim is the primary goal of the rescue. The benefit of prehospital treatment efforts needs careful scientific assessment, as advanced life support not necessarily results in better outcomes than basic life support.

Key Concepts

- Have a trauma system in place and support centralization of polytraumatized patients
- Triage polytraumatized patients to Level I trauma centers
- Be aware of undertriage of polytraumatized patients
- Have a prehospital triage protocol in place with ongoing quality control of accuracy
- Reduce the delay to definitive treatment of trauma victims
- Carefully consider and assess prehospital treatment efforts, as advanced life support may not necessarily result in better outcomes than basic life support

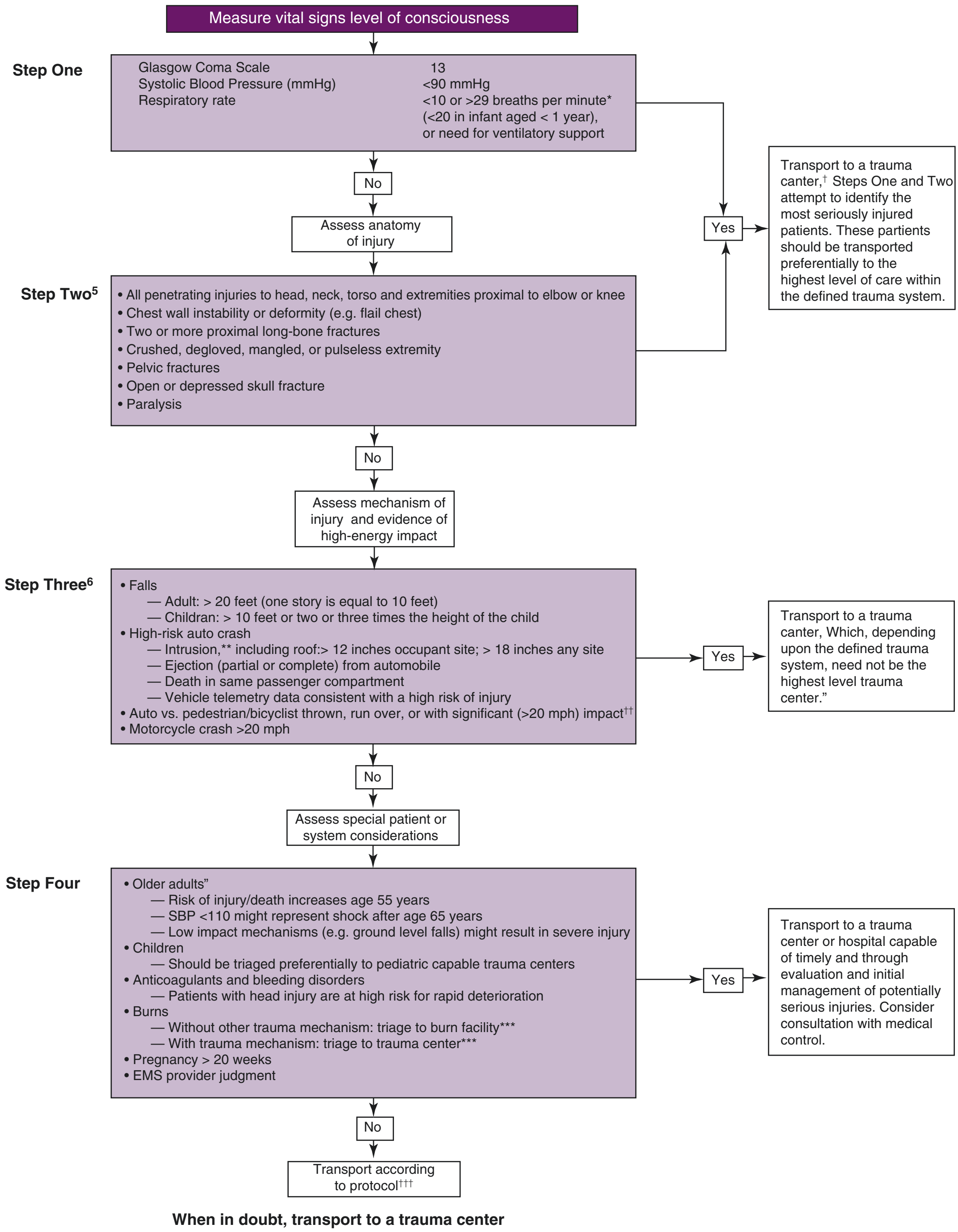

Fig. 4.1 Guideline for field triage of injured patients [46]

Take Home Messages

- A trauma system is a prearranged approach to trauma patients in a defined geographical area that provides full and optimal care.
- A significant reduction in mortality is found when a regional trauma system is present.
- The key elements of a trauma system are access to care, prehospital and hospital care, and rehabilitation.
- Undertriaged trauma patients are at increased risk for preventable morbidity and mortality.
- Elderly patients with more co-morbidities or patients with traumatic brain injury are susceptible for an undertriage.
- Prehospital trauma care providers should always consider the delay to definitive care against the potential benefit from their field treatment.

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