Surgical Decision-Making in the Management of Polytrauma Patients

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Anthony Duncan, Ergest Isak, Mentor Ahmeti, and Anthony Duncan

Abbreviations

AIS	Abbreviated Injury Score
ATLS	Advanced Trauma Life Support
DCR	Damage Control Resuscitation
DCL	Damage Control Laparotomy
DCO	Damage Control Orthopedics
TBI	Traumatic Brain Injury

Introduction

Polytrauma is not a novel term within the medical field, originally described by Border et al. as encompassing any patient who has sustained two or more significant injuries [1]. Its most recent iteration, established by the Berlin definition, is evidence-based and encompasses all patients with an Abbreviated Injury Score (AIS) of greater than or equal to 3 in two or more bodily systems [2]. Despite continuous research and advances in polytrauma management, it remains a significant global cause of mortality, despite notable improvements in medical care and trauma management [3, 4]. Managing polytrauma patients necessitates a multidisciplinary approach, swift assessment, and well-coordinated care to optimize outcomes. This chapter delineates the fundamental principles and steps essential to the effective management of polytrauma patients.

A. Duncan

A. Duncan · E. Isak
Department of Surgery, University of North Dakota School of Medicine and Health Science, Grand Forks, ND, USA
e-mail: Anthony.Duncan@und.edu; ergest.isak@und.edu

M. Ahmeti (✉)
Department of Surgery, University of North Dakota School of Medicine and Health Science, Grand Forks, ND, USA

Department of Trauma and Acute Care Surgery, Sanford Medical Center Fargo, Fargo, ND, USA

Initial Assessment and Stabilization

Primary Survey

Upon the patient's arrival at the hospital, a meticulously organized approach to their management becomes imperative. The foundations of this initial management can be discovered in the Advanced Trauma Life Support (ATLS) guidelines, which serve to enhance the quality and efficiency of care for polytrauma cases. The primary survey in ATLS adheres to the ABCDE approach, addressing the following key aspects: Airway, Breathing, Circulation, Disability, and Exposure [5].

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Airway

Airway management takes precedence in ATLS and should be addressed before proceeding with the rest of the algorithm [5]. Additionally, in these patients, the mechanism of injury should be carefully considered, and cervical spine stabilization should be maintained if necessary. Assessing the patient's response is crucial, as it enables the determination of airway patency and the sufficiency of cerebral oxygen supply for cognitive function. If issues arise with the patient's oxygenation, simple interventions can be attempted to improve the situation, such as oral suctioning or the use of a chin lift/jaw thrust to enhance airway patency.

In most clinical scenarios involving patients with a Glasgow Coma Scale (GCS) score of less than 8, securing a definitive airway becomes imperative. This is typically achieved through the insertion of an endotracheal tube, a method widely recommended. In the context of polytrauma, many clinicians advocate for the use of video laryngoscopy, as it reduces strain on the neck in patients with potential cervical spine injuries and has shown to increase first-attempt intubation success rates [6, 7].

If endotracheal intubation is unsuccessful or not feasible, the next step involves establishing a surgical airway. This can be accomplished through either cricothyroidotomy or tracheostomy. Cricothyroidotomy is often preferred as it is less technically challenging and can be performed more expeditiously. Both percutaneous and open techniques have been described, with animal models demonstrating that an open scalpel technique is superior in terms of achieving a timely airway [8, 9].

Breathing

Breathing is the vital process responsible for oxygenating the blood, primarily reliant on lung parenchyma. The initial assessment entails several key steps: auscultating for bilateral breath sounds, monitoring pulse oximetry readings, and observing respiratory rate and effort. Absence of breath sounds warrants immediate consideration of conditions that could compromise respiration, such as tension pneumothorax or hemothorax. Left untreated, these conditions can swiftly escalate into life-threatening emergencies. Depending on the clinical setting and availability of supplies, the choice between needle thoracentesis, finger thoracostomy, or tube thoracotomy should be made. When opting for needle thoracentesis, it should be executed at the fifth intercostal space, just anterior to the mid-axillary line, with a prompt transition to tube thoracostomy as soon as practical [10]. Tube thoracostomy placement is ideally positioned at the fifth intercostal space along the mid-axillary line.

Circulation

In the Advanced Trauma Life Support (ATLS) protocol, the "C" signifies "Circulation," highlighting its pivotal role in managing a patient's cardiovascular system during trauma care [5]. Swift and precise assessment of circulatory status is paramount, as inadequate perfusion can lead to life-threatening complications. Healthcare providers concentrate on evaluating critical parameters, including blood pressure, heart rate, capillary refill time, and overall hemodynamic stability. Identifying and controlling sources of blood loss are of paramount importance during this phase. External blood loss can be readily detected through observation and physical examination, with common external bleeding sites including long-bone fractures and scalp lacerations. On the other hand, internal blood loss can be more challenging to pinpoint. To aid in diagnosis, chest X-rays can be used to assess intrathoracic hemorrhage, and a focused assessment with sonography (FAST) examination can provide valuable information, although it may not entirely rule out internal bleeding. In cases where significant blood loss is suspected, initiating a balanced transfusion of packed red cells, fresh frozen plasma, and platelets at a 1:1:1 ratio as soon as possible has been shown to improve outcomes compared to crystalloid resuscitation [11, 12]. Hemostatic resuscitation studies reported the ratio for platelets in pooled packs. It is important to note that platelet volume nomenclature has changed to platelet units which are equivalent to 6 platelet packs, as to reduce confusion, the actual transfusion ratio should be 6:1:6. More recently, there has been a shift toward using whole blood, where available, for cases involving significant blood loss [13, 14]. Tranexamic acid (TXA) has also demonstrated promise in trauma patients, as it effectively reduces the rate of fibrinolysis, preserving clot integrity. Administration should begin with a 1-gram bolus within 3 hours of the initial injury, followed by an additional 1-gram infusion over the subsequent 8 hours [15–17].

Disability

The assessment of a patient's disability status necessitates a comprehensive evaluation of their entire neurological condition. This encompasses obtaining the Glasgow Coma Scale (GCS) score, conducting a thorough examination of pupils, and assessing motor and sensory functions in the extremities to detect any deficits. It is of utmost importance to meticulously document and record these findings, as this documentation serves as a baseline to monitor for any potential deterioration in the patient's condition. In cases where a patient presents with a diminished level of consciousness, traumatic brain injury should always be a primary consideration.

Exposure/Environment

During this phase of the evaluation, it is essential to remove all of the patient's clothing to facilitate a comprehensive head-to-toe examination, which includes the back, to uncover any potential concealed injuries. Additionally, meticulous care must be exercised to prevent the onset of hypothermia by providing warm blankets to shield the patient from temperature loss and maintain their body heat.

Management priorities

While the linear sequence of airway-breathing-circulation has been a long-standing principle taught for decades and adopted by the ATLS course for ease of didactic teaching, management of polytrauma patients should focus on addressing immediately life-threatening injuries. While a principle of Tactical Combat Casualty Care for decades, recently this concept has been gaining acceptance in civilian trauma management, supported by civilian evidence as described by Ferrada that hypotensive patients who underwent intubation before blood transfusion exhibited a significantly higher mortality rate compared to those who underwent transfusion first [18]. Conversely, other studies indicate no disparity in mortality when comparing CAB (Circulation-Airway-Breathing) and ABC sequences [19]. We maintain the belief that there is no one-size-fits-all approach for polytrauma patients, given the unique patterns of injury each individual presents with. Particularly, in real-time situations where multiple issues demand simultaneous attention, patients should be assessed and treated for the most immediate concern—whether it be hypovolemic shock or critical hypoxia. Authors are excited to learn that new ATLS formats will shift from the historic ABCDE to xABCDE priority, where **x** stands for e-**x**-anguination and/or e-**x**-tremity, in recognition of evidence available.

Management of injuries based on system

Damage Control Resuscitation (DCR)

DCR was initially developed by the military after witnessing the benefit of giving whole blood to patients. As polytrauma patients undergo continued blood loss, there is a shift toward the trauma patient lethal triad including metabolic acidosis, hypothermia, and coagulopathy. DCR focuses on prevention of the coagulopathy aspect of the lethal triad but must occur in conjunction with immediate control of bleeding, either by direct pressure, tourniquets, or damage control laparotomy (DCL) depending on the scenario. DCR does not substitute bleeding control. There continues to be a growing amount of evidence for use of balanced transfusion or whole blood in trauma patients with limiting the amount of crystalloid products given [12]. Despite lack of controlled randomized trials, benefits of whole blood continue to be described; including a decreased amount of excess volume given compared to component therapy, better coagulation profile, improved function of product, decreased 24-hour and in-hospital mortality, and decreased complication rates [12, 20, 21].

Traumatic Brain Injury (TBI)

The initial evaluation of polytrauma patients with suspected TBI should prioritize the assessment of neurological status. The Glasgow Coma Scale (GCS) remains a valuable tool for quantifying the severity of TBI. The goal of preventing secondary injury in traumatic brain injury (TBI) is a crucial focus of evidence-based management. It is one of the major effects clinicians can have to prevent worsening of patient outcomes. The two major and preventable causes that are seen to cause secondary injury are hypoxia and hypotension.

Maintaining adequate cerebral perfusion pressure (CPP) by optimizing blood pressure and oxygen delivery to the brain is essential. Cerebral perfusion pressure = mean arterial pressure-ICP. Current guidelines support the use of advanced monitoring techniques to guide the management of TBI in polytrauma patients [22]. Intracranial pressure (ICP) monitoring is crucial for early detection and management of intracranial hypertension, which can lead to secondary brain injury. Classical recommendations per the Brain Trauma Foundation recommend maintaining an ICP of ≤22. However, more recent studies suggest that a patient specific ICP goal is more correlated with improved outcomes [23, 24]. There has recently been questioning if agents like hypertonic saline or mannitol are beneficial. While they have been shown to decrease ICP, there appears to be no benefit in mortality or neurological outcome with them [25–27].

Two recent randomized control trials evaluated the utility of using prophylactic hypothermia in severe TBI. They differed slightly with one using hypothermia in patients with elevated ICP and the other study performed this in patients without elevated ICP [28, 29]. While prophylactic hypothermia was successful at decreasing ICP, but at the cost of increased mortality and worst neurological outcomes [28, 29]. Further, patients with TBI that present with accidental hypothermia are found to have significantly higher rates of mortality [30].

Surgical Interventions: In select cases of severe TBI, surgical interventions like decompressive craniectomy have gained prominence as a means to reduce intracranial pressure and prevent herniation. Some data suggests that use of decompressive craniectomy can improve outcomes, particularly in patients with refractory intracranial hypertension [31, 32]. In contrast, the DECRA study showed while early decompressive craniectomy decreased intracranial pressure, it was associated with worst 6-month mortality [33]. However, the correct patients that would benefit most from decompressive craniectomy and have meaningful quality of life are still being investigated.

Hypoxia and hypotension are associated with poorer outcomes in TBI patients, emphasizing the importance of oxygenation and hemodynamic stability. Addressing injuries that cause hemodynamic instability becomes a priority in patients with TBI. Additionally, avoiding hypercapnia and maintaining normocapnia, as well as managing temperature to prevent hyperthermia, have been shown to reduce secondary injury. Close neurological monitoring, the use of advanced neuromonitoring techniques, and a multidisciplinary approach are integral to the evidence-based prevention of secondary brain injury in TBI patients.

Abdominal Injuries

Damage Control Laparotomy

Damage Control Laparotomy (DCL) continues to be a fundamental part of trauma surgery. DCL focuses on controlling hemorrhage and contamination while minimizing operative time to save the physiologic reserve of the patient. Typical indications for DCL are as follows: metabolic acidosis ($pH < 7.2$), hypothermia (<35 °C), coagulopathy, patients who are unstable and operation will last longer than 2 hours, or patients that will require further intra-abdominal surgical evaluation at a later time [34].

Combination of improvements in temporary abdominal closures and hemostatic resuscitation over the past decade have made the DCL more efficient and decreased the rate of complications we see. As stated above the focus of DCL is first controlling hemorrhage and second, contamination. Hemorrhage should be controlled with timely repair, packing, simple ligation, or temporary shunts. Hollow viscus injuries should be resected and anastomosis left for the time of definitive repair. Multiple different methods of temporary negative pressure systems exist commercially or can be fashioned with equipment readily available in the operating room, to serve as an optimal method of temporary abdominal closure. The initial portion consists of a porous plastic covering that allows extraction of fluid while preventing the formation of adhesions. In authors' experience, a sterile X-ray film cover with perforations works very well, is inexpensive and readily available. Foam or operating room sterile towels are then placed with an eventual occlusive dressing overtop with airtight drains being laid in bilateral gutters. Negative pressure is then typically applied between 100 and 150 mmHg. There are also readily available commercial products that include all parts in a single package. Once the patient has been removed from the operating room, focus should be placed on further resuscitation, hemodynamic stability, correction of acid/base, electrolyte abnormalities and rewarming.

After the patient has been stabilized and physiologically optimized in the ICU setting, they should be considered for return to the operating room either for repeat exploration or definitive repair. While multiple centers and surgeons will opt for an arbitrary 48-hour period, we recommend returning to the operating room once the patient is physiologically optimized.

With the evolution of and utilization of the open abdomen strategy, it is important to keep in mind closure of the abdomen. Delay in closure is associated with increase in ventral hernias, enterocutaneous or entero-atmospheric fistulas, and loss of abdominal domain. One recent study showed that closure of the abdomen within 8 days can minimize complications [35].

Non-operative management

High quality data shows the benefit of non-operative management (NOM) within abdominal trauma in certain clinical situations [36, 37]. The current standard of care for the majority of patients with blunt abdominal trauma who are hemodynamically stable without peritonitis is to pursue further radiological work up with computed tomography. However, patients who are hemodynamically unstable or exhibit peritonitis on examination should undergo surgical intervention, as stated above.

The management of transient responders involves institutional resources (availability of interventional radiology or surgical capabilities) to address the cause of hemodynamic instability. In facilities with quick access to interventional radiology, stable patients with solid organ injuries of advanced grading will often be effectively treated with angioembolization or other interventional radiologic interventions. Our institution uses the American Association for Surgery of Trauma grading of solid organ injuries.

Patients with known injuries who are being managed with NOM require hospital admittance with close monitoring for changes in the patient's clinical status. There are no current recommendations on the frequency of monitoring; however, it typically consists of serial laboratory values, NPO status, initial short-term limitations of activity, and repeat abdominal examinations. Clinicians also need to maintain a high index of suspicion for injuries that are often missed on the patient's initial CT scan, including hollow viscus injuries and diaphragmatic injuries. Furthermore, patients who experience deterioration in their clinical status should undergo operative intervention as quickly as possible.

Thoracic Injuries

Injuries resulting from trauma stand as the primary global cause of mortality. In the United States, thoracic trauma contributes to as much as 35% of trauma-related fatalities, involving a diverse array of injuries resulting in significant morbidity and mortality [38, 39]. Thoracic trauma is seen in approximately two-thirds of trauma patients and with varying degrees of severity, often ranging from simple rib fractures to more complex penetrating injuries. Thoracic trauma is broadly categorized as blunt or penetrating trauma. Blunt chest trauma is the most common, accounting for 80% of incidents, with less than 10% needing any form of surgical intervention vs. 15 to 30% in patients that sustained penetrating chest injuries [38]. However, blunt chest trauma directly contributes to 20 to 25% of trauma deaths [38]. Mortality rates, second only to head injuries, emphasize the critical significance of prompt and effective initial management. Timely diagnosis and treatment can prevent a significant number of these fatalities [38].

The management of chest trauma can be categorized into three specific tiers of care: prehospital trauma support, in-hospital or emergency room trauma support, and surgical trauma support [36]. Recognizing thoracic injuries at each care level is pivotal for subsequent outcomes. The initial resuscitation and management of a patient with chest trauma adhere to protocols outlined in Advanced Trauma Life Support (ATLS) [5]. Following a primary survey, the focus is on promptly excluding or addressing immediately life-threatening injuries, such as tension pneumothorax, massive hemothorax, flail chest, cardiac tamponade, aortic injury, and tracheobronchial disruption.

Prehospital support: The initial evaluation of the trauma patient begins with the primary survey, which is an essential step in recognizing immediately life-threatening conditions such as tension pneumothorax, pulmonary contusion, massive hemothorax, and cardiac tamponade. General inspection of the thorax for asymmetry; palpation for tenderness, crepitus, and flail segments; percussion; and auscultation [sensitivity of 90% and specificity of 98% will aid in identifying life-threatening conditions such as tension pneumothorax, which may necessitate immediate intervention such as needle decompression or tube thoracostomy [40, 41]. Given that tension pneumothorax stands as the most frequently reversible cause of death in trauma patients experiencing cardiac arrest, prompt and accurate assessment is crucial [42–44].

In-hospital support: The assessment of patients with thoracic trauma commences with Advanced Trauma Life Support (ATLS) and subsequently utilizes diverse imaging methods contingent on the initial symptoms observed. Swift intervention is imperative for life-threatening injuries identified during the initial trauma assessment.

Ever since its initial formal description nearly five decades ago, the emergency department thoracotomy (EDT) has remained a subject of debate for many years [45]. Research indicates that outcomes depend on the mechanism of injury, anatomic location of injury, and the presence of signs of life on arrival [39]. Defined by the American College of Surgeons Committee on Trauma in 2001, signs of life are considered present with any of the following: pupillary response, spontaneous ventilation, presence of carotid pulse, measurable or palpable blood pressure, extremity movement, or cardiac electrical activity [45]. In penetrating chest trauma, the survival rate after resuscitative thoracotomy is 8.8%, contrasting with 1.4% in blunt chest trauma. Notably, patients with penetrating chest trauma and signs of life upon arrival have an overall survival rate of 19.4% in contrast to 4.6% overall survival in blunt chest trauma with signs of life present upon arrival [46]. There have recently been some suggestions as to different indications in pediatric patients compared to adult patients [47, 48]. Adult and pediatric patient indications/contraindications for resuscitative thoracotomy include [49–51]:

Adult Indications:

Salvageable postinjury cardiac arrest:

- Patients sustaining witnessed penetrating trauma with <15 minutes of prehospital CPR.
- Patients sustaining witnessed blunt trauma with <5 minutes of prehospital CPR.

Persistent severe postinjury hypotension (SBP $\leq$ 60 mmHg) due to:

- Cardiac tamponade.
- Hemorrhage—intrathoracic, intra-abdominal, extremity, cervical.
- Air embolism.

Adult Contraindications:

- Penetrating trauma: CPR > 15 minutes and no signs of life (pupillary response, respiratory effort, or motor activity).
- Blunt trauma: CPR > 5 minutes and no signs of life or asystole.

Pediatric Indications:

- Pediatric patients with penetrating thoracic or abdominopelvic injury and signs of life on presentation.
- Pediatric patients with blunt injury and signs of life on presentation.

Pediatric Contraindications:

- Pediatric patients with penetrating thoracic or abdominopelvic injury without signs of life on presentation.
- Pediatric patients with blunt injury without signs of life on presentation.

Hemothorax and pneumothorax are the most common injuries frequently encountered in thoracic trauma. These can be definitively managed through the use of a chest tube in 80% of cases [39]. Approximately 10% of all trauma patients and 30% of those with chest trauma exhibit rib fractures [43]. Initial management in patients with three or more rib fractures entails ensuring adequate analgesia, thoracostomy drainage if required, and pulmonary hygiene. Effective pain control is paramount and involves a multimodal approach beginning with acetaminophen and NSAIDs, with opioids administered on an as-needed basis. Regional anesthesia, such as epidural anesthesia can be used as a step-up approach for patients with multiple or displaced rib fractures, and for those with pain unresponsive to pharmacologic management [45]. Surgical rib fixation is typically performed within 48 to 72 hours of the injury and is reserved for cases where adequate pain control cannot be achieved and for patients facing impending respiratory failure or unable to wean off ventilatory support [39]. Certain patients require urgent or emergent operative intervention. Thoracotomy performed in the operating room is indicated for various conditions in thoracic trauma including massive hemothorax with blood loss ≥1500 mL initially or > 200 mL/hour of chest tube output over 2–4 hours, cardiac tamponade, great vessel injury, significant air leak persisting after thoracostomy placement, confirmed tracheobronchial injury, and open pneumothorax [34]. As minimally invasive techniques have become more popular, video-assisted thoracoscopic surgery (VATS) has been increasingly used in favor of thoracotomy in hemodynamically stable trauma patients, leading to faster recovery, reduced post-operative pain, and greater visualization of the entire pleural place for diagnosing and treating commonly missed injuries such as retained hemothoraces and diaphragmatic lesions [38, 52, 53].

Orthopedic Management

Orthopedic injuries are a significant source of hemorrhagic shock and blood loss for polytrauma patients and must be considered and addressed in the acute setting. It has been estimated that a significant amount of musculoskeletal injuries are missed during the primary survey [54].

Pelvic fractures can cause a significant amount of blood loss without external physical signs other than vital changes. Open long-bone fractures also must be recognized and addressed as they have major vascular supply and will have no means of self-tamponade. Orthopedic trauma surgery has also taken a similar paradigm shift from what was previously known as “Early Total Care” (ETC) to what is now standard of care as “Damage Control Orthopedics” (DCO). The notion that the polytrauma patients with significant musculoskeletal injuries were considered too physiologically unstable to undergo any major orthopedic surgery was questioned by the Bone et al. study in 1989 [55]. This landmark study found that early fixation of all long-bone fractures within 24 hours of initial injury led to reduced morbidity among patients, including reduced pulmonary complications and length of ICU and hospital stay [55]. The term "Early Total Care" was shortly established following this study, and it referred to definitive fracture surgery within 24–48 hours for all long-bone fractures in a polytrauma patient. The practice of ETC was challenged as studies that followed found a rise in pulmonary complications and multiorgan dysfunction observed in polytraumatized and physiologically unstable patients that were managed using this approach. The studies described these complications as arising from the "second hit" or inflammatory response associated with fracture surgery [56]. This led to the emergence of "DCO." Modeled after the concept of "damage control surgery," "DCO" emphasizes that a certain subgroup of patients require further resuscitation and medical optimization prior to undergoing definitive fracture surgery and thus, temporizing measures such as external fixation of fractures can lead to more favorable outcomes in such patient groups [57]. Current recommendations though are for open fractures to be taken to the OR within 24 hours for initially debridement and possible early closure [55].

Infection Prevention and Antibiotics

Prophylactic Antibiotics

Prompt antibiotic use is important in indicated clinical settings, while not overusing to create antibiotic resistance is also essential. The usage of antibiotics must still be driven by the etiology of disease process that the patient is experiencing. Patients who have open fractures, lacerations, or concern for viscus injuries justify the usage of antibiotics. The majority of trauma centers will have intuitional protocols for recommended antibiotic and dosages given their area specific microbiome. Those who are being taken to the operating room for intervention also justify the use of prophylactic antibiotics given within one hour prior to incision. In regard to doing open abdomen, evidence shows that there is a benefit in prompt prophylactic administration of antibiotics and early discontinuation in appropriate patients [58].

Multidisciplinary Care

Team Collaboration

The polytrauma patient often presents with injuries spanning various medical specialties, necessitating a comprehensive, multidisciplinary treatment approach. The optimal approach to caring for multiply injured patients requires a multidisciplinary team, including but not limited to trauma surgeons, orthopedic surgeons, anesthesiologists, intensivists, neurosurgeons, maxillofacial surgeons, ophthalmologists, diagnostic/interventional radiologists, and various other specialists [59]. Vertical integration of various teams within the healthcare system is essential in the delivery of care and management of the polytrauma patient. This includes integration of nursing, advanced practice providers, pharmacists, blood bank, case managers, social workers, clinical psychiatry, and physical and occupational therapists to name a few.

This comprehensive approach to managing polytraumatized patients spans across various disciplines, commencing in the prehospital phase with the involvement of early responders and emergency medical service (EMS) personnel. It is these highly specialized prehospital teams who are tasked with the initial assessment, stabilization, and transportation of the polytrauma patient to the nearest trauma center equipped to address their needs [60]. Given the substantial volume of trauma patients, accurate triage is crucial, with over 90% best served in local community hospitals [60]. The remaining 10%, comprising severely injured individuals necessitating higher level of care at Level I and II trauma centers, demands a multidisciplinary approach to enhance overall clinical outcomes [60]. When in the trauma bay, effective, closed-loop communication and level-appropriate division of tasks among members of the team is of crucial importance in effectively managing a polytrauma patient [61]. Team members such as anesthesiologists play a major role in both the peri-operative and intraoperative care of the polytrauma patient. Ensuring that recommended large bore peripheral IV access (or when not possible adequate vascular access, intraosseous needle, central venous line, or arterial line for hemodynamic monitoring) has been obtained for resuscitation and infusion of intravenous fluids, blood products, and medications is a task that can be accomplished by trained emergency room providers while the trauma surgeon can focus on the operative management aspect of the patient. Once the patient has been stabilized, the intensivists not only provide additional critical care to trauma patients but are also intimately involved in consulting and coordinating care between different members of the healthcare team. Thus, successful integration of a collaborative, multidisciplinary team approach in managing the polytrauma patient is crucial for minimizing complications, lowering mortality rates, and expediting recovery following injury [59].

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