Surgical Management of Musculoskeletal Trauma

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• Extremity trauma • Limb salvage • Limb reconstruction
• Damage control orthopedics • Early total care • Early appropriate care

KEY POINTS

- Extremity injuries account for more than 50% of the total costs to society for nonfatal injuries.
- Communication between the orthopedic surgeon, trauma team leader, and other surgical services is paramount to optimize outcomes.
- Damage control orthopedics (DCO) is reserved for the physiologically unstable or borderline patient.
- Early total care (ETC) is often ideal for the management of stable trauma patients with isolated extremity injuries.
- Early appropriate care refers to the decision to apply either DCO or ETC depending on the patient's physiologic status and response to resuscitation.

SOCIETAL BURDEN OF EXTREMITY TRAUMA

Injuries remain a leading cause of death in people younger the age of 65 years. When considering years of potential life lost, it ranks higher than malignant neoplasms, heart disease, and cerebrovascular disease. However, deaths are truly just the tip of the iceberg. For every trauma-related death there are 13 hospital discharges and 140 emergency department visits related to injury or trauma.[1] With advances in automobile safety and improvements in acute resuscitation strategies, lives are being saved, but that comes at a cost for both the patient and society. When evaluating societal costs due to injury, 20% can be attributed to medical and related costs, another 35% are due to productivity losses due to death, and 45% are due to productivity losses

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due to disability. When looking specifically at the comprehensive costs on society of nonfatal injuries, upper limb injuries account for 16% and lower limb injuries account for 38%, attributing well more than 50% of the total costs on society for nonfatal injuries to the extremities.[2] Furthermore, of those working before an injury from a moderate to high-energy force with an orthopedic injury with an Abbreviated Injury Scale (AIS) of 3 or more, only 58% have returned to work at 1 year.[3] This gives orthopedic surgeons the opportunity to have a significant impact on minimizing this burden by doing their part to optimize outcomes of those with extremity injuries.

NEED FOR A COORDINATED NATIONAL TRAUMA SYSTEM TO OPTIMIZE OUTCOMES

Having an established and optimized trauma system is essential to improve the outcomes of those who sustain high-energy extremity trauma. Research clearly demonstrates that those sustaining severe lower-limb injuries benefit from treatment at a trauma center.[4,5] Interestingly enough, although the total number of trauma centers is increasing throughout the United States, the number of severe orthopedic injuries seen at these centers seems to be decreasing, which ultimately results in less trauma volume per orthopedic surgeon.[6] The American College of Surgeons Committee on Trauma has recognized this dilemma and has published a position statement outlining several guidelines for the optimization of a regional trauma system, which seeks to best serve the needs of the injured patient.[7] In addition, through the establishment of a coordinated National Trauma System, which may be on the horizon in the United States, outcomes of extremity trauma patients are likely to improve.[8]

TRAUMA-RELATED MORTALITY

In the developed world, trauma is the most common cause of death in those younger than the age of 44 years and is most commonly due to road traffic accidents. Donald Trunkey[9] described a predictable trimodal distribution of death in 1983.

Acute or Primary Mortality

The casualties that belong in this group are ones that have sustained injuries that are incompatible with life. Typical injuries include severe head injuries, major hemorrhage, high cervical vertebra (C3 and above) and spinal cord injuries, airway obstruction, or mediastinal and cardiac disruption. Casualties often succumb to these injuries within seconds because they are not amenable to medical intervention regardless of the timeline.

Secondary Mortality

Death in the second peak usually occurs within minutes to hours and is potentially preventable by early and appropriate medical intervention. Examples of early or acute injuries in this group are intracranial hemorrhage, pneumothorax, cardiac tamponade, hemothorax, intra-abdominal hemorrhage, pelvic fracture, or long bone fracture, in particular femoral fractures. All of these are characterized by the need for early invasive medical intervention to stabilize the casualty before physiologic disruption and organ failure occurs. For the orthopedic surgeon, interventions include pelvis and long bone stabilization; however, it is important for them to be aware that patients with these injuries often require significant resuscitation.

Tertiary Mortality

Thirty percent of all trauma-related deaths occur within days or weeks following the injury.[10] The triggering of multiorgan failure and subsequent death is usually on a continuum and starts with potentially reversible physiologic dysfunction usually caused by sepsis or cardiorespiratory failure. This concept of multiple, progressive or sequential systems failure was first described in 1975 by Baue.[10] The term multiorgan dysfunction syndrome has been adopted to describe this condition and is characterized by the failure of at least 2 organs.

The goal of the orthopedic surgeon is to attempt to prevent secondary or tertiary deaths and subsequently minimize morbidity related to musculoskeletal injury. Typically, mortality in the secondary peak can be minimized by stabilization of fractures to the pelvis and long bones. Stabilization of such injuries not only helps with the reduction of blood loss but also deceases the pain stimuli, reducing the analgesia and anesthetic requirement, which can help with the regulation and normalization of physiology. Furthermore, stabilization of the long bones can also minimize the risk of pulmonary complications due to fat emboli and inability to mobilize.

ADVANCED TRAUMA LIFE SUPPORT

During the primary survey, the orthopedic surgeon can assist in the management of musculoskeletal injuries that have a direct impact on the primary survey or injuries that are diagnosed during primary investigations. Overtly fractured limbs impeding assessment, the fractured pelvis with hemodynamic instability, and open long bone fractures with ongoing hemorrhage are all indications for the early intervention by the orthopedic surgeon. As the orthopedic surgeon identifies these injuries, they must stay in continual communication with the trauma team leader because they may affect resuscitation strategies.

Restoring gross length and alignment of fractures and stabilizing long bone and/or pelvic ring fractures with splints and/or a pelvic binder can minimize further blood loss, bone and soft tissue trauma, and reduce patient pain and analgesia requirement. However, it should be noted that resuscitation and the primary survey always take precedence over splinting of extremity fractures.

Of note, missed extremity injuries, especially in the hand and foot, can occur in more than 8% of trauma patients, which emphasizes the importance of repeat assessment.[11] A low threshold for a high index of suspicion of spinal injuries should also be considered in an unconscious patient and triple immobilization should be maintained until formal clinical evaluation is possible. If this is not possible due to a persistent unconscious or anesthetized patient, spine-specific imaging, computed tomography (CT), and MRI should be performed before removal of the immobilization. Adjuncts to the secondary survey include further radiographic imaging. It is now commonplace to perform a trauma protocol CT scan that may replace the need for other radiographs.[12]

ORTHOPEDICS IN THE EMERGENCY DEPARTMENT: EARLY INTERVENTIONS CAN IMPROVE OUTCOMES

Although the orthopedic surgeon may not be directly involved in the primary survey of the severely injured patient, their acute management of several conditions can have a dramatic effect on the patient's overall outcome.

Major Hemorrhage

The patient who presents in major hemorrhage is often in extremis. In the setting of major hemorrhage from an extremity injury, the main goal for the orthopedic surgeon is to assist in the so-called Stop the Bleed. This is initially managed by direct pressure, whether manual or via a pressure bandage. Failure to control hemorrhage through direct pressure should result in tourniquet application.[13,14] Because tourniquet use is more common prehospital, a patient may arrive with a tourniquet in place. Caution should always be taken when removing a tourniquet and it is advisable to have another ready to use proximally on removal or ensure it is removed in a controlled environment to ensure more harm is not inflicted. In the setting of a traumatic amputation, a tourniquet should be applied if hemorrhage control is needed and then it can be reassessed in the operating room.

Open Fractures

Open fractures involve a direct communication of the injured bone with the environment and are often the reflection of a high-energy injury. Not only does the potential for contamination worsen the injury burden but the high energy indicates severe damage to the local soft tissues, both leading to wound complications and an increased potential for infection. Open fractures are commonly classified by 2 different systems. The more commonly used Gustilo-Anderson Classification and the newer Orthopaedic Trauma Association's Open Fracture Classification (**Boxes 1** and **2**).[15,16] The most important predictor of infection following open fracture seems to be timeliness of antibiotic administration, with antibiotics given more than 60 minutes after injury being an independent risk factor for infection.[17] Typically, a first-generation cephalosporin is recommended with additional broader coverage only in certain scenarios.[18] Surgical debridement and irrigation should be performed within 24 hours, and ideally sooner depending on the level of contamination. The type of fixation, which can be either temporary or definitive, depends of the level of soft tissue injury and contamination. When required, wound coverage should be performed within 5 to 7 days.[17,19]

Femur Fractures

In the presence of hemodynamic instability and physiologic parameters that indicate hypovolemic shock, the assessment of circulation and hemorrhage involves the examination of the lower extremity for swelling. Even in the context of a closed femoral fracture, blood loss can be as much as 2.2 L.[20,21] Furthermore, 40% of isolated femoral fractures require blood transfusion.[22] In such situations it is advocated that skeletal immobilization of long bone fractures be performed during the primary survey.

Box 1
Gustilo-Anderson open fracture classification

Type 1

Wound is ≤1 cm with minimal soft tissue injury

Type 2

Wound is greater than 1 cm in length, moderate soft tissue injury

Type 3

- Extensive soft tissue injury, degloving, or periosteal stripping, but soft tissue closure is possible
- Extensive soft tissue injury with periosteal stripping, requires flap coverage
- Associated with an arterial injury requiring repair

From Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. J Trauma 1984;24(8):743.

Box 2
Orthopaedic Trauma Association open fracture classification

Skin
1. Can be approximated
2. Cannot be approximated
3. Extensive degloving

Muscle
1. No muscle in area, no appreciable muscle necrosis, some muscle injury with intact muscle function
2. Loss of muscle but the muscle remains functional, some localized necrosis in the zone of injury that requires excision, intact muscle-tendon unit
3. Dead muscle, loss of muscle function, partial or complete compartment excision, complete disruption of a muscle-tendon unit, muscle defect does not approximate

Arterial
1. No injury
2. Artery injury without ischemia
3. Artery injury with distal ischemia

Contamination
1. None or minimal contamination
2. Surface contamination (easily removed; not embedded in bone or deep soft tissues)
3a. Imbedded in bone or deep soft tissues
3b. High-risk environmental conditions (eg, barnyard, fecal, dirty water)

Bone loss
1. None
2. Bone missing or devascularized but still some contact between proximal and distal fragments
3. Segmental bone loss

From Agel J, Evans AR, Marsh JL, et al. The OTA open fracture classification. J Orthop Trauma 2013;27(7):379–84; with permission.

The femur can be immobilized with in-line traction bucks or skeletal traction until early operative skeletal stabilization is performed.[23]

Pelvic Ring Injuries

Because of the energy needed to create a pelvic ring injury, they are often associated with hemodynamic instability, head injuries, thoracoabdominal injuries, and long bone fractures. In fact, pelvic fractures resulting in blood loss and hypovolemia have a mortality rate between 3% and 20%.[24] With increasing fracture severity, that is, more posterior pelvic disruption, the pelvic venous plexus, and internal iliac vessels are at an increased risk of injury and subsequent uncontrolled hemorrhage. Fluid resuscitation and hemorrhage control are vital. Many trauma centers have an algorithm based on the facility's capabilities to direct management, which involves stabilization of the pelvic ring injury at a minimum, for example, pelvic binder initially followed by external fixation.

Compartment Syndrome

Acute compartment syndrome (ACS) occurs when there is progressive myoneural ischemia due to the accumulation of fluid within a confined myofascial space or prolonged elevated pressure due to an external source such as a crush injury. ACS is considered a surgical emergency because irreversible muscle necrosis can begin within 6 hours of injury. Clinical examination findings of ACS consist of the 5 Ps:

pain out of proportion, pallor, paresthesia, pulselessness, and paralysis in the setting of a swollen extremity. The extremity often feels tight and the soft tissues are less compressible than the contralateral limb. ACS remains a clinical diagnosis; however, tools to measure intramuscular pressure and tissue oxygenation can be used to confirm the clinical diagnosis, which can be extremely useful in making the diagnosis in the obtunded patient. When obtaining intramuscular pressure measurements, a difference of less than 30 mm Hg from the diastolic blood pressure is concerning for ACS. Once ACS is diagnosed, emergent fasciotomies are performed to relieve the pressure and prevent further myoneural ischemia.

Vascular Injury

A vascular injury should be suspected if the injured extremity shows signs of pallor, reduced temperature, prolonged capillary refill, and reduced pulses. Before further examination, gross limb length and alignment should be obtained and the limb reexamined. The ankle-brachial index should be obtained if a vascular injury is suspected with a value of 0.90 or lower having a high positive predictive value for an associated vascular injury.[25] Re-establishment of the blood supply to the limb is an emergency because muscle necrosis begins to occur within 6 hours of injury. Close coordination with the vascular surgeon is vital because each surgical plan depends on the other. The sequence of the surgical procedure must be discussed to maximize care and minimize the ischemia time and risk of further injury to the patient and vascular repair if skeletal stabilization is done after the vascular repair.

Major Joint Dislocations

The close proximity and tethering of neurovascular structures to joints places them at significant risk of injury in joint dislocation. Localized soft-tissue swelling, distal extremity edema, abnormal neurology or the signs of vascular compromise are all markers for a high index of suspicion of a major joint dislocation. Expedient joint relocation and stabilization in a splint or traction may be necessary. Unlike most dislocations, a hip dislocation is considered an orthopedic emergency and should be reduced immediately on recognition because an increased time to reduction is associated with subsequent development of avascular necrosis.[26]

SCORING SYSTEMS: ARE THEY RELIABLE?

The decision to perform limb salvage or an amputation remains difficult. Scoring systems, such as the Mangled Extremity Severity Score (MESS)[27] and Limb Salvage Index (LSI),[28] have been developed to help guide surgeons in their decision-making process. However, the decision to salvage or amputate a limb often requires more factors to be considered than those commonly used in the scoring systems. As a result, their utility came into question and, in 2001, Bosse and colleagues[29] found that, out of all scoring systems evaluated, the MESS; the LSI; the Predictive Salvage Index; the Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age of Patient Score; and the Hannover Fracture scale-98, none were able to predict the need for amputation in a large, multicenter prospective observational study. In 2008, Ly and colleagues[30] followed the same set of patients and found that the same scoring systems also lacked the ability to predict outcome and patient recovery following high-energy lower extremity trauma. Scoring systems also do not seem to have utility when treating severe combat injuries, as demonstrated by Sheean and colleagues.[31]

Other clinical examination findings have been considered in the decision-making process, such as the presence of plantar sensation on presentation. In fact, the absence of plantar sensation has historically been a primary reason for orthopedic and general surgeons to consider acute amputation.[32] However, an analysis performed by Bosse and colleagues[33] of subjects presenting without plantar sensation compared with matched controls following high-energy trauma demonstrated no difference in outcomes between groups at 2 years. Therefore, the treating surgeon should use all factors that are available in helping to make the decision and not hang their hat on 1 scoring system or 1 primary clinical examination finding. In addition, when time permits, that is, the patient is not in extremis, it is always helpful to confer with colleagues, other members of the trauma team, and, when able, the patient before the decision is made to amputate or salvage a severely injured extremity because there may be other factors to consider.

WHEN SHOULD IT BE FIXED?

One of the frequent discussions among orthopedic and general surgeons revolves around the appropriate timing to stabilize fractures. Although the discussion is often short and indications for urgent operative stabilization in those with isolated extremities is rather clear, the discussion can be longer and may involve multiple services in the polytrauma patient because more factors must be considered to ensure that the surgical intervention does not increase patient morbidity. Ideally, the right surgery is performed for each patient, personally tailored to their physiologic status. The term used to describe this is the application of early appropriate care (EAC). However, to apply EAC, what constitutes appropriate care must be understood. To do so, it is helpful to understand both sides of the historical argument between early total care (ETC) and damage control orthopedics (DCO), which can be used to selectively provide appropriate care, depending on the patient's clinical status and response to resuscitation. Although most research evaluating optimal timing of fracture fixation is centered on the femur, the principles can be applied to fractures of other long bones and the pelvic ring.

Early Total Care

Patients with unstable fractures of the femur, pelvis, acetabulum, and spine are often forced into a recumbent position, which predisposes them to pulmonary complications and prolonged systemic inflammation. Early stabilization of these injuries can lead to improved pain relief and mobility. Several studies have clearly demonstrated the benefits of ETC. Harvin and colleagues[34] published their decade of experience comparing femur fractures definitively stabilized with intramedullary nails before and after 24 hours. After adjusting for anatomic (Injury Severity Score [ISS]) and physiologic (Revised Trauma Score) indices, early fracture fixation was independently associated with a reduction in pulmonary complications by nearly 60%. It was also associated with a reduction in ventilator days, hospital length of stay, and overall hospital charges. These results are similar to those demonstrated by Vallier and colleagues,[35] who compared definitive fixation of unstable femur, acetabulum, pelvis, and thoracolumbar fractures performed before and after 24 hours. After adjusting for age and ISS, days in the intensive care unit and total hospital stay were lower with early fixation. In addition, there were greater than 10% fewer overall complications (24% vs 35.8%), and lower rates of acute respiratory distress syndrome (ARDS), pneumonia, and sepsis in those undergoing early versus delayed fixation.

As this evidence suggests, early definitive treatment may be safely used for patients with multiple injuries. However, ETC is not ideal for all patients because there is a clear subset of patients who benefit from DCO.

Damage Control Orthopedics

As the pendulum swung toward ETC, it was realized that not all patients did well having their fractures undergo definitive stabilization early. In fact, some types of patients seemed to do quite poorly with ETC. It became apparent that in certain patients, particularly those with pulmonary or head injuries, a less aggressive approach to fracture fixation might be needed. Trauma causes a sustained response of the immune system and the early hyperinflammatory response is often followed by a hypoinflammatory stage. In the polytrauma patient, extended surgery, which can lead to increased blood loss, hypothermia, and surgical trauma, can result in an excessive inflammatory reaction, which has been termed the second hit. In these patients, extensive surgical procedures can overwhelm the immune system, which can trigger a pulmonary complication, such as ARDS, or multiple organ failure.[36]

One alternative is delayed fracture care, that is, splinting or traction, of unstable fractures and performing surgical skeletal stabilization days to weeks later. Before the advent of modern surgical skeletal stabilization techniques, this was the norm. There are, however, significant disadvantages to delayed fracture care. In patients without adequate stabilization, in the case of the femur this would usually involve some form of skeletal traction, patients cannot be mobilized. As a result, they are at an increased risk for pulmonary complications and pressure ulcers. With the advancement in surgical skeletal stabilization techniques, there was a shift toward aggressive early stabilization of extremity fractures but, as alluded to earlier, ETC is not appropriate for everyone. Thus, the emergence of DCO.

DCO involves doing the necessary surgical interventions to stabilize the fracture to minimize excessive blood loss, improve pain, and promote mobilization. This usually involves procedures such as external fixation of long bone fractures or unstable pelvic ring injuries. Through the placement of external fixation in the acute period, that is, avoiding open and often lengthy and/or bloody surgical procedures, the second hit is theoretically avoided and definitive reconstruction can occur at a later point after the patient's physiologic parameters have improved. The benefits of this strategy on the immune system have been demonstrated by Pape and colleagues.[37] In a prospective, randomized, multicenter study, 35 polytrauma subjects (ISS >16) with a diaphyseal femur fracture were randomized to either ETC or DCO, and serum inflammatory markers were trended over time. In those with ETC (intramedullary nail), there was a sustained increase in serum inflammatory markers, which was not seen in the DCO group following both the initial external fixation and subsequent conversion to definitive fixation with an intramedullary nail.

In a retrospective study, Harwood and colleagues[38] compared the Systemic Inflammatory Response Syndrome (SIRS) Score and Marshall multiorgan dysfunction score of subjects with femur fractures treated with either ETC or DCO. It was not surprising that the DCO group had more severe injuries based on the new ISS, and more head and thoracic injuries. Despite this, they had a smaller, shorter postoperative SIRS and did not suffer significantly more pronounced organ failure than the ETC group. Interestingly, those in the DCO group who underwent conversion to an intramedullary nail when their SIRS score was raised suffered the most pronounced subsequent inflammatory response and organ failure, which emphasizes the impact that the second hit can have and the importance of planning the definitive fixation based on physiologic improvement.

Early Appropriate Care: When to Choose Early Total Care Versus Damage Control Orthopedics

What is very clear is that stable patients should be treated with ETC, whereas unstable patients should undergo DCO. The challenge has been defining the appropriate clinical indications to perform DCO or ETC in the borderline patient. Various definitions of the borderline patient have been made to include that by Pape and colleagues,[37] who define it by the following: ISS greater than 40, multiple injuries (ISS >20) in combination with thorax trauma, multiple injuries in combination with severe abdominal or pelvic injury, hemorrhagic shock at the moment of administration, moderate or severe head trauma, radiographic evidence of pulmonary contusion, bilateral femur fractures, or a body temperature below 35°C.[36] D'Alleyrand and O'Toole[39] have proposed 3 common indicators for DCO of borderline patients that they use at the R. Adams Cowley Shock Trauma Center in Baltimore, MD: (1) closed head injury, (2) poor response to resuscitation in the first 12 hours, and (3) poor respiratory status at the time of fracture treatment.

It is helpful to know where these indications have come from and what defines an appropriate response to resuscitation to safely apply them. One increasingly used method of assessing response to resuscitation is trending lactate levels. In patients undergoing definitive fixation of a femur fracture with an intramedullary nail within 24 hours of injury, admission lactate is significantly associated with pulmonary complications when other factors such as age, Glasgow Coma Scale, and AIS were controlled. However, preoperative lactate was not found to be a risk factor.[40] A median preoperative lactate of 2.8 mmol/L was not associated with increased pulmonary complications, as opposed to previous publications.[41] These results are similar to those seen by Vallier and colleagues[35,42] in which admission lactate, in addition to the severity of the abdominal and thoracic injuries, contribute most to the development of pulmonary morbidity. It is likely that the trend in lactate, that is, a lactate level improving and approaching 2.5 mmol/L, demonstrates an adequate response to resuscitation and, therefore, can lead to safe application of ETC. On the contrary, in those with closed head injuries, severe abdominal, or severe thoracic injuries, DCO should be considered.

This was also demonstrated in a review by Vallier and colleagues[42] of subjects with pelvis, acetabulum, spine, and/or proximal or diaphyseal femur fractures treated surgically. Pulmonary complications occurred in 12% of subjects with 8.2% developing pneumonia. Lactate levels were greater with pulmonary complications and were the single most specific predictor of complications. An uncomplicated course was associated with absence of a chest injury and definitive fixation within 24 or 48 hours. The investigators concluded that complications can be minimized when isolated fractures are treated on early and, when patients have injuries to other body systems and/or severe hemorrhage, DCO may be advisable to optimize outcomes.

In summary, if the patient demonstrates any physiologic signs of end-organ hypoperfusion, DCO should be pursued. It is also important for the orthopedic surgeon to communicate with both the general surgeon and the anesthetist so that care is optimized. This allows the treatment plan to be altered in an effort to optimize the patient's outcomes if the patient's physiologic parameters change throughout the resuscitation process or surgical procedure.

SUMMARY

Severe extremity injuries are not only a challenge to treat but doing so results in high resource utilization and often high levels of levels of disability.[3,43] The decision to pursue DCO versus ETC may lead to a shorter hospital stay and fewer complications, but there is likely more that surgeons can do optimize patient outcomes throughout the entire care continuum beyond the decisions made or actions taken within the first few hours following injury. The best available data comparing outcomes of limb salvage and amputees from the Lower Extremity Assessment Project (LEAP) Study Group found no difference in outcomes between groups at both 2 and 7 years. They did, however, identify several predictors of poor outcome, regardless of group, to include a poor social support network and low self-efficacy.[3,44] This concept of self-efficacy and social support network is something that many orthopedic surgeons have not paid much attention to in the past. Multiple studies have highlighted the importance of various factors in a patient's overall recovery process, such as access to vocational and mental health support.[45] In addition, certain psychological factors play a significant role in predicting pain following trauma.[46,47] It is important that orthopedic surgeons and members of the trauma team take their level of care a step further beyond saving life and limb, and take these factors into consideration when attempting to optimize patient outcomes.

REFERENCES

1. WISQARS (Web-based Injury Statistics Query and Reporting System), Injury Center, CDC. Available at: https://www.cdc.gov/injury/wisqars/index.html. Accessed March 2, 2017.
2. Miller TR, Pindus NM, Douglass JB, et al. Databook on nonfatal injury: incidence, costs, and consequences. Washington, DC: Urban Institute Press; 1995.
3. MacKenzie EJ, Bosse MJ, Pollak AN, et al. Long-term persistence of disability following severe lower-limb trauma. Results of a seven-year follow-up. J Bone Joint Surg Am 2005;87(8):1801–9.
4. Mackenzie EJ, Rivara FP, Jurkovich GJ, et al. The impact of trauma-center care on functional outcomes following major lower-limb trauma. J Bone Joint Surg Am 2008;90(1):101–9.
5. Morshed S, Knops S, Jurkovich GJ, et al. The impact of trauma-center care on mortality and function following pelvic ring and acetabular injuries. J Bone Joint Surg Am 2015;97(4):265–72.
6. Sielatycki JA, Sawyer JR, Mir HR. Supply and demand analysis of the orthopaedic trauma surgeon workforce in the United States. J Orthop Trauma 2016;30(5): 278–83.
7. American College of Surgeons Committee on Trauma. Statement on trauma center designation based upon system need. Bull Am Coll Surg 2015;100(1):51–2. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25626271. Accessed March 2, 2017.
8. Stinner DJ, Johnson AE, Pollak A, et al. "Zero preventable deaths and minimizing disability" – the challenge set forth by the national academies of sciences, engineering, and medicine. J Orthop Trauma 2017. http://dx.doi.org/10.1097/BOT.0000000000000806.
9. Trunkey DD. Trauma. Accidental and intentional injuries account for more years of life lost in the U.S. than cancer and heart disease. Among the prescribed remedies are improved preventive efforts, speedier surgery and further research. Sci Am 1983;249(2):28–35. Available at: http://www.ncbi.nlm.nih.gov/pubmed/6623052. Accessed March 2, 2017.
10. Baue AE. Multiple, progressive, or sequential systems failure. A syndrome of the 1970s. Arch Surg 1975;110(7):779–81. Available at: http://www.ncbi.nlm.nih.gov/pubmed/1079720. Accessed March 2, 2017.
11. Giannakopoulos GF, Saltzherr TP, Beenen LFM, et al. Missed injuries during the initial assessment in a cohort of 1124 level-1 trauma patients. Injury 2012;43(9): 1517–21.

12. Huber-Wagner S, Lefering R, Qvick L-M, et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet 2009;373(9673):1455–61.
13. Brodie S, Hodgetts TJ, Ollerton J, et al. Tourniquet use in combat trauma: UK military experience. J R Army Med Corps 2007;153(4):310–3. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18619170. Accessed March 2, 2017.
14. Kragh JF, Walters TJ, Baer DG, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. Ann Surg 2009;249(1):1–7.
15. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg Am 1976;58(4):453–8. Available at: http://www.ncbi.nlm.nih.gov/pubmed/773941. Accessed March 2, 2017.
16. Agel J, Evans AR, Marsh JL, et al. The OTA open fracture classification. J Orthop Trauma 2013;27(7):379–84.
17. Lack WD, Karunakar MA, Angerame MR, et al. Type III open tibia fractures. J Orthop Trauma 2014;29(1):1.
18. Murray CK, Obremskey WT, Hsu JR, et al. Prevention of infections associated with combat-related extremity injuries. J Trauma 2011;71(2 Suppl 2):S235–57.
19. D'Alleyrand J-CG, Manson TT, Dancy L, et al. Is time to flap coverage of open tibial fractures an independent predictor of flap-related complications? J Orthop Trauma 2014;28(5):288–93.
20. Powers WF, Hensley CD. Circulating blood volume changes incident to major orthopedic surgery. J Am Med Assoc 1959;169(6):545–7. Available at: http://www.ncbi.nlm.nih.gov/pubmed/13620501. Accessed March 2, 2017.
21. Clarke R, Topley E, Flear CT. Assessment of blood-loss in civilian trauma. Lancet 1955;268(6865):629–38. Available at: http://www.ncbi.nlm.nih.gov/pubmed/14354953. Accessed March 2, 2017.
22. Lieurance R, Benjamin JB, Rappaport WD. Blood loss and transfusion in patients with isolated femur fractures. J Orthop Trauma 1992;6(2):175–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/1602337. Accessed March 2, 2017.
23. Even JL, Richards JE, Crosby CG, et al. Preoperative skeletal versus cutaneous traction for femoral shaft fractures treated within 24 hours. J Orthop Trauma 2012;26(10):e177–82.
24. Giannoudis PV, Grotz MRW, Tzioupis C, et al. Prevalence of pelvic fractures, associated injuries, and mortality: the United Kingdom perspective. J Trauma 2007;63(4):875–83.
25. Mills WJ, Barei DP, McNair P. The value of the ankle-brachial index for diagnosing arterial injury after knee dislocation: a prospective study. J Trauma 2004;56(6):1261–5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15211135. Accessed March 2, 2017.
26. Sahin V, Karakas E, Aksu S, et al. Traumatic dislocation and fracture-dislocation of the hip: a long-term follow-up study. J Trauma 2003;54(3):520–9.
27. Johansen K, Daines M, Howey T, et al. Objective criteria accurately predict amputation following lower extremity trauma. J Trauma 1990;30(5):568–72 [discussion: 572–3]. Available at: http://www.ncbi.nlm.nih.gov/pubmed/2342140. Accessed March 2, 2017.
28. Russell WL, Sailors DM, Whittle TB, et al. Limb salvage versus traumatic amputation. A decision based on a seven-part predictive index. Ann Surg 1991;213(5):473–80 [discussion: 480–1]. Available at: http://www.ncbi.nlm.nih.gov/pubmed/2025068. Accessed March 2, 2017.

29. Bosse MJ, MacKenzie EJ, Kellam JF, et al. A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. J Bone Joint Surg Am 2001; 83-A(1):3–14. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11205855.
30. Ly TV, Travison TG, Castillo RC, et al. Ability of lower-extremity injury severity scores to predict functional outcome after limb salvage. J Bone Joint Surg Am 2008;90(8):1738–43.
31. Sheean AJ, Krueger CA, Napierala MA, et al, Skeletal Trauma and Research Consortium (STReC). Evaluation of the mangled extremity severity score in combat-related type III open tibia fracture. J Orthop Trauma 2014;28(9):523–6.
32. MacKenzie EJ, Bosse MJ, Kellam JF, et al. Factors influencing the decision to amputate or reconstruct after high-energy lower extremity trauma. J Trauma 2002;52(4):641–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11956376. Accessed March 2, 2017.
33. Bosse MJ, McCarthy ML, Jones AL, et al. The insensate foot following severe lower extremity trauma: an indication for amputation? J Bone Joint Surg Am 2005;87(12):2601–8.
34. Harvin JA, Harvin WH, Camp E, et al. Early femur fracture fixation is associated with a reduction in pulmonary complications and hospital charges: a decade of experience with 1,376 diaphyseal femur fractures. J Trauma Acute Care Surg 2012;73(6):1442–8.
35. Vallier HA, Super DM, Moore TA, et al. Do patients with multiple system injury benefit from early fixation of unstable axial fractures? The effects of timing of surgery on initial hospital course. J Orthop Trauma 2013;27(7):405–12.
36. Lichte P, Kobbe P, Dombroski D, et al. Damage control orthopedics: current evidence. Curr Opin Crit Care 2012;18(6):647–50.
37. Pape HC, Grimme K, van Griensven M, et al, EPOFF Study Group. Impact of intramedullary instrumentation versus damage control for femoral fractures on immunoinflammatory parameters: prospective randomized analysis by the EPOFF Study Group. J Trauma 2003;55(1):7–13.
38. Harwood PJ, Giannoudis PV, van Griensven M, et al. Alterations in the systemic inflammatory response after early total care and damage control procedures for femoral shaft fracture in severely injured patients. J Trauma 2005;58(3): 446–52.
39. D'Alleyrand JCG, O'Toole RV. The evolution of damage control orthopedics. Current evidence and practical applications of early appropriate care. Orthop Clin North Am 2013;44(4):499–507.
40. Richards JE, Matuszewski PE, Griffin SM, et al. The role of elevated lactate as a risk factor for pulmonary morbidity after early fixation of femoral shaft fractures. J Orthop Trauma 2016;30(6):312–8.
41. Crowl AC, Young JS, Kahler DM, et al. Occult hypoperfusion is associated with increased morbidity in patients undergoing early femur fracture fixation. J Trauma 2000;48(2):260–7. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10697084. Accessed March 2, 2017.
42. Vallier HA, Wang X, Moore TA, et al. Timing of orthopaedic surgery in multiple trauma patients: development of a protocol for early appropriate care. J Orthop Trauma 2013;27(10):543–51.
43. Masini BD, Waterman SM, Wenke JC, et al. Resource utilization and disability outcome assessment of combat casualties from operation Iraqi freedom and operation enduring freedom. J Orthop Trauma 2009;23(4):261–6.

44. Bosse MJ, MacKenzie EJ, Kellam JF, et al. An analysis of outcomes of reconstruction or amputation after leg-threatening injuries. N Engl J Med 2002;347(24):1924–31.
45. Archer KR, Castillo RC, MacKenzie EJ, et al, LEAP Study Group. Perceived need and unmet need for vocational, mental health, and other support services after severe lower-extremity trauma. Arch Phys Med Rehabil 2010;91(5):774–80.
46. Vranceanu A-M, Bachoura A, Weening A, et al. Psychological factors predict disability and pain intensity after skeletal trauma. J Bone Joint Surg Am 2014;96(3):e20.
47. Castillo RC, Wegener ST, Heins SE, et al. Longitudinal relationships between anxiety, depression, and pain: results from a two-year cohort study of lower extremity trauma patients. Pain 2013;154(12):2860–6.