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Orthopaedic trauma surgery versus fracture care: what's the difference?

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Summary

Objective. The purpose of this review is to aid in recognition and understanding the differences between isolated fracture care and fracture treatment in the polytrauma patient.
Methods. The three elemental goals of treating any fracture are to optimize function and decrease pain while minimizing the risks incurred by the patient. When considering patients with fractures as a result of polytrauma, these same goals remain crucial, but become subordinate to survival and the prevention of physiologic or organ system complications. Multiple factors will alter priorities and force compromises in treatment strategies and expectations, including patient physiology, complexity of fracture and soft tissue injury, logistical limitations imposed by associated injuries or external devices, and impediments to patient input.
Conclusions. Treatment of the polytraumatized patient are fraught with biologic and logistic challenges. An understanding of systemic and local pathophysiology as well as carefully staged planning can minimize many of these problems.

Key words: polytrauma, fracture care, isolated fracture, damage control

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Introduction

Restoration of painless function by focusing on stable alignment and anatomic reduction of joint surfaces through familiar approaches is the fundamental objective of fracture care. In high energy injuries and patients with polytrauma, this common and idealistic approach to isolated fractures must be weighed against differing priorities, compromised patients, and treatment limitations.

Differences

Two elements which set isolated fracture care apart from orthopedic trauma are energy and host factors.
The ability of a moving object, whether the host or colliding object, to cause injury is related to its kinetic energy. An object's kinetic energy is determined by mass, contact area, and duration, but, most profoundly, by velocity:
$E=1/2mv^2$
The transfer of this energy to the host and tissues will result in work through either displacement or deformity(δ):
$W = Fd$
$W = F\delta$ [1]
Each type of tissue will have its own tolerance for failure, dependent on ener-

gy transfer, its material properties and geometry. The energy transferred from a skiing accident has previously been estimated between 300-500 ft/lb, while that of a bumper injury at 20 mph is 100,000 ft/lb [2].
Host factors that set the orthopedic trauma patient apart from those with isolated fractures include associated injuries, physiologic dysfunction, impaired healing, and the frequent inability to participate in active decision making [3-9].

Priorities

In isolated fracture care, the goals of increased function, decreased pain, and minimizing risk can be achieved by utilizing nonoperative and conservative operative intervention. This treatment approach can be expected to yield more predictable results with limited impedance in contrast to the patient with soft tissue injury or multi-trauma in which additional local or systemic injury may influence outcomes [10,11]. When challenged with the polytrauma patient, survival is another priority not encountered in isolated fracture care [4,6-8,12,13]. The relevance of treating fractures for optimal function and pain relief not only changes but also is accompanied by the ever-frequent burden of managing compromised soft tissue and bone defects [14]. Stability of pelvic injuries associated with life-threatening hemorrhage plays a critical role in patient resuscitation and improving early survival. The orthopedic surgeon must be able to recognize pelvic injury patterns prone to hemorrhage and quickly intervene with appropriate measures such as temporary or permanent stabilization, pelvic packing, or identifying patients who would benefit from embolization. Long bone, pelvic and hip girdle stabilization, debridement of open wounds, and decompression of impending compartment syndrome contribute to prevent systemic deterioration and further soft tissue damage [12,15-18]. The timing and type of femur fracture stabilization, in particular, will influence morbidity and mortality risk.

Limitations

While each patient is unique, the treatment and outcomes of isolated injures are often more predictable [19,20]. Surgeons are faced with fewer barriers to favorable results. In contrast, the trauma patient presents with an endless array of possible impediments. Unlike isolated fractures, polytrauma patients are often not suitable for early stabilization. As a result, reductions become more difficult and time-consuming; even short delays invite complications such as tissue necrosis and open wounds from impending fractures. Paradoxically, complex fractures vulnerable to soft tissue compromise become more suitable for delayed fixation to avoid problematic wound closures, dehiscence, and infections [10,11,21-26]. Early definitive stabilization of fractures, particularly of the long bones, which in isolation may be considered physiologically benign, now become potential mediators of morbidity and mortality for a physiologically borderline patient or patients with severe head, abdomen, and chest injuries [4,5,7,8,12,15,18]. The surgeon must have an understanding of these effects, just as one would have of the common complications encountered for isolated fracture care. The trauma patient also poses logistical problems in the operating room. The patient's condition, other injuries, or pre-existing surgical incisions in proximity of the fracture may impose limitations on positioning, approaches, and choice of implant [12,13]. The surgeon may encounter injuries in which approaches to one fracture may interfere with an otherwise common or more desirable exposure of the same extremity, thus requiring creativity or compromise. Treating isolated fractures is preceded by a thorough discussion and decision-making process with the patient, but this may be not possible in the polytrauma patient who may be obtunded or impaired for extended periods. Although emergent procedures are justifiable, delayed complex reconstruction in a patient who remains impaired for long periods becomes more complicated. Even in the presence of family members authorized to make decisions, stress, disagreement, and uncertainty can make the treatment process more arduous.
In isolated high energy injuries, limitations are most often imposed by soft tissue conditions [13]. In contrast to low-grade open and low energy closed fractures, high-energy injuries are more prone to infection, non-union, and amputation. They are more often associated with complex fracture patterns, or require unanticipated intra-operative repairs of musculotendinous and ligamentous injuries. Reductions become more difficult by virtue of interposed soft tissues, lack of ligamentotaxis, and delays to surgery. All these factors contribute to subpar outcomes [10,13,22-24,26-33]. Complexity of the fracture itself may pose more difficult problems in choosing the optimal approach that satisfies all access needs without devitalization of tissue. Open fractures with soft tissue and bone loss pose the most conspicuous limitation in treating high-energy fractures; even the simplest fracture patterns become monumental challenges. Despite achieving a clean, tension free wound, it may not offer a prudent avenue for internal fixation due to already compromised vascularity, or lack of access. Alternative and potentially less desirable forms of fixation or approaches may be necessary. Soft tissue defects pose similar problems in addition to the necessity of tissue transfer for optimal success. The surgeon will need to conceive a plan that not only accounts for fracture stabilization but soft tissue coverage, optimally within 3-7 days [12,14].
In contrast to treating a patient with an isolated fracture, treating the polytrauma patient means having to manage their ever-changing condition. Their labile physiology and condition of wounds may rapidly alter treatment plans within the same 24 hours as a planned surgery, requiring rearrangement of care during an already busy schedule. The care of an isolated fracture in a young patient is coordinated by the surgeon. The care of the trauma patient requires the coordinated care of not only the orthopedic surgeon, but also other participating disciplines

including trauma surgery, neurosurgery, vascular surgery, plastic surgery, and anesthesiology. This means the orthopedist must efficiently communicate and coordinate concomitant procedures with other disciplines, all within a desirable window of time.

Fractures sustained in conjunction with polytrauma and those characterized as high energy have been reported to be associated with poorer outcomes and increased complications, whether open or closed. Factors contributing to these complications include fracture complexity and soft tissue injury. Jones et al. [27] retrospectively reviewed 69 proximal humerus fractures in 66 patients with locked humeral plating. They reported poorer Short Musculoskeletal Function Assessment scores and worse mobility at 2 years post-operatively in polytrauma patients. Roh et al. concluded that fracture severity and high-energy trauma were associated with delayed functional recovery following a prospective analysis of 122 patients who underwent volar plate fixation for distal radius fractures [28]. SooHoo et al. [26] identified 57,183 patients who underwent open reduction and internal fixation for lateral, bimalleolar, and trimalleolar ankle fractures, and found that open injury and severity of fracture were predictors of reoperation for arthrodesis and arthroplasty. In a matched case control of 262 patients following operative treatment of ankle fractures, Ovaska reported fracture dislocation and severity of closed soft tissue injury as predictors of deep infection [32]. A retrospective analysis of 32 patients with Lisfranc fracture dislocations by Demirkale found patients with more severe soft tissue injury had significantly lower American Foot and Ankle Society Scores and Foot and Ankle Disability Index at an average of 55 months post-operatively [33]. Barei et al. [34] in a retrospective study of 83 severe bicondylar tibial plateau fractures treated with internal fixation were only able to obtain accurate articular reduction in half of patients and found that both polytrauma and fracture severity were predictive of poorer musculoskeletal functional assessment scores.

Trauma induced pathophysiologic states have been implicated as a source of increased complications. In two separate studies, Karunakur and Richards [35,36] found a significant association between the stress-induced hyperglycemic states of trauma patients and wound infections. Heterotopic ossification (HO) may plague certain high energy injuries and those with multiple trauma more frequently than low energy injuries. Periarticular injuries of the elbow are particularly prone to HO and occur as a result of both high and low energy mechanisms with some frequency. Foruria et al reported the results of 142 elbow fractures and fracture dislocations involving the proximal aspect of the radius or ulna treated surgically. More severe HO was reported to be associated with distal humeral fractures and fracture dislocations. Patients with open injury and severe chest trauma had a higher prevalence of heterotopic ossification [37]. Douglas found that severity of injury was an independent risk factor for Brooker class 3 or 4 HO among 156 patients who underwent operative intervention for a distal humerus fracture or an ulna humeral fracture dislocation [38]. To further complicate the situation, polytrauma patients may not receive the early range of motion and supervised therapy, which are staples of recovery following fracture care. Castillo et al. using data retrieved from the Lower Extremity Assessment Project found a significant proportion of patients with severe lower extremity trauma had unmet physical therapy needs [39].

Strategy

Several strategies can help minimize the complications of orthopedic trauma and high-energy fractures. Priorities include not only patient survival and prevention of organ dysfunction, but also limb salvage. The orthopedic traumatologist strives to obtain a vascular soft tissue sleeve that tolerates reconstructive efforts in order to attempt to provide the patient with a pain-free, functional limb [13]. Several pathophysiologic states can contribute to the physiologic and organ demise of the polytrauma patient. Activation of the innate immune system in response to tissue damage has become known as Systemic Inflammatory Response Syndrome (SIRS). On a cellular level, it is characterized by increases in complement and neutrophil activation as well as vascular endothelial permeability. In conjunction with SIRS, a defective suppression of adaptive immunity will develop: Compensatory Anti-inflammatory response syndrome (CARS) (Tab. I). The timing of onset is controversial, but each state when exacerbated by further tissue insult such as surgery, hypoxia and/or blood loss may tip the scales toward physiologic decline and death [40]. The development of SIRS and/or CARS in the polytraumatized patient makes them vulnerable to further complications such as acute respiratory distress syndrome (ARDS), disseminated intravascular coagulation (DIC) and/or multisystem organ failure (MOF). A single, severe, traumatic event may lead to hemorrhagic shock, SIRS, and eventual MSOF and is termed the one-hit model. The two-hit model of MOF involves a less severe initial event with subsequent MOF developing from a second insult such as additional transfusions, sepsis, surgery, long bone fixation and fat emboli [41]. In an attempt to avoid the second hit and safely navigate these physiologically compromised patients, damage control orthopedics (DCO) has now become a widely accepted form of temporary stabilization [4,8,15].

Using the concepts of DCO, the orthopedic traumatologist attempts to strike a balance between the risks and benefits that more extensive definitive care would offer in the setting of comprised physiologic parameters and associated injuries. These parameters are based upon state of shock, coagulopathy, temperature, and associated organ injuries and guide the surgeon in managing long bone fractures, particularly those involving the femur [4,5,7,8]. Having an understanding of these concepts and recognizing the essential elements of each will help circumvent complications. In contrast to fracture care, which is often planned definitive treatment, the orthopedic trauma surgeon should be aware of the optimal operative windows of

Table I. Initial response to trauma.

Systemic inflammatory response syndrome	Compensatory anti-inflammatory response-syndrome
Inizial respon se to trauma	Delayed post-inflammatory response
Increased cytokines, complement	Immunosuppressed state
Increased neutrophils	Increased anti-inflammatory cytokines
Increased vascular permeability	Decreased adaptive immunity
Heart rate > 20/min	May occur simultaneously with SIRS
$PaCO_2$ < 32 mm	
Temp < 36 or > 38 degrees Celsius	
WBC < 4000 or > 12,000 cells/cubic mm	
Acute respiratory distress syndrome	
Disseminated intravascular coagulopathy	
Multiple organ dysfunction	
Enhanced inflammatory response	

each injury based on the patient's physiology and soft tissue condition or coverage. While a low energy fracture may be more amenable and forgiving to direct exposure and anatomic reduction, high-energy injuries are highly susceptible to vascular insult. The precarious nature of the extraosseous blood supply deserves increased respect in these injuries. Not only do the fracture fragments become extensively stripped of periosteum, but any method of plating whether minimally invasive or direct may disrupt the remaining blood supply to fragments. Borrelli et al supported this by demonstrating open plating of the distal tibia significantly damaged the extraosseous blood supply compared to percutaneous plating [42]. The treatment of high-grade open fractures requires a baseline knowledge of soft tissue viability to facilitate surgical planning and ultimately salvage of the limb. The AO and Tscherne classifications have been developed to characterize levels of severity of soft tissue injury in closed fractures [43,44]. Equally as important is recognizing when soft tissues are amendable for surgery. Tissue should be supple without tension and produce wrinkles. Fracture blisters should be epithelialized [25]. Avoid direct and immediate fixation in areas of full thickness skin contusion with necrosis until debrided and closed without tension or treated with soft tissue transfer. Smaller areas or those with ample vascular tissue beneath can be observed if no signs of infection develop.

Surgical preparation also becomes more complex for polytrauma patients and high energy injuries. 1) First, it is imperative to establish adequate communication not only with the patient and family but all services closely involved in patient care; (2) When planning multiple procedures, have a well-planned sequence that will facilitate easy access and transition from one extremity to the other for surgeon, operating team, and imaging without interference to anesthesia; 3) This patient population is better served by focusing on procedures that provide benefit to the overall survival or physiology of the patient first, as opposed to focusing on the most complex fracture; 4) For isolated fractures, positioning is often routine but in multi trauma or complex injuries, it should be coordinated with other services if necessary; 5) Devise a plan of definitive fixation that will not compromise local biology, lead to infection or nonunion, but yet allows adequate access for reduction and stability; 6) Embrace the concept of staging complex fractures if necessary. Be opportunistic and perform critical elements of stabilization, such as an open periarticular fracture that is amenable to gaining length with external fixation, or minimally invasive fixation of components of the fracture and return when the patient's soft tissue and positioning requirements are more amenable. These tactics have found particular success for tibial plateau, pilon, ankle, and midfoot fractures [10,21,22,24,45]; 7) It is important to ensure that precursory fixation does not jeopardize remaining stages; 8) Prepare for expected future interventions or salvage by planning how traumatic wounds may be safely incorporated into approaches or that may afford exposure for several different injuries in the same proximity without sacrificing excessive dissection and vascularity. When dealing with open wounds requiring extension for exploration, make efforts to avoid acute angles and expand toward areas with ample underlying muscle. Certain high-energy periarticular fractures may benefit from definitive external fixation with minimally invasive or percutaneous techniques to optimally reduce and stabilize the articular surface. These circumstances are dictated not only by fracture complexity and severity of soft tissue injury, but also the ability to recognize when this is a more suitable plan.

In the operating room, injuries to the other organ systems or limbs should not be compromised to accommodate adequate

Table II. Approach and fixation may limit future operative goals.

Establish communication	▪ Patient/family preferences ▪ Recommendation of other services
Emergent *versus* urgent	▪ Perform procedures with most benefit to survival first ▪ Do not focus on the most complex fracture
Optimal sequence for each operative event	▪ Multiple procedures ▪ Consider imaging/anesthesia/other surgical teams
Patient positioning	▪ Consider other injuries ▪ Requirements for additional procedures ▪ Access for proposed approaches
Operative plan	▪ Preserve biology to prevent non-union and/or infection ▪ Adequate access for reduction and fixation
Consider staging	▪ Complex fractures ▪ Damaged soft tissue envelope
Don't burn bridges	▪ Consider future procedures ▪ Approches and fixation may limit future operative goals
Have multiple secondary plans	▪ Failed primary plans ▪ Beware of unexpected intra-operative findngs

exposure. Be attentive to padding limbs and their positions. Plan for possible obstructions to imaging. Visualization may be obstructed by positioning limitations from other injuries or physiologic obstruction such as air in the abdomen or residual contrast leading to suboptimal intra-operative pelvic imaging. It is imperative to ensure visualization prior to commencing procedures. Small adjustments in positioning are often all that is necessary and if obstruction is still present, having a preoperative alternative to account for such instances is crucial; 9) Because of the complexity of injuries and potential for unexpected findings or complications, have an optimal first operative plan with alternatives prepared (Tab. II).

As in any fracture reduction, stable anatomic restoration is still desirable, but as a result of the hazards of high energy injuries, anatomic reduction and obtaining the perfect X-ray must not supersede preserving the remaining biology [22,24]. If the soft tissue sleeve and bone healing are compromised, the early enthusiasm for an anatomic reduction now becomes an even more complex limb salvage.

Conclusions

The goals of optimizing function and decreasing pain while limiting risks to the patient remain crucial elements of treating any fracture. Complex, high-energy fractures and polytrauma patients require awareness and management of new priorities including survival, prevention of systemic complications, and recovery or restoration of soft tissue. Treatment of these injuries are fraught with biologic and logistic limitations. Complications are not infrequent, and outcomes may be poor. An understanding of systemic and local pathophysiology as well as careful staged planning can minimize many of these problems.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

MM: conceptualization, project administration, supervision, writing – review & editing; PY: conceptualization, writing – review & editing; TJ: conceptualization, investigation, methodology, roles/writing – original draft.

Ethical consideration

This study was approved by the LSUHSC-Shreveport (approval number: STUDY00000256).

The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.

Written informed consent was obtained from each participant/patient for study participation and data publication.

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