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DOI: 10.5435/00124635-200909000-00001 · Source: PubMed

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Timing of Fracture Fixation in Multitrauma Patients: The Role of Early Total Care and Damage Control Surgery

Abstract

The optimal timing of surgical stabilization of fractures in the multitrauma patient is controversial. There are advantages to early definitive surgery for most patients. Early temporary fixation using external fixators, followed by definitive fixation (ie, the damage control approach), may increase the chance for survival in a subset of patients with severe multisystem injuries. Improved understanding of the pathophysiology of trauma has led to a greater ability to identify patients who would benefit from damage control surgery. A patient is classified as physiologically stable, unstable, borderline, or in extremis. The stable patient can undergo fracture surgery as necessary. An unstable patient should be resuscitated and adequately stabilized before receiving definitive orthopaedic care. The decision whether to perform initial temporary or definitive fixation in the borderline patient is individualized based on the clinical condition. In patients presenting in extremis, life-saving measures are pivotal, followed by a damage control approach to their injuries.

The timing of definitive fixation of major extremity fractures in the multitrauma patient has been the subject of debate for the past four decades. Recommendations for early total care versus a damage control approach are based on the physiology of these critically ill patients, with the benefits of early fracture stabilization balanced against the potential side effects of excessive surgical burden. Advances in orthopaedic trauma surgery, along with pivotal improvements in anesthesia and critical care medicine, have increasingly enabled orthopaedic surgeons to perform definitive operations on initial presentation. However, a subset of patients may benefit from a damage control approach. Recent clinical data have yielded recommendations for optimal musculoskeletal care of the multitrauma patient. Historically, several eras can be differentiated.

Rationale for Delayed Fixation: The 1960s

In the 1960s, immediate stabilization of long-bone fracture in the patient with multiple traumatic injuries was associated with an unacceptably high mortality rate. The major concern of surgeons treating multitrauma patients was the development of fat embolism syndrome and associated pulmonary dysfunction. Fat and intramedullary contents liberated from...
the fracture were linked to pulmonary failure. Perioperative cardiovascular and pulmonary support was not well established, leading to mortality rates of up to 50%. As a result, long-bone fractures were initially treated with splints, casts, or traction until the systemic effects of fat embolism syndrome resolved. Definitive surgical stabilization was often delayed for 10 to 14 days until the pulmonary, cardiovascular, and neurologic systems and the coagulation profile had stabilized.

In 1967, Küntscher provided three recommendations for intramedullary stabilization of major fractures: (1) “Do not nail as long as symptoms of fat embolization are present.” (2) “Take special precautions for patients with multiple fractures and extensive injuries to soft tissues.” (3) “Do not nail immediately, but wait a few days.”

**Negative Effects of Delayed Fixation**

Delayed fixation of major fractures is fraught with local and systemic implications. Without adequate fixation, the patient cannot be mobilized and is often forced into supine recumbency for prolonged periods. This can result in dysfunction of multiple organ systems, leading to a variety of disorders, including pneumonia, decubitus ulcers, vascular abnormalities, psychological disturbance, and gastrointestinal stasis, which is associated with a high risk of aspiration. Seibel et al were the first to describe an association between delayed stabilization and a longer intensive care unit (ICU) stay, including more episodes of leukocytosis and fever.

Frequently, musculoskeletal outcomes are compromised when fracture surgery is delayed. Prolonged immobilization prevents initiation of comprehensive physiotherapy. Major joints cannot be exercised, which sometimes leads to profound stiffness. Disuse muscle atrophy hampers recovery in the long term.

**Rationale for Early Fixation: The 1980s**

A radical shift in the treatment paradigm of the multitrauma patient with major long-bone fracture occurred in the 1980s as a result of outcome studies that focused on the timing of orthopaedic fixation and the development of acute respiratory distress syndrome (ARDS). Femur fracture in the multiply injured patient became the focus of and the study model for intensive clinical research. Better outcomes were achieved in the multitrauma patient when intramedullary nailing of femur fracture was performed within the first few days after admission.

Bone et al performed the first prospective study that revealed the potential benefits of early fracture fixation. One hundred seventy-eight patients with acute femoral fracture were randomized to receive early fixation or traction. Within the original study population, 83 presented with multiple injuries. The cohort of patients treated with traction and late femoral fixation had the highest incidence of ARDS. These research efforts and others culminated in a change in orthopaedic practice. In light of the convincing results of Bone et al, patients with femur fracture spent less time in traction and were stabilized more rapidly. Time in traction decreased from an average of 9 days to 2 days. However, “early fracture fixation” was loosely defined and could be interpreted as several days after hospital admission.

Along with a better understanding of pathophysiology after trauma, major improvements were made in the general physiologic support of severely injured patients. Border emphasized that optimizing nutrition was correlated with decreased mechanical ventilation requirements and prolonged recumbency. Ventilation strategies improved and allowed orthopaedic surgery to be performed earlier than previously.

The principle of early fixation surgery sometimes was interpreted too literally, however, resulting in an overly aggressive treatment protocol in the multitrauma patient. Orthopaedic operations for both major (ie, immobilizing) and minor musculoskeletal injuries were being performed within 24 hours of admission, a practice that appeared to be associated with an increased complication rate. The beneficial effects of fracture fixation were often negated by the harm inflicted to the overall physiology of the patient as a result of lengthy operations associated with substantial blood loss. The lessons learned from this overly aggressive, comprehensive approach to managing orthopaedic injuries led to further consideration of the timing...
of fracture fixation in the multi-trauma patient.

Role of the Immune System

Trauma causes sustained changes in the immune response. A hyperinflammatory early phase may be followed by a hypoinflammatory phase, which often precedes the onset of organ failure. The magnitude of the inflammatory response depends on the degree of trauma, and it can be influenced by treatment. Surgery also incites an inflammatory response.14

In a normal host, there is usually no clinically significant consequence to the inflammatory response. However, in the multitrauma patient, exposure to prolonged surgery with considerable blood loss and hypothermia causes an exaggerated inflammatory response.15,16 In these patients, the beneficial effects of early definitive fracture stabilization may not outweigh the associated risk of immune-related side effects, such as ARDS and multiple organ failure.12 The surgical impact can act as a second hit (ie, second inflammatory insult after the initial trauma) when the timing and the duration are unfavorable. Waiting several days before performing surgery in multitrauma patients eradicates the danger of this detrimental immunologic response.16

Damage Control Surgery

The term damage control was originally used by the United States Navy to describe tactics necessary to keep afloat compromised vessels at sea. General trauma surgeons came to apply this term to a management strategy that involves reducing the impact of the initial operation and improving survival of critically ill patients. Damage control in general trauma surgery includes packing the major sources of hemorrhage rather than performing immediate, lengthy, definitive repair of the visceral organs. As part of the damage control philosophy, immediate life-saving interventions directed at stopping bleeding are applied, after which resuscitation and further stabilization are performed in the ICU. Only after the overall physiology has improved is definitive intervention performed.

This change in trauma practice resulted in improved survival rates.17 Soon orthopaedic trauma surgeons used a similar temporizing approach for major fractures in multitrauma patients. Initial surgery was done with the goal of achieving rapid skeletal stabilization of major orthopaedic injuries to stop the cycle of ongoing musculoskeletal injury and to control hemorrhage. This approach was termed damage control orthopaedics (DCO).12

The external fixator is the primary tool associated with DCO. This appliance can be used in extremity fractures and in select pelvic fractures (Figure 1). A fixator can be applied rapidly and with minimal blood loss. Compared with a splint, access to the soft tissues is relatively easy, allowing for wound management and monitoring of compartment pressure.18 In contrast to skeletal traction, treatment with initial external fixation improves patient mobility, which is beneficial for many aspects of management, including pulmonary toilet.11 Such fixation also facilitates nursing care. In some cases, especially those involving severe head trauma, external fixation can serve as a definitive treatment strategy until fracture union.

Damage control nailing has been advocated as an alternative to the spanning external fixator. In this approach, an unlocked retrograde nail is used with limited or no reaming19 (Figure 2). For this treatment, the patient is typically returned to the operating room for exchange nailing or locking of the original implant after resuscitation and stabilization.

Scala et al12 used a DCO approach on 43 critically ill patients with femoral fracture who underwent initial external fixation followed by conversion to an intramedullary nail. They reported minimal orthopaedic complications and optimal survival rates. Indications for DCO in this study included head injury (46%) and hemodynamic instability (65%). Taeger et al7 reported a prospective cohort of patients treated according to DCO criteria and described similar beneficial effects. Pape et al20 reported a lower incidence of pulmonary complications in borderline patients with femoral fractures (ie, those with increased risk of systemic complications) treated with external fixation initially. The largest study population was examined by Morshed et al,21 who reviewed 3,069 patients with multisystem trauma. The data were housed in the National Trauma Data Bank. Definitive stabilization done within 12 hours was associated with a higher mortality rate than was delayed management. The authors concluded that delaying repair of femoral shaft fracture beyond 12 hours in the multisystem trauma patient reduces mortality by approximately 50%. Patients with life-threatening abdominal injury benefited most from delayed treatment.

Patient Assessment

The initial patient assessment usually is performed using standard scoring systems such as the Injury Severity Score or the New Injury Severity Score. For life-threatening conditions, which frequently are the result of penetrating trauma, the triad of death (ie, blood loss, coagulopathy, loss of temperature) approach has been used. However, in patients with blunt trauma, it is important to ac-
Parameters to assess adequate oxygenation are useful for determining the clinical status of the patient. A patient can be classified as stable (grade I, cleared for surgery), borderline (grade II, uncertain condition with episodes of cardiovascular instability and hypoxemia), unstable (grade III, cardiovascular instability [systolic blood pressure <90 mm Hg]), or in extremis (grade IV, acutely life-threatening injuries). Although several parameters are considered in classifying patients, clear numerical cutoffs have not been established; thus, judgment and experience are required. The parameters used to identify a patient in borderline condition are listed in Table 1. Three of the four criteria delineated in Table 2 (shock, coagulation, temperature <35°C [95°F], soft-tissue injuries) should be present to qualify a patient for a specific category. The current level of evidence is insufficient to definitively stratify patients; thus, the proposed combination of these parameters is only suggestive. Nevertheless, most of these components are scores that have been routinely applied and are widely accepted.

For screening purposes, the following threshold levels have been used: pulmonary dysfunction (Pao₂/Fio₂ <250 mm Hg), platelet count <95,000/mm³, hypotension unresponsive to therapy with >10 blood units per 6 hours, and requirement for vasopressors. Inflammatory parameters have also been described to have predictive power for the development of complications. However, routine screening for inflammatory...
markers is not available at many trauma centers.23

Surgical Priorities

The first surgical priority is to save the patient’s life and, when feasible, the limb, as well as to limit the time in the operating room to ≤2 hours.22 Within this surgical window, open fractures should be débrided and stabilized with an external fixator. A splint may be sufficient for upper extremity injuries. Negative pressure therapy plays an integral role in the management of orthopaedic wounds. An initial guillotine amputation may be lifesaving for the patient who is in extremis because of an extremity fracture or who has an open fracture with vascular injury. It is not possi-

Table 2

Criteria Used to Determine the Clinical Condition of Multitrauma Patients and Refer to Treatment Guidelines*

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Parameter</th>
<th>Stable</th>
<th>Borderline</th>
<th>Unstable</th>
<th>In Extremis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock</td>
<td>Blood pressure (mm Hg)</td>
<td>≥100</td>
<td>80-100</td>
<td>&lt;90</td>
<td>≤70</td>
</tr>
<tr>
<td></td>
<td>Blood units given in a 2-hr period</td>
<td>0-2</td>
<td>2-8</td>
<td>5-15</td>
<td>&gt;15</td>
</tr>
<tr>
<td></td>
<td>Lactate levels (mg/dL)</td>
<td>Normal range according to local laboratory</td>
<td>&gt;2.5</td>
<td>&gt;2.5</td>
<td>Severe acidosis</td>
</tr>
<tr>
<td></td>
<td>Base deficit level (mmol/L)</td>
<td>Normal range according to local laboratory</td>
<td>No data</td>
<td>No data</td>
<td>&gt;6-8</td>
</tr>
<tr>
<td>Coagulation</td>
<td>ATLS classification</td>
<td>I (no shock)</td>
<td>II-III (slight shock)</td>
<td>III-IV (severe shock)</td>
<td>IV (severe shock)</td>
</tr>
<tr>
<td></td>
<td>Platelet count</td>
<td>&gt;110,000/mm³</td>
<td>90,000-110,000/mm³</td>
<td>&lt;70,000-90,000/mm³</td>
<td>&lt;70,000/mm³</td>
</tr>
<tr>
<td></td>
<td>Factor II and V (%)</td>
<td>90-100</td>
<td>70-89</td>
<td>50-70</td>
<td>&lt;50</td>
</tr>
<tr>
<td></td>
<td>Fibrinogen (g/L)</td>
<td>&gt;1</td>
<td>=1</td>
<td>&lt;1</td>
<td>Disseminated intra-vascular coagulation</td>
</tr>
<tr>
<td></td>
<td>D-dimer (µg/mL)</td>
<td>Normal range according to local laboratory</td>
<td>Abnormal</td>
<td>Abnormal</td>
<td>Disseminated intra-vascular coagulation</td>
</tr>
<tr>
<td>Temperature</td>
<td>Temperature (°C (°F))</td>
<td>&lt;33 (&lt;91.4)</td>
<td>33-35 (91.4-95.0)</td>
<td>30-32 (86.0-89.6)</td>
<td>≤30 (&lt;86.0)</td>
</tr>
<tr>
<td>Soft-tissue injuries</td>
<td>Lung function (Pao2/Fio2 [mm Hg])</td>
<td>350-400</td>
<td>300-350</td>
<td>200-300</td>
<td>&lt;200</td>
</tr>
<tr>
<td></td>
<td>Chest trauma scores (AIS)</td>
<td>1 or 2 (ie, abrasion)</td>
<td>≥2 (ie, 2-3 rib fractures)</td>
<td>≥3 (ie, serial rib fractures &gt;3)</td>
<td>≥3 (ie, unstable chest)</td>
</tr>
<tr>
<td></td>
<td>Chest trauma score (thoracic trauma severity score)</td>
<td>0 (concussion)</td>
<td>I-II (slight thoracic trauma)</td>
<td>II-III (moderate)</td>
<td>IV (severe)</td>
</tr>
<tr>
<td></td>
<td>Abdominal trauma (Moore classification)</td>
<td>≤II (none)</td>
<td>≤III (slight)</td>
<td>III (moderate)</td>
<td>≥III (severe)</td>
</tr>
<tr>
<td></td>
<td>Pelvic trauma (AO classification)</td>
<td>A (none)</td>
<td>B or C (slight)</td>
<td>C (moderate)</td>
<td>C (crush, rollover, abdominal)</td>
</tr>
<tr>
<td></td>
<td>External AIS I-II (eg, abrasion)</td>
<td>AIS II-III (eg, multiple tears &gt;20 cm)</td>
<td>AIS III-IV (eg, &lt;30% burn)</td>
<td>Crush injury (&gt;30% burn)</td>
<td></td>
</tr>
</tbody>
</table>

* Three of the four criteria must be met to classify for a certain grade. Note that the condition can change according to resuscitation or additional hemorrhage.

AIS = Abbreviated Injury Score, ATLS = Advanced Trauma Life Support
ble to indicate specific criteria for every situation because each decision must take into account a number of variables. However, some general recommendations can be made.

In the patient in extremis, hemorrhage control is paramount, followed by stabilization of vital parameters in the ICU. Major fractures are considered to be a secondary priority. In the unstable patient, major lower extremity fractures should be stabilized with a temporary method, such as external fixation. In the borderline patient who responds to resuscitation, definitive procedures (eg, intramedullary nailing) can be performed but within an upper surgical time limit of <2 hours. The patient with several lower extremity fractures should be continuously reassessed, with particular attention paid to the following parameters: lung function (Pao2/Fio2 should not drop below 250 mm Hg), temperature (should not be <32°C [89.6°F]), requirement of fluids (should not exceed 3 L, or 5 units of blood), and absence of significant coagulopathy. Provided that the patient maintains these levels, the surgeon may address the next major fracture; otherwise, a temporizing approach should be selected.24 In the stable patient, all fractures can be definitively stabilized within the first day. An algorithm for treatment of borderline and unstable patients is presented in Figure 3.

**Head Injury**

Following significant head injury, the brain loses the capacity for autoregulation of blood flow in zones of contusion. Furthermore, glucose utilization increases, adding to a flow-metabolism mismatch. Consequently, the injured brain is highly susceptible to ischemic injury.25

The individual with head trauma is at greatest risk for decreased cerebral blood flow during the first 12 to 24 hours following injury.26 Intraoperative hypotension is an important risk factor for secondary brain injury.27 The primary goals of management of traumatic brain injury are maintenance of adequate cerebral perfusion and avoidance of secondary insults.28

Treatment of the multitrauma patient with head injury requires a multidisciplinary approach that includes the neurosurgical team, with treatment tailored to the evolving status of the patient. The degree of cerebral swelling, imminent herniation, and increase in bleeding must be closely monitored.

Clinical studies have provided conflicting results. In one study that compared multitrauma patients who had closed head injury and femur fracture with multitrauma patients who had head injury but no femur fracture, McKee et al29 reported no significant difference in mortality, no difference in length of stay, and no
difference in neurologic outcome according to the timing of stabilization. However, in a study by Townsend et al,\(^\text{30}\) patients with a Glasgow Coma Scale value of \(<9\) on admission who were operated on within 2 hours had an eightfold increased risk of hypotension. Thirty-six of 43 patients with poor neurologic outcomes had cerebral perfusion pressures \(<70\) mm Hg within the first 24 hours. Jaicks et al\(^{31}\) reported that fracture fixation in the presence of severe head injury has negative effects; however, the authors did not include in their analysis patients who died before discharge. These conflicting results are noteworthy and may be attributable to different inclusion criteria in these respective studies.

In the multitrauma patient with head injury, acceptable thresholds for operating room time, blood loss, and temperature loss must be determined on an individual basis. In equivocal cases, monitoring of the intracranial pressure is prudent. During fracture fixation, the goals of management should include maintenance of adequate cerebral perfusion and avoidance of secondary insults.

**Chest Injury**

Chest injury in the multitrauma patient typically consists of either chest wall fracture or lung contusion, or both. In the patient with isolated rib fractures, the act of breathing is painful, causing hypoxemia that can be addressed with either local pain blocks or artificial ventilation.

Lung contusion is of utmost concern because it is closely associated with ARDS.\(^{32}\) In the patient with lung contusion, the disturbance of oxygenation can increase despite adequate efforts at mechanical ventilation, because of the formation of pulmonary edema. This pulmonary edema is mediated by inflammatory cells, causing a local immunologic reaction that affects the pulmonary endothelium, similar to the response described for general blood loss.\(^{33}\) The progressive nature of a pulmonary contusion can cause problems and is frequently underestimated.\(^{34}\)

Early diagnostic studies may not adequately reveal the extent of the evolving lung injury. Even when blood gas parameters are within normal limits and the chest radiograph is normal, pulmonary contusion may occur as a result of the immune response, resulting in an increased risk of ARDS.\(^{35,36}\)

Patient evaluation should be focused on the following clinical criteria: presence of a lung contusion on the initial chest radiograph or CT scan, worsening oxygenation (requirement of increased \(\text{FiO}_2 >40\%\) or \(\text{Pao}_2/\text{FiO}_2 <250\) mm Hg), and increased airway pressures (eg, \(>25\) to \(30\) cm \(\text{H}_2\text{O}\)). Pulmonary function can change within hours after the injury, and repeat blood gas analyses should be obtained.

The timing of fracture management in patients with thoracic injuries remains controversial, with conflicting studies and recommendations. Fakhry et al\(^{37}\) examined a statewide database and discovered a 4.6% mortality rate in patients with severe chest injuries who underwent surgery on day 1, compared with a 0% mortality rate in patients who were definitively stabilized \(>1\) day after admission to the hospital. The authors concluded that “the presence of severe chest injury may be an indication to delay the femoral repair for 24 to 48 hours until these injuries have been stabilized.” In a study by Pelias et al,\(^{18}\) the comparison between early and late fixation of long-bone fractures revealed no appreciable difference in pulmonary complications (early operation, 27.6%; late operation, 29.4%). The authors concluded that the incidence of ARDS in these patients is attributable to chest trauma complicated by the fracture and not to timing of fixation.

van Os et al\(^{19}\) found no statistical difference in the incidence of ARDS in patients treated with early versus late fixation and concluded that severe thoracic trauma is not a contraindication for early osteosynthesis. Bone et al\(^{40}\) compared three groups of chest-injured patients: those whose femoral fracture was treated with a nail, those whose fracture was treated with a plate, and those without a femur fracture. The authors concluded that the chest injury, not the method of femoral fracture fixation, was responsible for ARDS.

Pryor and Reilly\(^{41}\) noted that inclusion criteria may be responsible for the conflicting results in the literature. Most publications have relied on the Abbreviated Injury Scale for assessment,\(^{42}\) but use of a more sophisticated scoring system may be appropriate to precisely grade pulmonary injury. Because all authors agree that severe chest trauma represents a risk factor for ARDS, ruling out severe lung contusions by early CT scan is advisable; the decision regarding how to proceed should be made on an individualized basis using a multidisciplinary approach.

**Pelvic Ring Injury**

Pelvic fracture is an indicator of high-energy trauma. The systemic effects of severe pelvic injuries are determined by the degree of hemorrhage and soft-tissue injury. Unlike other injuries, autotamponade does not occur, and retroperitoneal bleeding may mimic intra-abdominal injury. Soft-tissue disruption can cause more severe side effects in pelvic fracture than in extremity fracture because, in the former, a higher degree of kinetic energy is required to cause substantial displacement. Open injuries are common. Gas-
trointestinal contamination is particularly worrisome because of the substantially increased risk of infection and late sepsis.43

Evaluation of the patient with pelvic fracture is similar to that for any patient with an injury associated with sustained hemorrhage. Timing of pelvic fixation is based on hemodynamic status and the presence of associated abdominal injuries. The decision to attempt definitive fixation within 24 to 48 hours appears to be dependent on the pelvic ring fracture pattern.44 Fixation can be attempted in stable and borderline patients. In unstable patients, the use of sheets wrapped about the pelvis or a pelvic binder, optimally placed at the level of the greater trochanters, allows for rapid circumferential splinting of the pelvic ring.45

There is a paucity of literature on the optimal timing of definitive pelvic stabilization. Favorable patterns may be treated with percutaneous fixation when certain criteria are met: a closed reduction is possible, the injury pattern is amenable to screw fixation alone, and the surgeon and operating team are available and experienced.46 In extreme cases of exsanguination resulting from pelvic ring injury, direct packing of the true pelvic space has been described.47 However, this technique must be performed with adjunctive pelvic ring stabilization, which may include a binder, external fixation, or internal fixation.

Currently it is recommended that the surgeon identify the source of pelvic hemorrhage and stop bleeding emergently, then stabilize the pelvic ring. The use of a binder is often successful in achieving a physiologic state that allows surgery. A single damaged artery may be treated by coil embolization instead. The local conditions in a given trauma center often determine the specific technique for stabilizing the pelvic ring.

**Summary**

The patient with multiple traumatic injuries may be classified as stable, borderline, unstable, or in extremis. Early definitive fracture fixation is recommended for the stable multitrauma patient and in the borderline or unstable patient who responds well to resuscitation. However, in the patient who presents with severe hemorrhagic shock or any other life-threatening condition, prolonged surgical procedures should be avoided, and staged fracture fixation should be done. The damage control approach, which uses external fixation as a primary tool, may be applied in such cases. For the patient who presents as borderline or in poorer condition, a multidisciplinary approach is required to determine the best timing of musculoskeletal care.

**References**

*Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 9, 14, and 18 are level I studies. References 7, 8, 30, 33, and 34 are level II studies. References 2, 3, 5, 6, 13, 15, 17, 21, 25-29, 35, and 36 are level III studies. References 1, 4, 10, 12, 16, 20, 22-24, 31, 32, 37-39, 44, and 45 are level IV studies. References 40-43 are level V expert opinion.*

Citation numbers printed in **bold type** indicate references published within the past 5 years.


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