Management of Orthopaedic Injuries in Polytrauma Patients

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Appropriate management of a polytrauma patient begins at the scene of the accident. Early initiation of Advanced Trauma Life Support (ATLS) protocols by emergency medical personnel and rapid transport to an appropriate facility is essential to maximize a patient’s chance of survival. Fifty percent of trauma deaths occur within minutes of the accident, usually due to hemorrhage or head injuries. Thirty percent of deaths occur within hours from similar causes. The remaining 20% of deaths occur days to weeks following the injury, typically from sepsis or multiple organ failure. For patients who have sustained major injuries, treatment at a designated regional trauma center that treats a significant volume of trauma patients has been shown to correlate with better survival rates.\(^1\,^2\)

A large percentage of trauma patients have orthopaedic injuries. Management of isolated long bone fractures is relatively simple; however, treatment of these and more complex injuries (i.e., pelvis and acetabulum fractures) in the multiply injured patient is more challenging. Pelvis and long bone fractures cause significant systemic complications that affect the physiological status of the patient. These systemic effects will potentially alter the overall treatment of the patient. Orthopaedic injuries in the polytrauma patient must be addressed in the context of the entire patient, not just as isolated fractures.

Initial Management

Standard ATLS protocols administered by an organized trauma team are critical. Initial assessment should include the standard airway, breathing, circulation, disability (neurological) survey, followed by careful physical examination to identify all injuries. Standard trauma series radiographs, including an anteroposterior chest, anteroposterior pelvis, and lateral of the cervical spine with visualization from the occiput to T1, should be obtained.

Life-threatening injuries, including orthopaedic injuries such as an unstable pelvis fracture, need to be addressed first. Limb-threatening and spinal injuries follow closely behind. These include open fractures, compartment syndromes, and fractures with associated vascular disruptions. These injuries need to be addressed prior to performing more elective skeletal stabilization and reconstruction.

Timing of Orthopaedic Intervention

Early mobilization of trauma patients is critical in the prevention of pulmonary complications such as pneumonia and adult respiratory distress syndrome (ARDS), along with other complications of trauma such as decubitus ulcers and joint contractures. Skeletal injuries must be stabilized prior to mobilizing a patient.

Bone and colleagues\(^3\) randomized patients with a femur fracture into two groups: early stabilization (within the first 24 hours of injury) and delayed stabilization (greater than 48 hours). Early stabilization led to significantly lower incidences of ARDS, pneumonia, and fat emboli syndrome. Length of stay in the hospital and intensive care unit was shortened as well, along with sig-
nificantly lower cost.

In a later study by Bone and associates, in 1994, the authors prospectively followed mortality in polytrauma patients who underwent orthopaedic stabilization within the first 48 hours of injury. Mortality was compared to a cohort of trauma patients treated without an early stabilization protocol. Mortality was consistently lower in the early stabilization group by more than 50%. The lower decreased incidence of mortality was even more pronounced in older patients and those with higher injury severity scores.

Multiply injured patients clearly benefit from early stabilization of their orthopaedic injuries. Early fracture fixation allows mobilization of the patient and hence improved pulmonary care, along with a lower risk of ARDS, fat and thromboembolic disease.

Fracture Fixation in Head-Injured Patients

Head injuries are a significant source of morbidity and mortality in the trauma patient population. Blunt trauma can lead to mass lesions such as epidural, subdural, or intraparenchymal hematoma, along with diffuse axonal injury. Hematomas may require surgical evacuation if they are of sufficient size. Regardless of the mechanism, head trauma may lead to a rise in intracranial pressure (ICP).

Analogous to compartment syndrome of an extremity, an elevated ICP will result in reduced blood flow to the brain, causing ongoing ischemic injury. Cerebral perfusion pressure (CPP) is measured as the difference between the mean arterial pressure (MAP) and the ICP. CPP must be optimized in order to maintain adequate cerebral oxygenation. Insertion of an intracranial pressure monitor may be performed in the emergency department and will allow careful monitoring of the CPP. Invasive monitoring may be indicated in any patient with a significant head injury, particularly if they will be undergoing anesthesia for other surgical procedures. CPP should be maintained at 60 to 70 mmHg. This is accomplished by maintaining blood pressure, elevation of the head, hyperventilation, and mannitol diuresis. Steroids have not been useful in the management of acute closed head injuries.

Timing of fracture fixation in the head-injured patient is controversial. Jaicks and colleagues retrospectively reviewed patients with closed head injuries and fractures. The patients were divided into two groups based on the timing of orthopaedic stabilization: early fixation (less than 24 hours) and late fixation (greater than 24 hours). In this study, patients stabilized early had increased fluid requirements, and experienced more hypoxemia and hypotension than the late fixation group. The early stabilization patients also demonstrated a lower Glasgow Coma Scale (GCS) score at discharge. The authors concluded that early stabilization of orthopaedic injuries in a head-injured patient is deleterious. However, this was a small retrospective study of 33 patients, and only 11 patients were managed by invasive ICP monitoring. More aggressive management of cerebral perfusion may have obviated some of the worse neurological outcome observed in the study.

Townsend and associates reported on 61 patients with closed head injuries and femur fractures stabilized by plate fixation. There was a significantly increased risk of intraoperative hypotension associated with early fracture fixation. However, no correlation was established between neurological outcome and hypotension; outcome did correlate with severity of the initial injury. They concluded that surgery should be delayed until the patient was adequately resuscitated in order to make management of CPP easier.

The largest study to date is a retrospective review of 171 patients with head injuries and fractures treated at the R. Adams Cowley Shock Trauma Center in Baltimore. Of the 171 patients included in the study, 147 underwent fracture fixation within 24 hours of injury. The patients were equivalent in terms of multiple injury scores, including GCS. There was no difference in GCS at discharge or increased risk of neurological complications in patients who underwent early orthopaedic stabilization.

Early fracture fixation in a head-injured patient will certainly make mobilization easier and improve pulmonary function, provided that it does not cause neurological deterioration. While no prospective randomized study has been performed, evidence from multiple retrospective studies demonstrates that early fixation is likely beneficial and safe when combined with aggressive resuscitation and invasive intracranial pressure monitoring.

Cervical Spine Injuries

Cervical spine injuries are common in the blunt trauma patient, accounting for 55% of all spinal injuries. Eighty percent of spinal cord injuries occur in multi-trauma patients. A lateral radiograph of the cervical spine is a standard component of the basic trauma series. It is crucial to visualize the C7-T1 junction on this film; if this is not visible, a CT scan may be obtained.

However, a “normal” cross-table lateral of the cervical spine does not adequately exclude injury. Bachulis and colleagues demonstrated that a single lateral view missed 23% of injuries. Woodring and Lee identified injuries in 32% of patients with “normal” lateral films. Fifty-eight percent of these were unstable injuries. Therefore, cervical spine precautions must be maintained in all patients, including those with a “negative” lateral film, until the neck is adequately cleared.

Radiographic cervical spine clearance is based on a set of lateral, anteroposterior, and open-mouth radio-
graphs with adequate visualization. CT scanning may be used if regions are not adequately visualized on the plain radiographs. However, cervical precautions cannot be removed based on radiographic criteria alone. A reliable physical examination demonstrating no neck pain or tenderness is crucial to avoiding missing ligamentous injuries without associated fractures. This may necessitate maintaining a collar for an extended period, particularly in an intubated or head-injured patient.

Flexion-extension views of the cervical spine are often used in the elective setting to evaluate a patient for instability. Some centers have used these in the trauma setting to identify injuries when patients with negative plain films have neck pain. Wang and associates studied 290 trauma patients with neck pain and negative plain radiographs. Thirty-three percent of the views demonstrated inadequate flexion or extension, likely due to pain. Only one patient in the series demonstrated translation, and this patient was later shown to have pre-existing pathology at the involved level. Therefore, flexion-extension views are likely of little value in the evaluation of a trauma patient with neck pain. A patient in this situation demonstrates a neck injury by virtue of their pain; stressing the neck is potentially dangerous and is an unreliable examination.

Magnetic resonance imaging (MRI) has been investigated as a method of “clearing” the cervical spine in patients with persistent neck pain despite normal radiographs, or in patients who are unable to cooperate with a physical examination. Benzel and colleagues reported a prospective study of 174 consecutive conscious patients who possibly had cervical spine injuries but whose plain radiographs were negative. Thirty-six percent of these patients had soft-tissue injuries that were diagnosed by MRI imaging, including ligamentous and disc-space disruptions. No patient that was regarded as MRI-negative had any evidence of injury or instability at follow-up. MRI has not been investigated in the unconscious patient, but will likely be a useful tool in the evaluation of potential cervical spine injuries in all trauma patients.

In summary, cervical spine clearance requires a three-view, plain radiograph series (or CT scan of poorly visualized levels), as well as a clinical exam demonstrating no tenderness. Flexion-extension views are of no value in a trauma patient. MRI is potentially valuable in evaluating patients who are unable to cooperate with a physical examination.

**Pelvic Fractures**

Pelvic ring injuries are potentially devastating injuries. They carry a significant mortality and are often associated with shock and other serious injuries. Appropriate emergent management of these complex injuries is essential to maximize the chances of a patient surviving severe trauma.

The initial question to ask in the setting of pelvic trauma should be: Is this pelvic fracture going to kill the patient? The Young and Burgess classification is valuable in answering this question. This mechanism-based model classifies injuries as lateral compression (LC), anterior-posterior compression (APC), vertical shear (VS) and combined mechanism. In the reported series, high-grade (APC III) injuries had the most significant transfusion requirements (35 units in 24 hours), and carried the most significant mortality rate (20%). Overall mortality was 8.6%, with 50% of mortality directly attributable to pelvic causes.

The mechanism of injury has been shown to correlate with the pattern of associated injury. Lateral compression injuries are associated with significant head, chest, and upper abdominal injuries. Mortality in the lower grade LC injuries (LC-I and LC-II) is mostly due to head injuries, whereas direct pelvic causes are implicated in LC-III patterns. Anterior-posterior compression injuries are associated with significant intraabdominal injuries. Mortality is mostly due to torso injuries, as well as shock and sepsis. Vertical shear injuries behave similarly to high-grade APC fractures, and combined mechanism injuries are similar to lateral compression injuries.

The definition of hemodynamic instability varies from institution to institution. Criteria include systolic blood pressure less than 90 mmHg, ongoing transfusion requirements, and massive fluid requirements. The lack of uniform criteria has clouded the literature on the management of unstable patients with pelvic fractures. However, instability is defined, a pre-established protocol should be in place for managing the patient.

A pelvic fracture should be identified on the initial AP pelvis radiography. A careful physical inspection, including perineal, digital rectal, and vaginal examination, should be performed. “Rocking” the pelvis should not be performed as mechanical instability may be inferred based on the fracture pattern, or checked by fluoroscopic examination under anesthesia. There should be a high suspicion for urethral injury, with only a single attempt made at insertion of a Foley catheter.

In the setting of hemodynamic instability, the patient should not be brought to a CT scanner. It is necessary to identify the source of the patient’s hemorrhage. Abdominal ultrasound is becoming useful in assessing intraperitoneal bleeding; however, a diagnostic peritoneal lavage (DPL) remains the standard approach. In the setting of a pelvic fracture, DPL should be performed suprambically to avoid entering a pelvic hematoma. A negative DPL, in the absence of another identifiable source of bleeding, suggests that the bleeding is from the pelvic fracture. This may be bleeding from fracture surfaces, the venous plexus, or a named artery. A positive DPL should trigger an exploratory laparotomy; management of the pelvic bleeding should occur simultaneously.
Angiography is essential to the evaluation and management of pelvic hemorrhage. Burgess and associates demonstrated that 11% of patients required embolization of a bleeding vessel (20% of APC injuries). Superior gluteal artery bleeding is associated with posterior instability, and pudendal/obturator artery bleeds are associated with anterior instability. Other methods of controlling hemorrhage include open packing of the pelvis and mechanical stabilization of the pelvis. Open packing of the pelvis following external fixation has been advocated by centers in Europe. This is generally not used in North America. Acute external fixation is a quick method of mechanically stabilizing the pelvic ring. The first clot to form is the best because the patient has not consumed significant coagulation factors and is not hypothermic. A fixator will stabilize the initial clot and theoretically will tamponade the bleeding by reducing pelvic volume. Methods of mechanical stabilization of the pelvis include simply tying a sheet around the pelvis, application of a pelvic binder, or external fixation with a “C-clamp” or pin-and-bar fixator.

Laboratory studies have demonstrated that an external fixator reduces the retroperitoneal volume in a fractured pelvis. The same study also demonstrated that laparotomy causes a significant increase in pelvic volume due to release of the tension band effect of the abdominal wall, suggesting that an external fixator be placed prior to abdominal exploration. Anterior external fixation has also been shown to increase tamponade pressures after a significant volume of fluid has accumulated in the retroperitoneal space.

There are no prospective, randomized studies regarding emergent pelvic external fixation in the English language literature. Reimer and colleagues compared mortality in pelvic fracture patients before and after institution of a protocol for acute external fixation of mechanically unstable pelvic ring injuries. Mortality fell from 41% to 21% in this population. Mortality in patients with pelvic fractures and head injuries fell from 41% to 7%. The mortality for patients without pelvic fractures but similar Injury Severity Scores did not change during the study period. This suggests that external fixation may be beneficial in a subset of pelvic fracture patients.

A simple algorithm is as follows: Stable patients with a pelvic ring injury may undergo routine pelvic fixation. In the setting of hemodynamic instability, abdominal bleeding must be ruled out by DPL or ultrasound. A patient with an intraperitoneal bleed should undergo emergent pelvic fixation prior to laparotomy, with angiography following if the patient remains unstable. A patient without intraperitoneal bleeding will likely benefit from external pelvic stabilization, followed by angiography if hemodynamic instability persists. The surgeon ultimately responsible for treating the pelvic fracture should be involved in the decision-making early on, so that definitive fixation is not compromised by mistakes made earlier.

**Open Pelvis Fractures**

Open fractures of the pelvis are relatively uncommon. They are very high-energy injuries characterized by tensile failure of the soft tissue and implosion or extrusion of pelvic contents. Bleeding is problematic due to loss of all tamponade, and late sepsis associated with rectal/vaginal perforations is common. All of these wounds should be treated by rapid irrigation and debridement. Jones and associates reviewed the experience of several centers in the treatment of 39 open pelvic fractures. Twenty-seven of 39 were mechanically unstable. Of the 9 patients with rectal lacerations, 5 underwent diverting colostomy within the first 48 hours of injury. One of these patients died. Of the 4 who underwent delayed diversion, 3 died. This illustrates the need for early diversion of the fecal stream in patients with rectal or perineal lacerations in order to avoid sepsis. Similar conclusions were reached by Pell and colleagues, who reported no incidence of abdomino-pelvic sepsis in patients with rectal/perineal wounds who underwent early diverting colostomy.

**Pelvic Fractures with Urological Injuries**

Major injury to the lower urinary tract is reported in up to 16% of pelvic fractures. Bladder rupture may be intraperitoneal or extraperitoneal. Urethral injury is possible in both genders, but due to anatomic differences is much more common in males.

Blood at the urethral meatus, perineal/genital edema, and a high riding prostate are classically described findings in the setting of pelvic fracture with lower genitourinary trauma. However, 57% of males with documented urethral injuries had none of these findings within the first hour of injury. A high suspicion for injury is critical. Foley catheter passage should be attempted only once; if passage is not easy, a retrograde urethrogram should be performed. Urological consultation should then be obtained. In women, a vaginal speculum exam should be performed because vaginal tears may communicate with the urethra. After placement of a Foley catheter, a cystogram should be performed to rule out bladder rupture.

If there is urological injury, it must be treated in conjunction with the pelvic fracture. If the pelvic fracture is non-operative, routine management of the urological injury should proceed. This may include realignment of a urethral tear over a Foley catheter or direct repair of an intraperitoneal bladder rupture. Extraperitoneal bladder ruptures may be managed by either direct repair or simple urinary drainage. If surgery is performed, care must be taken to avoid disrupting the retroperitoneal hematoma.
There is a risk of bladder colonization with any indwell-
ing catheter, which may lead to seeding of the retroperi-
toneal hematoma.

In the setting of mechanical instability of the pelvis, management of urological injuries is controversial. A su-
prapubic cystostomy may contaminate hardware in the an-
terior pelvis. If this must be used, it should be tun-
neled away from the site of any future incisions (i.e., for pelvic or acetabular fixation). Definitive treatment of
anterior injuries may be the safest because it obviates
the need for hardware in proximity to the bladder. How-
ever, this is often not the ideal treatment.

Routt and associates\textsuperscript{22} described a successful algo-

rithm for the treatment of these injuries that avoids su-
prapubic cystostomy. They report a low infection rate
and a method that does not compromise pelvic fixation.
Pelvic reduction is performed via a Pfannenstiel inci-
sion. Indirect urethral realignment is achieved via a cys-
totomY and any bladder lacerations are repaired. The
pelvis is stabilized internally and urinary drainage is
achieved via a large diameter Foley catheter. Early in-
volve ment and close communication between the ortho-
paedist and urologist is essential to ensure the best out-
comes for these complex injuries.

**Femur Fractures**

Early stabilization of femur fractures has been demon-
strated to increase survival and decrease pulmonary
morbidity amongst trauma patients. However, there is
concern that intramedullary fixation may cause pulmo-
nary dysfunction in some trauma patients. Fat emboli
syndrome (FES) is related to long bone fractures, par-
ticularly when associated with other major trauma. It
ranges from subclinical to fulminant ARDS. Onset is
typically within 24 to 72 hours from the time of injury.
Diagnosis is according to Gurd’s Criteria (one major and
three minor signs, or two major and two minor signs).\textsuperscript{23}
Major signs include hypoxia (\(PaO_2 < 60 \text{ mmHg} \) and \(FiO_2 > 40\%\)), CNS depression, and petechiae. Minor signs in-
clude tachycardia (HR > 120), pyrexia, thrombocytopen-
ia, fat globules in the urine or sputum, retinal emboli,
and a decline in hematocrit not explained by blood loss
or dilution. The pathophysiology is unclear, but is likely
due to aggregation of fat in the pulmonary vasculature
along with biochemical breakdown of the fat into toxic
free fatty acids. Treatment is by prevention; ventilator
support is often necessary when the syndrome is present.

The gold standard treatment of femoral shaft fractures
is a reamed antegrade intramedullary locked nail. Union
rates of up to 99\% have been reported with this treat-
ment.\textsuperscript{24} Reaming has been implicated as a cause of FES
due to increased marrow extravasation. Studies from
Europe have suggested that reamed femoral nailing may
lead to pulmonary dysfunction. Differences in pulmo-
nary dysfunction between reamed and unreamed nails
were not statistically significant, but Pape and col-
leagues\textsuperscript{25} concluded that reaming is potentially danger-
ous. In a sheep model, reamed nailing led to increased
pulmonary artery pressures when compared to unreamed
nailing in lungs subjected to crush injury.\textsuperscript{26} Both reamed
and unreamed nailing led to increased pulmonary vas-
cular permeability. However, studies on another sheep
model demonstrated that reamed nailing did not inde-
pendently lead to increased vascular permeability; hy-
potension (shock) was associated with permeability.\textsuperscript{27-29}
Wolinsky and colleagues\textsuperscript{28,29} developed an open-chest
model to study the pulmonary effects of reaming in
sheep. After induction of a chemically-induced ARDS-
like state, reamed intramedullary nailing was performed.
They demonstrated no significant change in pulmonary
parameters induced by reaming. In animal models, ream-
ing of the femur does not seem to alter pulmonary func-
tion in the absence of hypotension.

Bosse and associates\textsuperscript{30} reported a multicenter review
comparing nailing versus plate fixation of femur frac-
tures in the presence of a chest injury. The incidence
of ARDS was similar (and low) in both groups. They con-
cluded that the method of fixation of a femur fracture
does not influence the rate of ARDS in patients with a
chest injury. The general consensus is that reamed nai-
ing is safe in the adequately resuscitated trauma patient.

**Damage Control**

Multiply injured patients may be too sick initially to tol-
erate prolonged orthopaedic reconstruction. However, the
benefits of early skeletal stabilization are well known.
External fixation is a useful technique for providing in-
terim stabilization of any long bone, and functions as
“traveling traction.” External fixation may be used for
definitive treatment of tibia fractures. Conversion of a
femoral external fixator to an intramedullary nail has
been demonstrated to be safe in the absence of acute
pin-track infections.\textsuperscript{31}

**Conclusions**

- Urgent stabilization of long bone injuries will de-
crease morbidity and mortality in the polytrauma
patient.
- Recognition of cervical spine injuries is critical;
however, removal of spine precautions cannot oc-
cur without a cooperative patient or, possibly, a
negative MRI.
- Hemodynamically unstable patients with pelvic
fractures should have some form of pelvic stabil-
ization applied prior to laparotomy or angiography.
- Patients with pelvic fractures and rectal/perineal
lacerations should undergo an urgent diverting co-
lcostomy.
- Primary internal fixation of a pelvic fracture com-
bined with urological repair is safe and effective.
without the use of a suprapubic cystostomy.

- Reaming of long bones is safe in the adequately resuscitated patient, even with a chest injury.

- When in doubt, external fixation is a safe and fast method of stabilizing long bone fractures.

References


