Femoral Shaft Fracture Fixation and Chest Injury After Polytrauma

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Current Concepts Review

Femoral Shaft Fracture Fixation and Chest Injury After Polytrauma

By Lawrence B. Bone, MD, and Peter Giannoudis, MD, FRCS

Thirty years ago, the standard of care for the multiply injured patient with fractures was placement of the fractured limb in a splint or skeletal traction, until the patient was considered stable enough to undergo surgery for fracture fixation[1]. This led to a number of complications[2], such as adult respiratory distress syndrome (ARDS), infection, pneumonia, malunion, nonunion, and death, particularly when the patient had a high Injury Severity Score (ISS)[3]. Retrospective studies showed that the incidence of fat embolism syndrome could be reduced with stabilization of long-bone fractures in a multiply injured patient. Riska et al. noted a decrease in fat embolism syndrome from 22% (twenty-one of ninety-five) with traction treatment to 1% (one of ninety-five) with early operative fracture stabilization[4]. This finding led to greater use of early surgical stabilization of femoral fractures in the multiply injured patient. Subsequent follow-up studies demonstrated decreases in mortality and morbidity with early surgical stabilization of long-bone fractures in the multiply injured patient[5-9]. Moreover, retrospective noncontrolled studies showed that the patients with the highest ISS or greatest number of injuries derived more benefit from surgical stabilization of a femoral fracture shortly after the injury than from treatment with skeletal traction for seven to ten days prior to operative femoral fixation. Border et al.[5] and Johnson et al.[6] showed a decrease in pulmonary failure, time on a ventilator, time in the intensive care unit, septic complications, and death with early surgical stabilization.

Because of the lack of control of these retrospective studies, and skepticism by both general surgeons and orthopaedic surgeons about the importance of early fracture stabilization, one of us (L.B.B.) and others performed a prospective randomized study to compare femoral fractures treated within twenty-four hours after injury with those treated more than forty-eight hours after injury[10]. The investigators randomized all femoral fractures of patients admitted acutely to Parkland Hospital in Dallas, Texas, over a two-year period, from 1984 to 1986. One hundred and seventy-seven patients were randomized: eighty-seven to the early fixation group and ninety to the late fixation group. Each group was then subdivided into patients with multiple injuries, defined as an ISS of ≥18, and patients with essentially an isolated femoral fracture and an ISS of <18. Pulmonary complications consisting of ARDS, pulmonary dysfunction, fat emboli, pulmonary emboli, and pneumonia were present in 38% (fourteen) of thirty-seven patients in the late fixation/multiple injuries group and 4% (two) of forty-six in the early fixation/multiple injuries group; pulmonary dysfunction developed only in the late fixation/multiple injuries group (5%; two of thirty-seven). The average age and ISS were very similar in both multiply injured groups. However, the numbers of days on assisted ventilation, in the intensive care unit, and in the hospital as well as the cost of treatment were significantly increased in the late fixation group. This prospective and randomized study impacted the care of musculoskeletal injuries in the multiply injured patient and became the foundation for the dogma of early total care[10].

Misuse of early total care, however, led to early surgical fracture fixation in some patients whose physiologic state did not tolerate the additional trauma of fracture fixation in the first twenty-four hours[11-14]. Patients considered borderline for tolerating fracture surgery, or more appropriately "at risk," include those who are hemodynamically unstable or hypothermic, have coagulation abnormalities, or have poor oxygenation due to traumatic lung injury (Table I). Early stabilization of fractures in "patients at risk" was never advocated by authors of early total care studies[1,15]. Early fracture fixation in these "patients at risk" (Table I) is associated with a potential for higher complication rates. The need for fracture stabilization in these patients combined with the need for less physiologic stress when stabilizing the skeleton led to the introduction of damage control orthopaedics, in which external fixators are placed across long-bone fractures for temporary stabilization (Fig. 1)[16-19]. These "patients at risk" could be treated in a temporizing fashion while still maintaining stability of the fracture, allowing potential mobilization of the patient. Pape et al. popularized and prospectively studied the use of damage control orthopaedics with temporary external fixation for stabilization of the musculoskeletal injuries in "patients at risk" or patients in extremis ("at the point

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TABLE I Definition of ''Patient at Risk''

Multiply injured patient with ISS of >20 and thoracic trauma
Multiply injured patient with hemorrhagic shock (initial systolic blood pressure of <90 mm Hg)
Bilateral pulmonary contusion
Initial mean pulmonary artery pressure of >24 mm Hg

of death")[20,21]. These "patients at risk" require aggressive resuscitation with hemorrhage control and need to be reevaluated and monitored closely as their physiologic state can rapidly change. If they are stabilized with good oxygenation and good urinary output and the end points of resuscitation have been achieved, it is safe to proceed with definitive stabilization of the long-bone fractures in the operating room[1,19]. If, however, the patient remains unstable or has fluctuation of the vital signs (i.e., is a transient responder to shock treatment), then damage control orthopaedics should be performed.

Over this past decade, it has been shown that stable, multiply injured patients with musculoskeletal injuries can safely receive definitive treatment of long-bone fractures very soon after their injury (early total care)[22]. In contrast, a patient in extremis, or who is hemodynamically unstable or has impaired oxygenation, should have temporizing early stabilization with external fixators (damage control orthopaedics). Prospective and randomized studies have shown that the "patient at risk" who can be stabilized can also be safely treated with definitive intramedullary nailing of femoral fractures or be treated with external fixation (the damage control approach)[20,21]. However, one must be careful not to apply the damage control concept to stable patients or to "patients at risk" who could be potentially treated with early total care. It has been shown that stable patients who undergo external fixation instead of definitive treatment of a femoral fracture have an unnecessary delay in definitive treatment, with a longer stay in the intensive care unit, a longer duration of ventilator use, longer hospitalization, and an increase in the cost of care[23]. It therefore is advantageous to the patient to undergo definitive treatment whenever it can be safely performed.

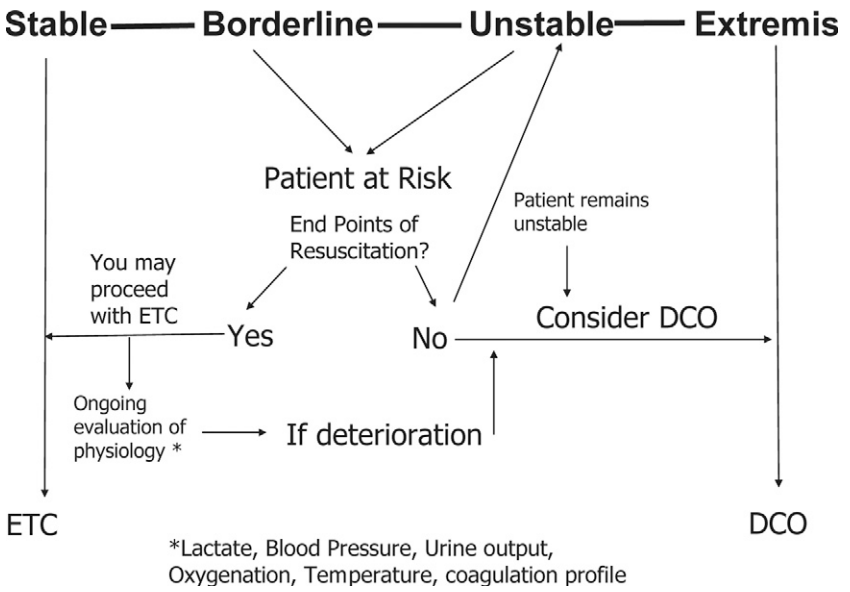

Fig. 1

The condition of a trauma patient on admission can range from hemodynamically stable to in extremis—i.e., in the process of dying. The stable patient is best managed with early definitive stabilization of the fractures (early total care [ETC]). The patient in extremis requires rapid temporary stabilization with external fixation. A ''patient at risk'' is a patient with a higher Injury Severity Score (ISS), an initial systolic blood pressure of <100 mm Hg, a lactate level of >2.5 mmol/L, and associated chest and abdominal injuries. These patients need aggressive resuscitation, and if they can be stabilized with fluid and blood replacement and ventilatory assistance definitive stabilization can be done. If they do not stabilize, they require damage control orthopaedics (DCO). The unstable patient, defined as one who remains hypotensive but who also may have hypothermia, coagulation abnormalities, and decreased oxygenation, needs constant reassessment, aggressive resuscitation, warming, and improvement of the coagulation profile. If this can be achieved in a timely fashion, the patient may also have definitive surgery. If not, then damage control stabilization is required. The grade of recommendation for the treatment strategy presented in this figure is B.

Despite these advances in our understanding of patient management, it is still unclear how to best treat a patient with multiple injuries and pulmonary contusion or one with bilateral femoral fracture.

Pulmonary Injury and Contusion

Pulmonary injury/contusion is one of the most important factors contributing to increased morbidity and mortality of patients with multiple injuries and thoracic trauma and is the most common intrathoracic injury encountered in a patient who has sustained nonpenetrating chest trauma[24]. The presence of pulmonary contusion is a good independent predictor of the development of ARDS and pneumonia[25,26].

Pulmonary contusion leads to alveolar hemorrhage and pulmonary parenchymal destruction. Clinical symptoms, including respiratory distress with hypoxemia and hypercarbia, peak at about seventy-two hours after injury and can last as long as seven to ten days. Management of pulmonary contusion is primarily supportive. The use of kinetic therapy (a prone-oscillating bed) appears to be advantageous[27].

Recently, the strategy of lung recruitment, or the open lung concept, has gained popularity for the management of pulmonary contusion[28]. This concept refers to the dynamic process of opening previously collapsed lung units by increasing transpulmonary pressure. The goal of the open lung concept is to have little or no atelectasis in the mechanically ventilated lung and to generate gas exchange that is as close to optimal as possible for the individual patient. Several studies have shown that a recruitment maneuver (opening previously collapsed lung units by increasing transpulmonary pressure) applied at an early state of severe lung injury can dramatically improve oxygenation, recruit lung tissue by reducing the number of collapsed alveoli, and maintain the newly recruited lung tissue[29,30].

Bosse et al. performed a retrospective study comparing the management of femoral fractures associated with chest injuries, femoral fractures without chest injuries, and chest injuries without an associated femoral fracture[31]. The femoral fractures were treated with an intramedullary nail or plate fixation. Two hundred and seventeen patients with thoracic injuries underwent acute primary intramedullary nailing, while 206 patients with thoracic injuries underwent plate fixation. The investigators found no differences in the rates of ARDS between these methods (118 of the 217 and 114 of the 206 developed ARDS). On the other hand, the rate of ARDS in patients who had sustained thoracic trauma without a femoral fracture was 6% to 8% (eight of 129 to ten of 125), and the rate in those with thoracic trauma and a femoral fracture was 2% (ten of 453).

Turchin et al. compared the outcomes in patients who had isolated pulmonary contusion with those in patients who had pulmonary contusion and musculoskeletal injury[32]. They found no difference in the number of days of ventilator use or the number of days in the intensive care unit or of hospitalization between the two groups of patients. The patients with a femoral fracture had acute intramedullary nailing (early total care). The investigators found that the overall prevalence of pulmonary complications was not increased in patients with a femoral fracture, nor was the mortality increased. The investigators concluded that the morbidity and mortality of patients with pulmonary contusions were due to the pulmonary contusions alone and were not increased by the presence of a femoral fracture or the method of operative treatment of the femoral fracture[32]. Additional evidence supporting the concept that the pulmonary contusion, and not the femoral fracture treatment, leads to ARDS was demonstrated by retrospective studies by one of us (L.B.B.) and colleagues[33], van Os et al.[34], and Charash et al.[35]. The limiting factor for a favorable outcome is the percentage of the lung parenchyma that is injured and the degree of residual compensation in the uninjured lung. Other important factors that have not been analyzed but also play an important role are the extent of intramedullary femoral reaming, the type of fracture, and the presence of preexisting respiratory comorbid conditions.

The Canadian Orthopaedic Trauma Society examined the question of whether the use of unreamed nailing would reduce the risk of ARDS in the multiply injured patient in a prospective, randomized, multicenter study. The investigators found that patients requiring intramedullary nailing have low rates of ARDS and mortality. They also noted no detectable difference in the rate of ARDS between patients with and those without femoral reaming[36].

Several experimental studies of animals have been done to examine the effect of femoral fracture fixation in a thoracic injury model. Wozasek et al. studied the pulmonary reaction during fracture management with an intramedullary nail in a sheep model of traumatic shock[37]. There was no difference in the pulmonary hemodynamic response among groups treated with reamed nailing, unreamed nailing, or plate fixation of the femoral fracture, suggesting that intramedullary nailing, even with reaming, has no detectable effect on the hemodynamics of the lung. This study corroborated the clinical experience that acute reamed intramedullary nailing of the femur is a safe procedure when performed in a patient whose cardiovascular function is stable, even if there has been a thoracic injury. Similar conclusions were made in other animal studies[38,39].

Taken together, these studies suggest that acute reamed intramedullary femoral nailing is safe as long as cardiovascular and hemodynamic functions are stable and the patient is well oxygenated during the procedure (Fig. 2). It is clear that unstable patients do not tolerate the additional physiologic insult caused by acute primary nailing of a femoral fracture.

In an investigation by Pape et al., 121 stable patients and forty-four "patients at risk" were randomized to receive intramedullary nailing (early total care) or external fixation (damage control orthopaedics)[21]. Comparison of the damage control orthopaedics and early total care groups showed very little difference other than a slight increase in the number of hours in the intensive care unit and on ventilator support in the damage control orthopaedics group. In the early total care group, there was a fivefold increase in acute lung injury in the "patients at risk"; however, this did not lead to a significant increase in ARDS, systemic inflammatory response, or multiple organ

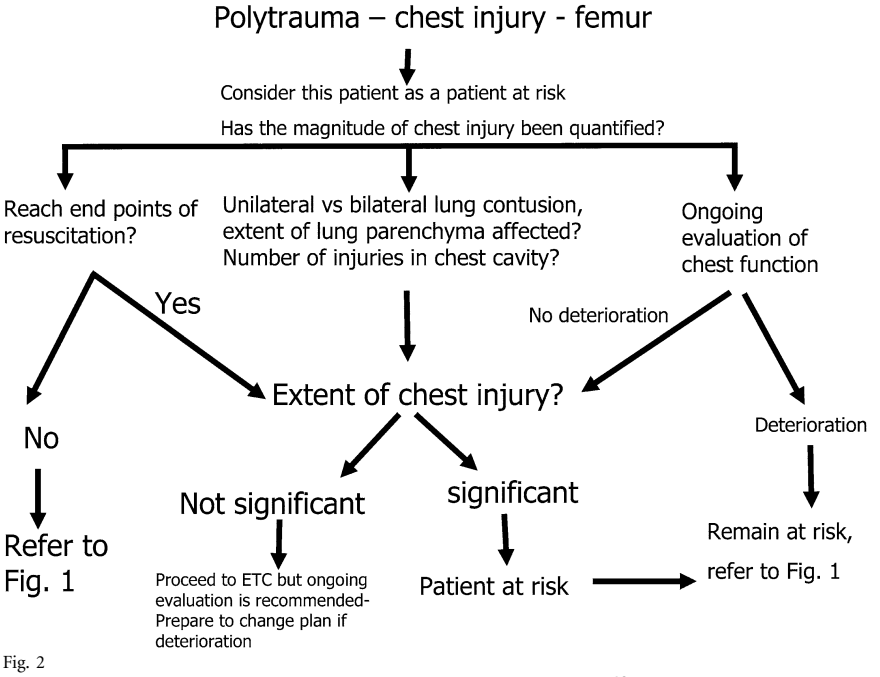

Fig. 2

Any patient with a chest injury with an AIS (Abbreviated Injury Scale[46]) score of ≥2 and a femoral fracture should be considered a patient at risk. A computed tomography (CT) scan of the chest should be performed to quantify the extent of chest involvement. If the patient can reach a satisfactory end point of resuscitation with stable blood pressure, adequate oxygenation, and a reduced lactate level, he or she may proceed to definitive early total care (ETC) but will require ongoing evaluation. If the patient cannot reach an adequate end point of resuscitation, he or she is considered an unstable patient and requires the damage control approach. If the extent of the chest injury is shown to be substantial by magnetic resonance imaging evaluation—i.e., >25% of the lung is injured—the patient is at substantial risk and should have damage control orthopaedics. Throughout the resuscitation period, and any surgical intervention, the chest injury needs ongoing evaluation. If no deterioration occurs, then definitive stabilization can proceed. If lung function deteriorates, then the patient becomes ''at risk'' and requires damage control orthopaedics. The grade of recommendation for the treatment strategy presented in this figure is B.

failure. The investigators determined that both external fixation and intramedullary nailing can be safely done in a stable "patient at risk."

One important question is how to manage a patient who has bilateral femoral fracture. It is well recognized that reaming of the intramedullary canal or unreamed nailing leads to embolization of bone marrow content. This has no clinical importance for a well-hydrated stable patient; however, it can lead to pulmonary failure in a hypovolemic patient. It is also recognized that intramedullary nailing of fractures of both femora leads to a doubling of this bone marrow embolization, placing the patient at greater risk for pulmonary failure. The content of fat in the femoral shaft of a young adult has been estimated to be approximately 152 g[40]. It is possible that, with bilateral femoral reamed nailing, as much as 300 g of fat may embolize into the venous circulation and exert a substantial burden on the already traumatized lung.

An investigation of the effect of bilateral intramedullary nailing of the femur and tibiae in a sheep model showed no clinical effect in stable hydrated animals[41]. However, we are not aware any published animal or clinical study on the effect of bilateral intramedullary nailing of the femur in a patient with pulmonary contusion.

It has been well documented that bilateral femoral fracture is associated with substantial morbidity and mortality[42,43]. In a recent study of complications following bilateral femoral fracture stabilized with intramedullary nailing in the clinical setting, Stavlas et al. reported a 4% prevalence of fat embolism (six of 143), a 15% prevalence of ARDS (twenty-one of 143), and an overall mortality rate of 6% (twelve of 197)[44]. The authors concluded that the increased rates of mortality and systemic complications in patients with bilateral femoral fracture who are treated with intramedullary nailing make this injury a life-threatening one.

Overview

On the basis of all of the clinical evidence and findings from animal experiments, it appears that bilateral femoral fracture in a

hemodynamically stable patient can be safely managed with intramedullary nailing, but it is critical that the oxygenation and hydration of the patient be closely monitored during the initial nailing to be sure that the patient is still stable enough to undergo the second nailing in the same operative setting. Individual management is needed for those rare patients who have bilateral femoral fracture and pulmonary contusion. When patients are well oxygenated, even if they have a pulmonary contusion, either bilateral external fixation or, preferentially, intramedullary nailing of one of the femora and external fixation or plate fixation of the other may be performed. External fixation should be performed instead of intramedullary nailing for any patient who is not well oxygenated, regardless of whether he or she has an isolated or bilateral femoral fracture (Fig. 3).

In conclusion, the vast majority of patients with a femoral fracture who have an ISS of ≥18 are stable and can undergo immediate intramedullary nailing of the femoral fracture without undue risk. Patients who are unstable after resuscitation or who are in extremis should undergo temporary stabilization of the long-bone fracture with external fixation. A patient with a femoral fracture, an ISS of ≥18, and substantial lung injury who is hemodynamically stable, does not have hypothermia, and is well oxygenated and whose lactate level can be brought down to the 2.2 mmol/L range can also be safely treated with acute intramedullary femoral nailing[45].

The advantage of definitive stabilization is that the patient can be mobilized more quickly. This has been shown to improve lung function because an upright position is better for ventilation and oxygenation. The disadvantage is that this surgery may be poorly tolerated by an unstable patient. A certain percentage of multiply injured patients should not have acute intramedullary fixation of a femoral fracture. Temporary stabilization with external fixation can greatly reduce the second surgery insult in these patients. Those patients who are

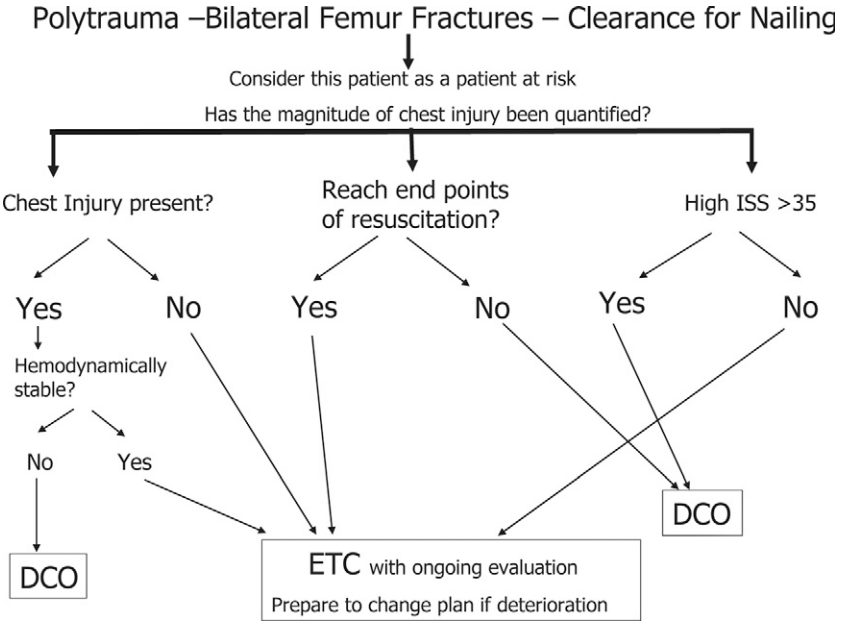

Fig. 3

The multiply injured patient with bilateral femoral fracture should be considered a ''patient at risk.'' If this patient has a chest injury, the chest injury needs to be quantified with a magnetic resonance imaging study. If there is no chest injury, and the patient is hemodynamically stable, early definitive treatment of the femoral fractures can be performed. If a chest injury is present but is not substantial, and the patient is hemodynamically stable, definitive stabilization may be performed. If the patient is hemodynamically unstable or has a substantial chest injury—i.e., if >25% of the lung is injured—damage control orthopaedics (DCO) should be performed. If a patient without a chest injury reaches a satisfactory end point of resuscitation and remains stable, definitive stabilization of the femoral fractures can be performed. If the patient remains unstable and cannot be adequately resuscitated, then the damage control approach is used. In a ''patient at risk,'' with an ISS of >35, damage control orthopaedics should be performed on the femoral fractures because of the associated injures. If early total care (ETC) is performed, ongoing evaluation of the physiologic state of the patient is necessary, with one prepared to change from definitive stabilization to temporizing stabilization if the patient's condition deteriorates. The grade of recommendation for the treatment strategy presented in this figure is B.

stable enough for intramedullary nailing should have definitive treatment within the first twenty-four hours. This reduces the time in the intensive care unit, time on ventilation support, days of hospitalization, and necessity for a second operative procedure. However, patients who are unstable need to be closely evaluated and closely monitored to be sure that they can safely undergo definitive fixation. Any patient who is hemodynamically unstable, has coagulation abnormalities, is hypothermic, or is oxygenating or ventilating poorly should not undergo definitive intramedullary fixation until his or her general condition is stabilized. Instead, he or she should have temporary fracture fixation, followed by definitive fixation once their condition has been optimized. ■

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