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Is the Timing of Fracture Fixation Important for the Patient with Multiple Trauma?

Mark A. Reynolds, M.D.,* J. David Richardson, M.D.,* David A. Spain, M.D.,* David Seligson, M.D.,† Mark A. Wilson, M.D.,*and Frank B. Miller, M.D.*

From the Departments of Surgery and Orthopedic Surgery,† University of Louisville School of Medicine, Louisville, Kentucky*

Objective

The effect of timing of femur fracture fixation for patients with multiple trauma was studied to determine the effect of operative timing on eventual outcome.

Methods

The relationship between timing of intramedullary rod (IMR) placement, degree of injury, and pulmonary complications was studied in 424 consecutive patients. The authors focused on 105 patients undergoing IMR placement with an Injury Severity score (ISS) of greater than or equal to 18. The effects of timing of IMR placement on various pulmonary complications, organ failure, intensive care unit (ICU) admission, and ventilatory assistance were studied for various time intervals.

Results

Of the 424 patients, pulmonary complications increased slightly in the more seriously injured group (ISS > 18) but were not influenced by the timing of IMR placement. Of the 105 patients undergoing IMR placement with an ISS ≥ 18, only 2 patients died. Both patients had an IMR placed in less than 24 hours and died later of head injury and delayed hemorrhage. The incidence of organ failure, number of ventilator days, and length of ICU stay did not differ between the groups based on timing of fracture fixation. The incidence of severe head injuries was higher in the group undergoing delayed IMR placement (>48 hours).

Conclusions

Modest delays in IMR placement did not adversely affect patient outcome. Pulmonary complications were related to the severity of injury rather than to timing of fracture fixation. In a well-integrated trauma system, clinical judgment regarding the timing of IMR placement was the most important determinant of outcome. Delays that were made to stabilize the patient, treat associated injuries, and plan orthopedic reconstruction did not adversely affect patient outcome.

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Address reprint requests to J. David Richardson, M.D., University of Louisville, Department of Surgery, Louisville, KY 40292.
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Blunt multiple trauma is a major cause of death and permanent disability. The patients most affected by such injuries are those in their most productive years, thus the combination of medical care expense and lost earnings leads to enormous societal costs. The effective treatment of the multiply traumatized patient has been the driving force behind trauma center development with an integrated team approach to care. The efficient prioritization of the care provided in this situation is mandatory. Until recently, prompt fracture management was not a priority of care.

Until the past decade or so, patients with fractures of the femur and other major long bones were often treated by traction and delayed fixation. These injuries were considered less critical to overall outcome. However, there exists a large body of evidence indicating the inappropriateness of this approach. The prompt fixation of femoral shaft fractures (i.e., within the first 24 hours) has been associated with, and is believed to result in, a significant reduction in the incidence of pulmonary and septic complications, lower mortality, decreased length of stay in the intensive care unit (ICU), and fewer days of mechanical ventilation.[1–6] This is thought to be a result of improved pulmonary mechanics due to decreased pain, increased mobility, and elimination of a potential source of continued injury and persistent cytokine release. Many major centers have a policy of fixation of all long-bone fractures within 6 to 12 hours of hospital admission and certainly within 24 hours.

Increasing evidence, however, reveals that immediate fracture fixation (<24 hours) is not always appropriate or necessary. Pooled data from a statewide trauma registry in North Carolina suggested that immediate fracture fixation for the patient with multiple trauma may result in increased mortality,[7] although the causes of those findings were not elucidated. A study from Germany indicated that immediate fixation in a case involving severe thoracic trauma may result in an increased incidence of pulmonary morbidity in the form of adult respiratory distress syndrome (ARDS).[8] Others have shown that immediate fixation for the patient with an isolated femoral fracture does not improve outcome and is more expensive.[9]

Our unit has not been dogmatic in its efforts to achieve osteosynthesis of femur fractures within the first postinjury day in polytrauma patients; instead we often allow a few days to pass to stabilize other injuries. This has allowed us to compare our experience with a variable schedule for femur fracture fixation based on surgical judgment with those series in which very early fixation was mandated. We reviewed our results of fracture fixation in two groups of patients with multiple injuries to determine the effect of delayed fixation on pulmonary complications and the effect of associated injuries on the timing of fracture fixation and occurrence of significant morbidity. We were interested in two questions: (1) Was there increased morbidity or untoward outcome resulting from a modest delay of a few days before fixing femur fractures? and (2) Were there serious physiologic derangements observed after fracture fixation in patients with other associated injuries, regardless of the timing of fixation?

MATERIALS AND METHODS

We analyzed the outcomes of all patients hospitalized at the University of Louisville from 1983 to 1994 who had a discharge diagnosis of femoral shaft fracture treated by intramedullary rod (IMR) placement during the same admission. Abbreviated Injury scores (AISs) were determined for various body sites. Injury Severity scores (ISSs) was determined from discharge diagnostic codes by standard methodology. Charts and operative logs were examined to determine the date and time of injury, emergency department admission, and placement of IMR for femur fracture fixation.

We treated 879 patients who sustained femur fractures; IMR placement was done for 692 of these patients. We studied 424 consecutive patients undergoing IMR placement to determine the effect of increased injury severity and the timing of IMR placement on pulmonary complications. We determined the effect of severity of injury by comparing the patients with an ISS $\geq$ 18 to those with an ISS below 18.

The charts of 105 patients with extensive polysystem trauma and an ISS $\geq$ 18 were reviewed in detail. The effect of the timing of IMR placement was analyzed regarding the site and severity of trauma, incidence of respiratory failure, ARDS, multiple organ failure, pneumonia, severe atelectasis, mortality, sepsis, days of mechanical ventilation, length of ICU stay, and length of hospital stay. The alveolar-arteriolar gradient was determined as a measure of intrapulmonary shunting at the time of admission and immediately before fracture fixation.

Our trauma unit has not had a rigid protocol mandating early fracture fixation. We have repaired fractures within the first few hours if patients' other injuries were stable or were able to be treated satisfactorily. We have generally delayed IMR placement if the patient had a prolonged resuscitation, was poorly resuscitated as evidenced by lingering base deficit or excess serum lactate level, or was hypothermic or coagulopathic. We often delayed IMR placement for patients with significant intrapulmonary shunting. Additionally, certain injuries, such as closed head injuries with Glasgow Coma Scores less than 8, chest injuries (e.g., pulmonary contusions), or severe pelvic fractures, often resulted in delayed IMR placement. If the patient has been in the operating suite for a prolonged period for repair of other injuries, we often defer IMR placement. If IMR placement cannot be done within 18 hours, we occasionally delay it for a few days to avoid additional trauma during the period of maximum inflammatory response (18–36 hours).

Groups

For the initial analysis, patients were divided into seven groups on the basis of timing of IMR placement, as follows: within the first 6 hours, second 6 hours, 12 to 24 hours, 24 to 48 hours, 48 to 72 hours, 4 to 6 days, and ≥ 7 days. To facilitate statistical analysis, we combined these groups into three cluster groups: IMR placement in the first 24 hours (n = 35), between 24 and 48 hours (n = 12), and after more than 48 hours (n = 58).

Definitions

Pulmonary Failure. Pulmonary failure was defined as ventilatory failure requiring mechanical ventilation for 3 or more days and/or tracheostomy. Adult respiratory distress syndrome was defined as (1) the need for mechanical ventilation for more than 3 days; (2) PaO_2 below 250 mm Hg with fraction of inspired oxygen of 100%; (3) intrapulmonary shunting greater than 25%; and (4) diffuse pulmonary infiltrates on chest radiograph.

Multiple Organ Failure. This was defined as failure or profound dysfunction in three or more systems, as follows: Central nervous system: Glasgow Coma Score of < 8; respiratory: pulmonary failure or ARDS; cardiovascular: cardiogenic shock requiring inotropic support or persistent arrhythmias requiring management; hepatic: hyperbilirubinemia count above 5.0; gastrointestinal: presence of stress bleeding requiring transfusion or operative intervention; renal: persistent azotemia; systemic: persistent systemic inflammatory syndrome or persistent and recurrent sepsis.

Pneumonia. Pneumonia was diagnosed as the presence of two or more of the following criteria: fever above 38 C., leukocytosis, purulent sputum, positive sputum cultures, and discrete infiltrate on chest radiograph. Severe atelectasis involved collapse of a lung, lobe, or segment, necessitating bronchoscopy. Pulmonary contusion was defined as persistent intrapulmonary shunting associated with thoracic injury and development of discrete pulmonary infiltrates within 24 hours of admission.

Statistical Analysis

The significance of variance of continuous variables was assessed with an analysis of variance (Tukey's HSD). The significance of the distribution of discrete variables was assessed with Pearson's chi square test for univariate comparisons and with stepwise logistic regression for multivariate comparisons.

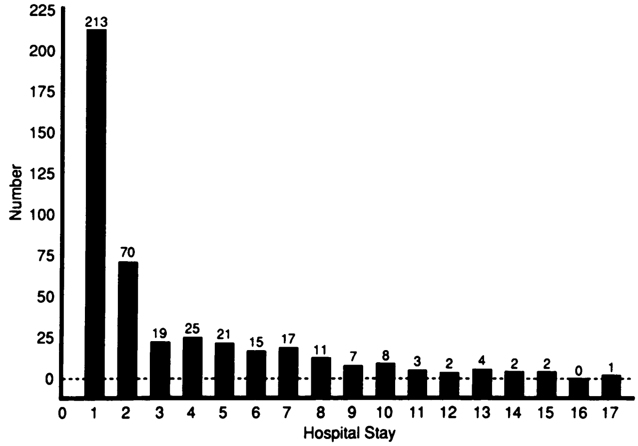

Figure 1. Pulmonary complications and timing of femoral shaft fracture fixation. The day of fracture fixation is shown for 424 patients. Half of the patients received IMR placement within 24 hours. About 10% of patients did not have IMR placement until about 7 days after injury.

RESULTS

The timing of fracture fixation by IMR placement in the 424 consecutive patients is shown in Figure 1. Approximately half of the patients underwent IMR placement within the first 24 hours, and the remaining patients were stabilized at various time intervals. Forty patients had IMR placement delayed for more than 7 days. The effect of severity of injury, as indicated by comparing patients with an ISS of below 18 to those with a score ≥ 18, and the timing of IMR placement is shown in Figure 2. For patients with an ISS below 18, we observed a gradual but statistically insignificant rise in pulmonary complications with progressive delay in IMR placement. For patients with an ISS ≥ 18, no relationship was found between pulmonary complications and timing of IMR placement. In fact, incidence of pulmonary complications was slightly higher in patients who received IMR placement within 24 hours, but the difference was not significant. The marked increase in incidence in pulmonary complications in patients with ISS scores above and below 18 suggests that the severity of injury rather than the timing of fracture fixation determines adverse pulmonary outcome.

When the 105 patients with an ISS ≥ 18 were examined in seven different time intervals, no outcome trends based on timing of IMR placement could be detected. These patients were therefore compared by the timing of fracture fixation within three cluster groups: less than 24 hours, 24 to 48 hours, and 48 hours or more. The patient groups were not comparable in terms of severity of overall injury and with respect to major injuries to important areas, such as the chest and head. The ISS was higher for those undergoing fixation after more than 48 hours

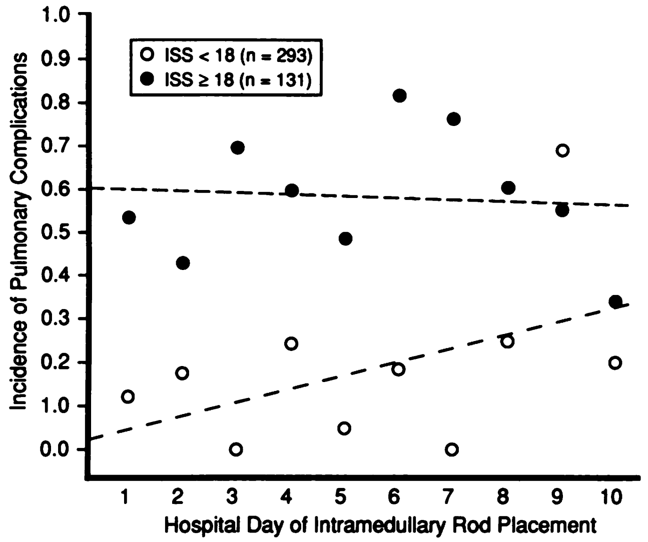

Figure 2. IMR placement fixation of femoral shaft fractures for all patients (n = 424). The incidence of pulmonary complications was influenced by increased ISS. For those with lesser injuries (ISS < 18), there was a trend toward higher pulmonary complications with delayed fixation. For patients with higher ISSs (>18), there was no such relationship, and outcome was unrelated to the timing of IMR placement.

compared with those undergoing IMR placement in less than 24 hours (34.4 *vs.* 27.4). The AIS for the head was higher in the delayed group compared with the group undergoing early fixation (2.36 *vs.* 1.96, respectively; $p < 0.05$) (Table 1). The remaining components of the ISS, including the thoracic components, did not differ significantly.

The degree of head injury present in each of the treatment groups is shown in Table 2. A significant difference in the scores was obtained on the Glasgow Coma Scale between those having IMR placement in the first 24 hours *versus* those having fracture fixation after more than 48 hours (13.3 *vs.* 8.6, respectively; $p < 0.05$). There was a greater change in the Glasgow Coma Score in those undergoing delayed fixation, thus indicating the dynamic nature of the closed head injuries in this group of patients. Skull fractures occurred more often in those having IMR placement after more than 48 hours (14.3 *vs.* 31.6%), although this difference was not statistically significance.

Although the AIS for thoracic injuries showed no difference between the three treatment groups, there was a much higher incidence of major pulmonary injuries among those patients undergoing fracture fixation after more than 48 hours compared with the patients who had IMR placement in the first 24 hours. The percentage of patients with thoracic injury was greater (61.4 *vs.* 37.1, late *vs.* early), and the incidence of pulmonary contusion was much higher in the delayed treatment group (Table 3). The incidence of rib fractures and hemothorax was identical, and there was a higher incidence of pneumothoraxes in the delayed IMR placement group (24.6 *vs.* 14.3%). The difference in overall thoracic injury and pulmonary contusion just failed to reach statistical significance.

The alveolar-arteriolar gradient at admission was higher in the delayed treatment group (224 *vs.* 156) but was identical at the time of fixation between the three groups. The normalization of alveolar-arteriolar gradient was one of the potential benefits of delaying IMR placement for patients with significant intrapulmonary shunting.

The relationship between the timing of IMR placement and pulmonary morbidity is shown in Table 4. The incidence of several adverse pulmonary parameters was somewhat higher in the delayed treatment group, but this was not statistically significant. In fact, the incidence of pulmonary complications closely paralleled the fre-

Table 1. SEVERITY OF INJURY *VERSUS* TIMING OF FIXATION

AIS	IMR < 24 hr (n = 35)	IMR 24-48 hr (n = 13)	IMR > 48 hr (n = 57)	Total (n = 105)
Head	1.97 ± 0.25	1.92 ± 0.47	2.36 ± 0.20*	2.20 ± 0.15
Face	1.31 ± 0.14	0.08 ± 0.08	1.14 ± 0.11	1.07 ± 0.08
Thorax	2.11 ± 0.29	1.77 ± 0.50	2.07 ∓ 0.23	2.05 ± 0.17
Abdomen	1.14 ± 0.25	0.08 ± 0.00	0.91 ± 0.18	0.91 ± 0.18
Extremity	3.00 ± 0.00	3.00 ± 0	3.00 ± 0.00	3.00 ± 0
Superficial	0.63 ± 0.15	1.00 ± 0.42	0.53 ± 0.11	0.62 ± 0.11
ISS	27.4 ± 0.96	25.2 ± 1.82	34.4 ± 0.91*	28.7 ± 0.62

Values are mean ± SEM.
AIS = Abbreviated Injury Score; ISS = Injury Severity Score; IMR = intramedullary rod placement.
* $p < 0.05$ (ANOVA) *vs.* IMR < 24 hr.

Table 2. HEAD INJURY *VERSUS* TIMING OF FRACTURE FIXATION

	IMR < 24 hr (n = 35)	IMR 24–48 hr (n = 13)	IMR > 48 hr (n = 57)	Total (n = 105)
Glasgow Coma Score (Admission SEM)	13.3 (0.93)	14.8 (0.45)	8.6 (0.83)*	10.6 (0.70)
Glasgow Coma Score (Change from baseline SEM)	0.78 (0.36)	0.20 (0.45)	3.22 (0.60)†	2.22 (0.44)
Skull fracture (%)	14.3	23.1	31.6	20.9
Facial fracture (%)	25.7	15.4	21.1	21.9

Values are mean (with SEM in parentheses).
IMR = intramedullary rod placement.
* $p < 0.05$ (ANOVA) *vs.* IMR < 24 hr.
† $p < 0.05$ (Pearson's chi square) *vs.* IMR < 24 hr.

quency of initial thoracic injury. There was no significant difference in the incidence of diagnosis of pneumonia, sepsis, or positive blood cultures.

No statistically significant association was found between timing of IMR placement and any measurable outcome. The only significant association we could detect was between the presence of head injury in the delayed IMR placement group and the need for prolonged ventilatory assistance. This reflects the severity of the intracranial lesion rather than the effect of delayed bone fixation.

Despite a higher incidence of pulmonary problems in patients undergoing delayed IMR placement, timing of osteosynthesis on eventual outcome had little effect (Table 5). The only significant difference in outcome was an increased length of stay in the delayed IMR placement group, which appeared to reflect overall severity of injury rather than time of fracture fixation. The length of hospital stay after fracture fixation was identical for the early and delayed fixation groups. The difference in length of stay was a function of longer prefixation times in the delayed group. The necessity for ICU admission and mechanical ventilation on admission was higher in the delayed group, indicating a more serious initial injury; however, there was no difference in the number of days of mechanical ventilation required or length of stay in the ICU.

Two deaths occurred out of the entire group of 105 patients (1.9%). Both patients who died had received IMR placement at less than 24 hours. The first patient died of sequelae of a severe closed head injury several weeks after placement. The other patient died of delayed hemorrhage from a missed subclavian artery injury. This patient had an abnormal mediastinum that prompted aortography. The angiogram showed views of the aorta and major intrathoracic vessels, and the results were interpreted as normal. The patient died of massive hemorrhage 11 days after injury. The injury was not detectable on a retrospective review of the angiogram and was not related temporally to the IMR placement itself. In addition, one patient who had undergone IMR placement developed within 12 hours fat embolism syndrome but recovered with ventilatory support.

We examined the records of the 105 patients to determine whether we could detect harm done by the IMR placement itself. Ten patients appeared to have suffered

Table 3. CHEST INJURY *VERSUS* TIMING OF FRACTURE FIXATION

	IMR < 24 hr (n = 35)	IMR 24–48 hr (n = 13)	IMR > 48 hr (n = 57)	Total (n = 105)
Thoracic injury (%)	37.1	53.9	61.4	45.7
Myocardial contusion (%)	14.3	0	10.5	10.5
Pulmonary contusion (%)	11.4	23.1	26.3	16.2
Rib fracture (%)	31.4	30.8	24.6	27.6
Pneumothorax (%)	14.3	38.5	26.3	23.8
Hemothorax (%)	11.4	0	7.0	7.6
A-a gradient (admission mmHg)	156	176	224	204

IMR = intramedullary rod placement.

Table 4. PULMONARY COMPLICATION

	Present			Absent			
	N	Mean	SEM	N	Mean	SEM	p Value
Any pulmonary complication							
ISS	60	31.05	1.71	45	25.58	1.03	0.0200
LOS	60	22.52	2.00	45	13.36	1.05	0.0009
Age	60	35.05	2.57	45	29.69	2.17	0.1565
IMR day	60	4.53	0.57	45	4.40	0.96	0.9069
ICU LOS	47	11.60	1.63	22	4.73	0.92	0.0201
Ventilation	42	7.98	1.11	16	3.44	1.14	0.0564
Pneumonia							
ISS	21	30.62	2.18	84	28.23	1.26	NS
LOS	21	31.81	4.34	84	15.29	0.93	0.0001
Age	21	36.48	4.21	84	31.82	1.92	0.4019
IMR day	21	6.39	1.22	84	4.00	0.57	0.1487
ICU LOS	21	15.57	2.40	46	6.71	1.20	0.0028
Ventilation	21	11.10	1.62	37	4.24	0.84	0.0006
ARDS							
ISS	14	42.57	5.47	91	26.57	0.75	0.0001
LOS	14	34.64	4.98	91	16.12	1.10	0.0002
Age	14	34.50	4.45	91	32.48	1.81	0.7676
IMR day	14	4.87	1.08	91	4.42	0.58	0.8230
ICU LOS	14	19.79	3.19	55	6.76	1.02	0.0003
Ventilation	14	13.79	2.07	44	4.48	0.72	0.0002
Respiratory failure							
ISS	36	34.53	2.57	69	25.67	0.80	0.0006
LOS	36	28.69	2.81	69	13.32	0.80	0.0001
Age	36	38.67	3.65	69	29.67	1.77	0.0314
IMR day	36	6.03	0.94	69	3.67	0.61	0.0608
ICU LOS	36	14.89	1.84	33	3.42	0.52	0.0001
Ventlation	36	10.11	1.12	22	1.18	0.14	0.0001
Atelectasis							
ISS	36	30.81	2.20	69	27.61	1.21	NS
LOS	36	22.92	2.66	69	16.33	1.36	0.0347
Age	36	36.67	3.59	69	30.71	1.87	0.1584
IMR day	36	4.50	0.86	69	4.47	0.67	0.9792
ICU LOS	27	13.26	2.53	42	6.93	0.99	0.0181
Ventilation	25	8.28	1.61	33	5.55	0.97	0.1585

ISS = Injury Severity Score; LOS = length of stay; ARDS = adult respiratory distress syndrome; NS = not significant; ICU = intensive care unit.

a potentially adverse outcome related temporally to fracture fixation, in addition to the patient with fat embolism syndrome. Six patients suffered pulmonary setbacks manifested as new or worsening hypoxemia. For three patients, this appeared to be related to atelectasis, and for two, fluid overload with pulmonary contusion was a problem. The cause was unknown in the remaining patient. The adverse outcomes were fairly evenly distributed between the three IMR placement groups, as follows: three in the early IMR placement group, one in the 24-to-48-hour group, and two in the 48-hours-or-more group.

Two patients experienced worsening of head injuries after IMR placement, as manifested by a deterioration of their Glasgow Coma Score. One was in the less-than-24-hour IMR placement group and one was in the 24-to-48-hour group. Two additional patients suffered severe volume depletion that required prolonged postoperative resuscitation. Both of these patients had undergone fixation of multiple fractures in addition to the IMR placement of the femur. One patient was treated in less than 24 hours, and the other after more than 48 hours.

DISCUSSION

Fracture of the femoral shaft is a devastating injury with potentially life- and limb-threatening consequences. The fracture of this robust bone requires high

Table 5. OUTCOME OF PATIENT GROUPS

	IMR < 24 hr (n = 35)	IMR 24–48 hr (n = 13)	IMR > 48 hr (n = 57)	Total (n = 105)
Age	32.7	24.7	34.6	32.8
Sex (M/F)	26/9	8/5	37/20	71/34
Mortality (%)	2 (5.7)	0 (0)	0 (0)	2 (1.9)
Mean hospital LOS (days)	13.7	17.3	21.9*	18.6
ICU admission (%)	62.9	38.5	73.9	65.7
ICU LOS (days)	6.7	21.9	9.4	9.4
Mechanical ventilation (%)	48.6	23.1	66.7	55.2
Ventilation days	4.9	13.0	7.1	6.7

IMR = intramedullary rod placement; LOS = length of stay; ICU = intensive care unit.
* $p < 0.05$ (ANOVA) *vs.* IMR < 24 hr.

energy and is frequently associated with other major injuries. Determination of which injury is responsible for general or systemic morbidity may be difficult but is critical to effective multimodality care.

The treatment of femoral shaft fractures has improved tremendously over the past few decades. The techniques used in traditional nonoperative, conservative management were developed a century ago, when the advent of radiography demonstrated the inadequacy of closed reduction and immobilization. During that era, Buck's traction, the Thomas splint, and skeletal traction were developed to improve anatomic alignment and functional result. These treatment modalities necessitated prolonged bed rest and recumbency and were associated with complications due to prolonged enforced immobility and the lack of an adequate fracture fixation. Complications included fat embolism syndrome, orthostatic pneumonia, deep vein thrombosis, pulmonary embolism, decubitus ulcer formation, severe deconditioning, and acute and chronic pain.

The development of an effective means of immediate anatomic fracture fixation in the 1940s was a major advance. With the technique of intramedullary nailing, stable anatomic reduction could be achieved immediately, greatly enhancing pain control and mobility. The superiority of this modality to traditional nonoperative means of therapy has been demonstrated numerous times over the course of decades.

Riska et al.[1] demonstrated a dramatic decline in the incidence of fat embolism syndrome associated with the increased use of "early" fracture fixation (i.e., within 14 days of injury) and attributed their results to the anatomic stabilization of the fracture and early mobilization. Goris and colleagues[2] demonstrated decreased mortality due to late sepsis in those who were treated with early osteosynthesis and a decreased incidence of ARDS in those who received early fracture fixation and prophylactic positive end-expiratory pressure. Seibel et al.,[3] Johnson et al.,[4] and others[5,6] in studies of patients with multiple trauma, demonstrated the association of early stabilization of femoral shaft fractures with significant reductions in pulmonary morbidity and hospital and ICU length of stay. Application of the principles documented in these studies has greatly helped many trauma patients.

However, none of these studies have proven that these improvements in outcome were an isolated effect of improved treatment of the femoral shaft fracture. In all of these studies, advanced and aggressive care of the fractures was systematically associated with advanced and aggressive care of other associated injuries. It is extremely difficult to separate the accrued benefits to overall patient well-being secondary to early fracture fixation from that which comes from overall vigorous intensive care. In the large group of patients we studied, there was no discernible difference in outcome between those patients who received fracture fixation within 24 hours and those who underwent IMR placement several days after injury. Only hospital length of stay was increased in the delayed IMR placement group, and this finding was related to the strong association with other major injuries, particularly injury to the central nervous system. The outcome of pulmonary complications was strongly associated with the degree of injury but not with the timing of IMR placement.

The complications associated with delayed IMR placement were almost always related to associated injuries. We found no increased pulmonary complications in patients with delayed IMR placement that could not be more readily explained by associated thoracic and cranial injuries. Patients who underwent IMR placement after 7 days tended to have a higher incidence of pulmonary complications. However, this group included only those patients who had extremely severe injuries that could not be stabilized earlier for IMR placement. All of these patients had either major head injuries with elevated intracranial pressure or severe associated injuries requiring prolonged treatment. Thus, we were not surprised that these patients had an increased incidence of pulmonary complications; early IMR placement would be unlikely to prevent pneumonia or pulmonary complications in a patient with severe head injury who could not be mobilized.

The theoretical concerns that the proponents of immediate fracture fixation raise involve the effects of prolonged immobilization, an echo of the era in which fractures were routinely treated with days or weeks of traction. There is no compelling theoretical reason for a fracture to be stabilized immediately *versus* 12 or 24 hours later. Patients with closed head injuries and cerebral edema generally experience worsening edema by 48 to 72 hours. Early fluid administration may be harmful in this group of patients. Our data indicate no untoward outcomes resulting from delay of treatment of up to several days in this group. A femoral shaft fracture cannot be ignored: the phenomenon of acute pulmonary compromise after fracture manipulation is real and potentially lethal.[10] We therefore advocate trusting the surgeon's judgment regarding the timing of IMR placement and believe that a positive outcome in not dependent on a rigid schedule of care demanding early IMR placement.

Recent studies have begun to modify this insistence on immediate fracture fixation. Considerable theoretical evidence shows that IMR placement is associated with the embolization of bone marrow elements that can cause short-lived pulmonary compromise.[10] With modern postoperative care for the otherwise healthy patient, this effect may be trivial; however, in patients with significant and possibly unrecognized pulmonary or cerebral injuries, it may be dangerous. Pape et al.[8] found that immediate IMR placement in patients with severe thoracic injury was associated with increased mortality and pulmonary morbidity. The few researchers[9] who tried to isolate the optimal time for IMR placement found little difference between immediate (<24 hours after injury) and early (24–72 hours after injury) fracture fixation in terms of the incidence of major pulmonary morbidity and hospital and ICU lengths of stay. However, these researchers have demonstrated a trend toward greater mortality in patients who received immediate fracture fixation and significant cost reductions when fracture fixation was delayed for 1 or 2 days.[7,9]

It is difficult to determine in a retrospective review whether early IMR placement is harmful for the polytrauma patient. We observed 11 patients who suffered adverse consequences associated temporally with IMR placement; however, there was no clearly defined relationship between the timing of IMR placement and untoward events that appeared to be caused by the procedure itself. Two patients had worsening Glasgow Coma Scores after early IMR placement. After completion of the current study, we treated a patient who had a mild closed head injury (Glasgow Coma Score, 13) and a midshaft femur fracture. A cranial CT scan showed mild cerebral edema. The patient underwent IMR placement within 8 hours of admission. After surgery, she was unresponsive neurologically; her CT scan showed diffuse cerebral edema and she died of cerebellar herniation within 24 hours. Although the relationship between her neurologic deterioration and IMR placement is unclear, it was certainly temporally related. Whether a delay in IMR placement would have changed the outcome is speculative; nonetheless, this outcome must be attributed at least in part to fracture fixation. Because we delayed IMR placement for most patients with major head injuries, we can only speculate as to how neurologic deterioration after early IMR placement might occur.

Provision of care to a patient who is rendered ventilator-dependent because of major thoracic or closed head injury can be extremely frustrating, but the last decade has seen major improvements in the critical care provided to these patients. Early fracture fixation is one of these improvements. When patients have suffered severe contusions to a large portion of their lungs or a major flail segment or deep coma secondary to major closed head injury, prolonged immobility and ventilatory support is mandated. The consequences of prolonged immobilization (deep vein thrombosis, pulmonary embolism, decubitus ulcer formation, orthostatic atelectasis, and pneumonia), prolonged intubation and ventilation (pneumonia, pulmonary sepsis), and prolonged invasive monitoring (line sepsis, thrombophlebitis) occur in proportion to the duration of treatment, the severity of the injury, and the quality of care. The modern ICU was designed to administer these treatments and to monitor for and treat the complications of therapy as they arise. These problems occur regardless of the presence of major long-bone fractures or early fracture fixation. Femur fractures are an important component of the multiply injured patient's condition but are only one of many extremely important elements of outcome. Therefore, fixation of all long-bone fractures within the first 24 hours is not the primary determinant of outcome for these severely traumatized patients.

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Discussion

DR. ANTHONY A. MEYER (Chapel Hill, North Carolina): I would like to congratulate Dr. Reynolds, Dr. Richardson, and the rest of the group from Louisville for their paper. I agree with the need to reassess some of our more closely held beliefs, such as the universal need for immediate fixation of long-bone fractures and the need for complete axillary node dissection to assess nodal spread of breast cancer.

A recent report from the North Carolina Trauma Registry was mentioned by the authors and cited in the paper. It was a review of data from a statewide population-based set of statistics that allowed us to look at this and break out individuals with an Injury Severity Score greater than 15 and a head Abbreviated Injury Score of greater than 3 and separate femur fractures for either nonoperative management, operation in the first 24 hours, 2 to 4 days, or greater than 4 days.

I agree these are relatively small numbers, but the mortality did not seem to be made significantly worse by waiting for a period of time. Obviously, hospital stay is longer. This is not a prospective randomized study. So I think that taking the time to step back and ask what is necessary and what is appropriate in some of these patients needs to be done. I have two questions I would like to ask the authors to address.

Who made the decision not to have immediate fixation done? Was it done by the trauma service or general surgeon? Was it done by the orthopedic surgeon? Was there input from the anesthesiologists in the operating room at the time? Was there some cooperation or were there any drawn-out battles trying to figure out who should get immediate fixation or not?

Secondly, the A-A gradient is increased as the length of time to fixation increases. Those who were kept for a longer period of time had a higher A-A gradient on admission. That was cited in the paper as being a reason to delay fixation to try to improve that. But what techniques were used to try to improve the A-A gradient? And by the time they went to fixation, how had the A-A gradient improved?

I think that adherence to rigid rules may lead to a situation somewhat analogous to that described in the recently published "The Death of Common Sense," where we make unstable patients worse by continued surgical intervention that could easily be delayed with equal or better outcomes. I think that it is important that we consider everything, but keep each patient an individual rather than get so locked into rules or critical pathways that we do not stop to think what is best for that individual patient.

DR. LEWIS M. FLINT, JR. (New Orleans, Louisiana): I enjoyed this paper. It represents another contribution from the trauma unit at the University of Louisville. The study asks a simple and straightforward question that challenges a long-held belief. I am willing to accept the fact that the exercise of surgical judgment is important in the management of trauma patients, and I have tried to stress this fact. On the other hand, this study covers quite a span of time. It is a little scary to think that the first 2 years of the study were 2 years when I was still at the University of Louisville. Dr. Polk had coal black hair, and a lot of things were different.

That leads to my first question. Were there differences in the clinical presentations or the clinical severity of the patients if you were to, for instance, divide the first half of the decade from the second half of the decade? Are we really benefiting from that much better surgical judgment? Or are the patients benefiting from better critical care, better nutritional support, better ventilator techniques and so on? I guess the question phrased simply is, is this good surgical judgment or simply the evolution of expertise over time?

I think the message from this study and the message from the study in North Carolina is not necessarily that rigid fixation of weight-bearing bones needs to happen in multiple-trauma patients within the first 24 hours, but that nonoperative therapy of fractures of the weight-bearing bones in multiple trauma patients is not a good practice and ought to be essentially abandoned.

The final thing I would want to focus on and ask a question about is the management of the femur fractures in patients with head injuries. You tended to wait longer to do these. Were there many patients with femur fractures and head injuries who did not get fixed at all? We think that fixation of fractures facilitates the care of head injuries. I just ask if you have still the lingering choice on the part of some orthopedic surgeons to not fix fractures in head-injured patients at all.

DR. ERNEST MOORE (Denver, Colorado): I thank the authors for the opportunity to review their excellent manuscript