Resuscitation Before Stabilization of Femoral Fractures Limits Acute Respiratory Distress Syndrome in Patients With Multiple Traumatic Injuries Despite Low Use of Damage Control Orthopedics

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Background: Femoral shaft fractures are associated with acute respiratory distress syndrome (ARDS). The idea that primary intramedullary nailing increases the incidence of ARDS has theoretical support. Our approach to treating femoral fractures in patients with multiple traumatic injuries is to perform reamed nailing after adequate resuscitation has been shown by normalizing lactate plus optimized ventilatory and hemodynamic parameters. Damage control orthopedics (DCO) with primary external fixation usually is reserved for those rare patients who do not respond to resuscitation. Our hypothesis was that this approach yields a low rate of ARDS.

Methods: A prospective trauma database was searched for all femoral shaft fractures treated at a Level I trauma center during a 3-year period, yielding 582 patients. Exclusion criteria included death before treatment (n = 9), age younger than 16 years (n = 16), age older than 65 years (n = 35), fractures that were not amenable to nail fixation (n = 31), shaft fractures treated with a plate (n = 3), patients with bilateral femoral shaft fractures who had a primary nail placed in one femur and an external fixator on the other limb (n = 1), and patients with an Injury Severity Score (ISS) ≤17 (n = 260), leaving 227 patients in the final study group. We defined ARDS as a mean partial pressure of oxygen/fraction of inspired oxygen <200 for 5 or more consecutive days. We compared our results with the results of a similar design in the literature.

Results: Of the 227 patients with ISS >17, only 12% were initially treated with DCO, and 88% were treated with primary reamed nailing. The 227 patients achieved successful early resuscitation as shown by lactate values that decreased significantly on the operative day compared with presenting values ($p < 0.05$). ARDS rates were low, including rates for the subgroup of patients with lung injury (thoracic Abbreviated Injury Scale score >2, n = 175) who were treated with nailing and had an ARDS rate of 2.0% and a death rate of 2.0%. The ARDS rate for the most severely injured patients who underwent nailing (ISS >28, thoracic Abbreviated Injury Scale score >2, n = 78) was only 3.3%, and 1.7% died.

Conclusions: In the context of resuscitation before reamed intramedullary nailing of femoral shaft fractures, our rate of ARDS was lower ($p < 0.001$) than that of a similar study reported in the literature in which the DCO approach was used in up to 36% of patients ($p < 0.001$) and was more in keeping with previously reported rates of ARDS. This remained true despite frequent use of early reamed femoral nailing and infrequent use of DCO. An explanation for the discrepancy between the centers might be differences in preoperative resuscitation or medical care provided to treat shock.

Key Words: Femoral shaft fractures, Intramedullary nailing, Acute respiratory distress syndrome, Damage control orthopedics.

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Femoral shaft fractures and their treatment have been associated with serious respiratory compromise, including acute lung injury and acute respiratory distress syndrome (ARDS),[1] particularly in patients with multiple injuries. Untreated, embolization of fat and marrow contents from the fractured femur can lead to secondary lung injury.[2,3] Although early reamed nailing of femoral shaft fractures in most patients with multiple injuries seems to decrease the incidence of pulmonary complications, ventilatory days, and intensive care days,[2,4–6] some studies have suggested that early reamed nailing in certain "at-risk" patient populations might be associated with an increased risk of secondary pulmonary insufficiency and ARDS.[7,8] Damage control orthopedics (DCO) with delayed nailing deferred until after adequate restoration of physiologic stability has been described as a method of mitigating the risk of secondary lung injury associated with the fracture while minimizing the risk of secondary lung injury from reamed nailing.[9–13]

The concept that primary intramedullary nailing can contribute to the development of ARDS has theoretical support.[14] It is known that fat can be embolized to the lungs any time the femoral canal is instrumented, whether in the context of arthroplasty[13] or reamed nailing.[15–18] Therefore, it has been postulated that femoral nailing can worsen pulmonary function, particularly in patients who already have lung injury.

Although animal studies have shown that reamed nailing seems to deleteriously affect pulmonary function[17,19–22] and case series have shown increases in inflammatory markers,[23–26] clinical evidence has been less convincing.[2,3,8] Some authors have argued that femoral nailing in patients with lung trauma leads to high rates of ARDS,[7,27,28] particularly if reaming is performed.[8,28] Other authors have argued that

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traumatic pulmonary insult and not treatment of the femoral fracture seems to dictate pulmonary outcome[29–31] and that intramedullary nailing in patients with pulmonary injury generally is safe.[32–36] Further, a study comparing plate with reamed nail fixation in patients failed to show a higher incidence of respiratory difficulty in the nail group.[37]

Prolonged shock, as defined by failure to achieve lactate clearance in a timely fashion after severe injury, also has been associated with increased pulmonary capillary membrane permeability, acute lung injury, ARDS, and death.[38–44] One explanation for the increased risk of ARDS associated with reamed femoral nailing in patients with multiple traumatic injuries is that the lungs have been primed for secondary injury by the initial injury to the capillary endothelium associated with shock from systemic injuries. In this scenario, the embolization of fat and marrow contents during intramedullary instrumentation might be synergistic to the initial injury associated with shock alone.

DCO has emerged as an approach to stabilize femoral fractures in a timely manner while avoiding potentially detrimental insult to the lungs and the overall inflammatory response that is associated with primary reamed nailing.[9,11,13] With the DCO model, a subset of patients with multiple traumatic injuries and femoral fractures who are considered to be at particularly high risk for development of pulmonary complications are selected and are treated first with an external fixator and then secondary conversion to intramedullary nailing deferred until appropriate restoration of physiologic stability.[13,45] It remains unclear which patients require DCO and which patients can safely be treated with primary reamed nailing.

Some authors have reported relatively high rates of ARDS and multisystem organ failure in patients with multiple traumatic injuries, despite frequent use of DCO.[27] Considering that DCO is intended to lower the incidence of ARDS and death,[46,47] it is possible that the rates of ARDS and death would have been even higher if DCO had been used less often. However, these studies contrast with others that show lower rates of ARDS.[37]

Our approach to treating femoral fractures in patients with multiple traumatic injuries is to perform reamed nailing after adequate resuscitation has been shown by normalizing lactate plus optimized ventilatory and hemodynamic parameters. We attempt to perform femoral nailing within 24 hours of injury when possible. DCO with primary external fixation is reserved for those rare patients who remain physiologically unstable despite aggressive initial resuscitation. Our hypothesis was that this approach yields a low rate of ARDS, even though relatively few of our patients are treated with DCO.

PATIENTS AND METHODS

Inclusion Criteria

After obtaining approval from our institutional review board, we searched our trauma database for all femoral shaft fractures treated at our institute between October 1, 2002, and September 30, 2005, yielding 582 patients. Exclusion criteria included death before treatment (n = 9), age younger than 16 years (n = 16), age older than 65 years (n = 35), and fractures that had been operatively treated at another institution or that were judged not to be amenable to intramedullary nail fixation (n = 31), leaving 491 patients with 524 fractures. Then, we excluded patients who had fractures that could have been treated with nailing but were treated with plating (n = 3), leaving 488 patients with 521 fractures. We next excluded any patient with bilateral femoral shaft fractures who had a primary nail placed in one femur and an external fixator on the other limb (n = 1), leaving 487 patients. Finally, we excluded all patients with Injury Severity Score (ISS) ≤17 (n = 260), leaving the final study group of 227 patients with 249 fractures.

Descriptive Parameters

Our trauma database included the following data points: age, ISS, Abbreviated Injury Scale (AIS) score, and disposition. All arterial blood gas (ABG) values obtained at admission were recorded from the electronic medical records. The ABG values included the partial pressure of oxygen (PaO_2), the fraction of inspired oxygen (FiO_2) when the ABG was drawn, and the time and date the sample was drawn. All lactate values for each patient, along with the time the lactate was drawn, were also recorded from the electronic medical records. We recorded the presenting lactate value, the last lactate value measured before the start of the surgical procedure, and the lowest lactate value obtained on the day of surgery. The date and time of each patient's admission to the trauma center also were recorded. Because of the retrospective nature of the study, it is unknown how many of the patients in this series had pelvic binders applied in our emergency department. However, we recorded the number of unstable pelvic ring fracture patterns defined as Young-Burgess fracture types anterior-posterior compression II, anterior-posterior compression III, lateral compression II, lateral compression III, and vertical shear, as detailed in Table 1.

Treatment Groups

All operative notes were reviewed for all patients. Patients were then segregated into two groups: those whose femoral fractures were treated with primary reamed intramedullary nailing and those whose fractures were treated with initial external fixation and then planned delayed conversion to intramedullary nailing. A small group of patients had fractures that could have been treated with nailing but were treated with plate fixation. That group was small (n = 3) and beyond the scope of our research question and was thus eliminated from analysis. Operating room logs were reviewed to determine the time and date of each surgical procedure.

Outcome Measures

We recorded two primary outcome measures: death and ARDS. Death during the primary hospitalization was documented in the trauma database. We calculated the occurrence of ARDS by using the two criteria discussed below. A secondary outcome measure recorded was length of stay in the intensive care unit.

TABLE 1. Patient Descriptive Parameters for Two Treatment Groups With Femoral Fractures and Injury Severity Scores >17

	Primary Nailing (n = 199)	DCO (n = 28)
Age (yr)	30.5	26.9
ISS	27.4	36.2*
Presenting SBP (mm Hg)	130.6	109.2*
Percentage of patients with SBP <90 mm Hg	10.6%	32.1%*
Presenting HR (beats/min)	101.6	120.1*
Presenting RR (breaths/min)	18.6	16.6
Presenting lactate value (mmol/L)	3.8	6.5*
Brain AIS score >2 (percentage of patients)	28.1%	39.3%
Abdomen AIS score >2 (percentage of patients)	21.6%	32.1%
Thoracic AIS score >2 (percentage of patients)	75.9%	85.7%
Exploratory laparotomy during first 24 h	11.6%	35.7%*
Pelvic fracture	23.6%	25.0%
Unstable pelvic fracture (Young-Burgess APC-II, APC-III, LC-II, LC-III, or VS)	14.0%	14.3%

SBP, systolic blood pressure at presentation; HR, heart rate; RR, respiratory rate; APC, anterior-posterior compression; LC, lateral compression; VS, vertical shear.

All values represent group means.

* $p < 0.05$ comparing the group treated with primary nailing and the DCO group.

Definition of ARDS

We defined ARDS by using the "PF ratio" (PaO_2/FiO_2) as adopted by the American-European Consensus Conference on ARDS.[48] The PF ratio measures the amount of oxygen that is arterial as a function of the fraction of oxygen given to the patient. Lower values indicate poorer function, and PF ratios <200 have been defined as consistent with ARDS.

However, to meet the diagnosis of ARDS, two other criteria were required: bilateral pulmonary infiltrates and no evidence of heart failure as measured by pulmonary wedge pressure.[48] We assumed that all our patients had the radiographic findings and that none had right atrial hypertension. This might have falsely elevated our ARDS rate by including patients with primary cardiac pathologic conditions or unilateral pulmonary processes, but these situations were thought to be clinically unusual at our institution. In addition, to meet the diagnosis of ARDS, PF ratios needed to remain <200 for at least 5 consecutive days.[7,27,37]

In addition to the PF ratio, we also analyzed the data by using an ARDS definition of an average FiO_2 ≥60% for 5 consecutive days. This definition was used for direct comparison with the definition used in a previous study.[27] Our results were essentially unchanged when assessed by using either definition of ARDS. We present the results assessed by using the PF ratio definition of ARDS, because it is the more accepted definition.

Femoral Reaming Technique

At our institution, we insert femoral nails using the standard technique of first reaming the femur over a guidewire to a diameter that is 1.5 to 2.0 mm larger than the nail size. We typically ream in increasing diameters of 0.5- or 1.0-mm increments, starting at a 9.5-mm-diameter reamer. We use Zimmer flexible reamers (Product Number 2228-reamer size; Zimmer, Inc., Warsaw, IN) with deep flutes and a narrow shaft, regardless of manufacturer of the nail. Our institution uses 10-, 11-, or 12-mm-diameter nails for almost all acute fractures. The vast majority of the nails used during the study period were standard titanium nails from Stryker (Mahwah, NJ) or Synthes (Paoli, PA). Nails were inserted either retrograde (n = 100 of 199 in nail group), through a standard intercondylar notch starting point, or antegrade, typically using piriformis starting points (n = 99). Because of the retrospective nature of the study, the rationale for choosing retrograde or antegrade nailing could not be determined.

Resuscitation Protocol

Resuscitation at our institution is driven by a number of patient care guidelines. At the time of initial presentation, patient stability is determined by routine measurement of vital signs. Depth of shock is estimated by measuring serum lactate and/or base deficit from ABG. All patients have placement of resuscitation lines. Patients are then classified as stable, unstable and responding to resuscitation, or unstable and unresponsive to initial resuscitation attempts.

Patients who present in extremis or those who do not respond to initial resuscitative attempts are treated with transfusion very early. We keep both universal donor red cells and universal donor thawed plasma in the blood refrigerator in our resuscitation unit. These types of patients get very limited crystalloid fluids and type O blood and plasma until crossmatched blood is available. Our resuscitation scheme for these patients is to transfuse red cells and plasma in a one-to-one ratio.

We attempt to estimate blood loss in patients with multiple traumatic injuries by using imaging of the torso and estimating two units of blood per long bone fracture. This is only a guideline, and resuscitation is tailored to individual response. Patients who are stable but clearly have injuries requiring transfusion are given crystalloid until crossmatched blood is available. For those patients, blood and plasma are also given in a one-to-one ratio.

Stable patients receive crystalloid resuscitation and serial hematocrit measurements. Transfusion therapy is individualized, but we generally provide transfusion when serum hemoglobin falls below 7.5 mg.

Fluid and blood are used to support cardiac output with the goal of normalizing serum lactate during the first 24 hours. Fluid is used as our primary inotrope. If hypoperfusion is still present after volume repletion, inotropic support is added. This virtually always involves using dobutamine starting at 5 μg/kg of body weight per minute, increasing to 20 μg/kg of body weight per minute, and titrating to effect. Cardiac performance is measured by using invasive monitoring when necessary. Pressors are virtually never used during the acute resuscitation scheme.

Although resuscitation is always patient specific, the ability to clear lactate to normal has been shown to be an accurate measure of the adequacy of resuscitation.[38] We generally measure serum lactate values every 6 hours and use fluid and inotropes with a goal of normalizing lactate within 24 hours of injury. To accurately describe the resuscitation our patients received, we recorded the blood products, crystalloid, and colloid each patient received during the first 24 hours after admission from our prospective trauma database.

Indications for DCO

Our general approach to treating femoral fractures in patients with multiple injuries is to perform reamed nailing once adequate resuscitation has been shown by normalizing lactate that is trending toward a value of 2.5 mmol/L or less. The patient must also have optimized ventilatory and hemodynamic parameters before we proceed with femoral nailing. We attempt to perform femoral nailing within 24 hours of injury, when possible.

DCO with primary external fixation is reserved for those patients whose conditions remain physiologically unstable despite aggressive initial resuscitation, as described earlier. Patients with closed head injuries who have unstable intracranial pressure measurements also are sometimes treated with external fixation until the neurosurgery team clears the patient for operative treatment. Because of the retrospective nature of this study, the reason why each patient was selected for DCO cannot be accurately determined. At our institution, all patients who receive operative care, whether DCO or nail fixation, are evaluated by the general surgery team, and the decision to "clear" the patient for nailing or external fixation is made by the general surgery team in consultation with the orthopedic team.

Subgroup Analysis

The two main treatment arms of primary intramedullary nailing and DCO were compared with each other in terms of the presenting demographics, death rates, ARDS, days spent in the intensive care unit, and lactate values. We assessed three subgroups: (1) patients with multiple traumatic injuries (ISS >17, n = 227), (2) patients with multiple traumatic injuries including lung injury (ISS >17 and thoracic AIS score >2, n = 175), and (3) patients with severe multiple traumatic injuries including lung injury (ISS >28 and thoracic AIS score >2, n = 78). These subgroups were selected to most closely match those reported in previously published series, thereby allowing the most valid comparison possible between our results and those presented in the literature.

Statistical Analysis

Independent sample *t* tests were used to analyze evidence of statistically significant differences among groups for outcome variables. When comparing ARDS and DCO rates from our study with those from previous studies, χ^2 tests of association were used to provide evidence of differences between the observed values from our study and the expected values from the previous studies.

RESULTS

The first subgroup analyzed included 227 patients with multiple traumatic injuries as defined by an ISS >17. Of the patients with ISS >17, 28 patients (12%) were treated with DCO, and 199 patients (88%) were treated with primary reamed nailing. Descriptive parameters of the two treatment groups are presented in Table 1. The average time from admission to start of surgical procedure was 13.0 hours for the patients treated with DCO and 14.0 hours for the patients treated with intramedullary nailing. Femoral fracture surgery started more than 8 hours after admission to the operating room for 48% of the patients. The DCO group had a higher average ISS, higher initial lactate values, and higher rate of exploratory laparotomy than did the primary intramedullary nailing group ($p < 0.05$, Table 1). Differences in AIS scores for chest, abdomen, and brain were not significant. There were differences in almost all resuscitation parameters between the two groups, as might be expected ($p < 0.05$, Table 2).

TABLE 2. Resuscitation During the First 24 h for Two Treatment Groups With Femoral Fractures and Injury Severity Scores >17*

	Primary Nailing (n = 199)	DCO (n = 28)
Percentage receiving pRBC	58.3%	92.9%†
Percentage receiving FFP	35.7%	75.0%†
Percentage receiving platelets	20.1%	57.1%†
Percentage receiving colloid	21.1%	21.4%
Percentage receiving crystalloid	100%	100%†
Average volume of crystalloid received (mL)	10,696	16,532†
Average pRBC transfused (units)	4.4	13.5†
Average FFP transfused (units)	2.6	9.9†
Average platelets transfused (units)	0.4	1.8†

pRBC, packed red blood cells; FFP, fresh-frozen plasma.
* All values presented as mean values.
† $p < 0.05$ comparing the group treated with primary nailing and the DCO group.

Among those patients with ISS >17, the primary nailing group had an ARDS rate of 1.5% and a death rate of 2.0% (Table 3). The DCO group had a significantly higher rate of death than did the nailing group (17.9% vs. 2.0%, $p < 0.05$) and a higher average number of days spent in the intensive care unit (17.3 vs. 7.1 days, $p < 0.05$). No cases of ARDS occurred in the DCO group, but that group was small and almost 20% of the patients died.

The second subgroup analyzed included patients who had both multiple traumatic injuries (ISS >17) and significant lung injury (thoracic AIS score >2). The analysis of the 175 patients in that category showed results similar to those of the patients with ISS >17 alone. Patients with multiple traumatic injuries including lung injury who were treated with nailing had an ARDS rate of 2.0% and a death rate of 2.0% (Table 4). No cases of ARDS occurred in the DCO group. The death rate (12.5%) was significantly higher in the DCO group ($p < 0.05$, Table 3).

The ARDS rate for the most severely injured patients (ISS >28, thoracic AIS score >2, n = 78) was 3.3%, and 1.7% died after undergoing nailing (Table 5). As with the other subgroups, the DCO group within this subgroup had a higher rate of death and longer intensive care unit stays.

In each of the three subgroups, the lactate values decreased significantly between the time of admission and the time of the operative procedure ($p < 0.05$), although the DCO group had higher lactate values at all time points (Tables 3–5).

TABLE 3. Comparison of Patients With Femoral Shaft Fractures and Injury Severity Scores >17 by Treatment Group

Initial Treatment	Patients, n (%)	Initial Lactate Value (mmol/L)	Lactate Value Before Surgery (mmol/L)	Best Lactate Value on the Day of Surgery (mmol/L)	Death Percentage of Patients	Intensive Care Unit (d)	ARDS Percentage of Patients
Nailing	199 (88)	3.8*	2.9*†	2.2*†	2.0*	7.1*	1.5
DCO	28 (12)	6.5	4.1†	2.7†	17.9	17.3	0.0

* $p < 0.05$ for all values comparing DCO with reamed nailing.
† $p < 0.05$ compared with presenting lactate.

TABLE 4. Comparison of Patients With Femoral Shaft Fractures and Injury Severity Scores >17 Plus Significant Lung Injury (Abbreviated Injury Scale Scores >2)

Initial Treatment	Patients, n (%)	ISS	Initial Lactate Value (mmol/L)	Lactate Value Before Surgery (mmol/L)	Best Lactate Value on Day of Surgery (mmol/L)	Death Percentage of Patients	Intensive Care Unit (d)	ARDS Percentage of Patients
Nailing	151 (86)	28.3*	3.8*	2.8*†	2.2*†	2.0*	7.6*	2.0
DCO	24 (14)	36.9	6.4	3.8†	2.7†	12.5	15.9	0.0

* $p < 0.05$ for all values comparing DCO with reamed nailing.
† $p < 0.05$ compared with presenting lactate.

TABLE 5. Comparison of Patients With Femoral Shaft Fractures and Injury Severity Scores >28 Plus Significant Lung Injury (Abbreviated Injury Scale Scores >2)

Initial Treatment	Patients, n (%)	ISS	Initial Lactate Value (mmol/L)	Lactate Value Before Surgery (mmol/L)	Best Lactate Value on the Day of Surgery (mmol/L)	Death Percentage of Patients	Intensive Care Unit (d)	ARDS Percentage of Patients
Nailing	60 (77)	36.6*	4.2*	2.6*†	2.2*†	1.7	13.4	3.3
DCO	18 (23)	41.4	6.3	3.9†	2.9†	11.1	17.2	0.0

* $p < 0.05$ for all values comparing DCO with reamed nailing.
† $p < 0.05$ compared with presenting lactate.

DISCUSSION

The management of patients with multiple traumatic injuries that include femoral fractures remains a source of controversy. The strategy of first performing spanning external fixation and then converting to femoral nailing after adequate restoration of physiologic stability is referred to as *damage control orthopedics* and is hypothesized to reduce the rate of respiratory compromise and death in a subset of patients with multiple traumatic injuries.[9,11,13,45] Which patients are best served by damage control remains unknown.

Our standard protocol for managing patients with multiple traumatic injuries is to proceed with primary reamed intramedullary nailing if the patient's lactate is approaching normal values (2.5 mmol/L) and if cardiopulmonary parameters are stable. No special considerations are given to treating patients with lung injury differently, assuming adequate oxygenation. We do not currently use unreamed nailing nor did we at any time when the cases included in the study were being treated. We attempt to perform early reamed intramedullary nail fixation within the first 24 hours after injury but do not think that treating the fractures in an emergent fashion is needed, as indicated by our average nailing procedure beginning 14.0 hours after the patient's admission to our hospital. Half of our patients (48%) had the femur treated operatively more than 8 hours after admission to the hospital. Typically, before intramedullary nailing was begun, the patient's presenting lactate value had already improved from 3.8 to 2.9 mmol/L, suggesting that significant resuscitation had occurred before the patient reached the operating room. The best lactate value on the day of surgery was a mean of 2.2 mmol/L for the cases included in the study, which showed success in normalizing lactate.

Although the DCO approach rarely was used in the present series, the data suggest that we selected sicker patients with multiple traumatic injuries to undergo DCO. As would be expected, the patients had higher ISS scores and higher presenting lactate values (Table 1), both important indicators of more severe injury. Anecdotally, our primary indications for using the DCO approach to treat femoral fractures were elevated lactate values that failed to normalize and closed head injuries with labile intracranial pressures.[49] Although we performed DCO within approximately the same time frame in which we performed intramedullary nailing (13.0 hours from presentation at our institution), the lactate values in the patients undergoing DCO improved to only 4.1 mmol/L from a presenting value of 6.5 mmol/L (Table 3). We defined "normalizing" as approaching the goal lactate value of 2.5 mmol/L by the time of surgery.

We performed DCO in only 12% of our patients with multiple traumatic injuries and ISS >17. This rate is much

TABLE 6. Comparison of Select Studies Evaluating Patients With Multiple Traumatic Injuries and Femoral Shaft Fractures With This Study

Study	Inclusion Criteria, (ISS)	DCO Rate (%)	No of Primary Nails	Average ISS With 1° Nail	ARDS Rate After 1° Nail (%)	Death Rate After 1° Nail (%)	MOF Rate After 1° Nail (%)
Present study	>17	12*	199	27.4	1.5†	2.0	NR
Pape et al.[27]	>17	36	110	35.8	26.4‡	NR	28
Brundage et al.[5]	>15§	NR	516‖¶	25.5	10.1#	4.1	NR
Bosse et al.[37]	>16	NR	235	28.0	3.0	2.6	2.1
Charash et al.[6]	>17	NR	138¶	26.5	3.6	5.1	NR
Bone et al.[4]	>17**	NR	83¶	30.6	8.4	3.6	NR

MOF, multisystem organ failure; NR, not reported.
* $p < 0.001$ by Student's t test comparing DCO rate from present study with that from study by Pape et al.[27]
† $p < 0.005$ by Student's t test comparing ARDS rate from present study with that from study by Pape et al.[27]
‡ Article reports 15.1% ARDS rate for primary nails in most recent era. However, subsequent publication states that was excluding retrograde nails and that ARDS rate for both antegrade and retrograde nails was 26.4%.[51,52] Either rate is still statistically different from our rate.
§ Article heading for patients with multiple injuries is ISS >15, but text of same paragraph states ISS ≥15.
‖ Article states approximately 95% were treated with reamed nails, 5% with plates or unreamed nails, no mention of DCO rate.
¶ Includes both early- and late-fixation groups.
# This is the ARDS value for all patients, calculated by combining the reported rates for early and late treatment groups.
** Article has conflicting ISS information: page 340 "more than 18 points" and page 338 "18 points or more."

lower ($p < 0.05$) than the rate recently reported by other authors.[27,46] A European center recently reported rates of DCO use ranging from 36% to 47%.[27,46] Despite our infrequent use of DCO, we observed a relatively low rate of ARDS and death among the patients whose femoral fractures were treated with primary reamed intramedullary nailing (Table 3). The rates were lower than the 26.4% ARDS rate observed by the German trauma service despite their more frequent use of DCO[27,50,51] ($p < 0.01$). It is unclear why our rates of ARDS and death were lower than rates previously reported in the German series,[27] but relatively low ARDS rates achieved in the United States in association with the treatment of femoral fractures with reamed nailing in patients with multiple traumatic injuries have been reported in the literature (Table 6).[4–6,37] The previous reports from North America did not detail the overall use of DCO and had varying definitions of ARDS, mean values of ISS, and inclusion criteria; therefore, it is difficult to directly compare them with our study and the study presented by Pape et al.[27] Furthermore, these other studies often included patients treated in a delayed fashion because that was the variable of interest in previous studies, thus potentially elevating the overall ARDS rate in these studies.[4–6]

One possible explanation for the lower rates of ARDS observed in our study might be the differences in resuscitation before intramedullary nail fixation. Some European centers aggressively attempt to stabilize femoral fractures in patients with multiple injuries within the first few hours after admission.[27] Pape et al.[27] found that for only 2% of the 525 patients with femoral fractures did surgical intervention begin more than 8 hours after admission to the trauma center. This contrasts with our results: 48% of our patients with femoral fractures underwent surgical intervention more than 8 hours after admission to our center ($p < 0.05$). Our average start time for either DCO or intramedullary nailing was more than 13 hours after admission, and the delay between injury and presentation at our center is almost 4 more hours on average. Clearly, the German trauma system is able to bring patients with femoral fractures to the operating room in a much timelier manner, which might manifest as resuscitation protocols that are very different from those adhered to at our center.

It is possible that the decreased time between injury and surgical intervention with the German system is associated with less preoperative resuscitation than that of our slower system, or perhaps the same fluid resuscitation is performed in a shorter time period, placing the patient at some risk for pulmonary edema. Direct comparisons of resuscitation levels between the patient populations are not possible because previous series did not describe any parameters of preoperative resuscitation, such as lactate values. Animal studies have provided some evidence that the negative effects of reamed intramedullary femoral nailing might be offset by proper resuscitation.[52] Similarly, some evidence indicates that persistence of elevation of lactate at the time of femoral nailing increases postoperative complications.[41]

We do not think that a prospective comparison of the two treatment protocols is warranted based on the results of our review. Our data suggest that early reamed nailing after initial resuscitation is safe, well tolerated, and associated with minimal incidence of ARDS, even in severely injured patient populations. Furthermore, we are unaware of any data that specifically show that stabilization of long bone fractures, in particular fractures of the femoral diaphysis, less than 8 hours after injury is more beneficial than such stabilization performed within 24 hours of injury.

Another possible explanation for the relatively lower rates of ARDS and death in our study, when compared with published series from European centers might be differences in the postoperative medical management of shock and intensive care unit differences. It is possible that some as yet undefined underlying differences in medical treatment among the centers cause the discrepancy and that our preoperative resuscitation protocol had little to do with the outcomes. This awaits future research.

Finally, it is possible that the patient populations are somehow intrinsically significantly different. In the study by Pape et al.,[27] the mean ISS for patients with ISS >17 was reported to be 37. Our mean ISS was only 28.4 for the patients with ISS >17. However, even when we moved our ISS up to >28 to match the mean ISS reported by Pape et al. and then also included only patients with additional lung injuries, our ARDS rate was approximately eight times less than the rate presented by Pape et al. (Table 5).

It is possible that some other intrinsic patient factor, such as underlying higher rates of smoking in Germany (smoking rates for males are 34.5% in Germany and 24.5% in the United States[53,54]), worse lung injuries from higher speed motor vehicle collisions, or a difference in genetic predisposition toward ARDS, might contribute to the differences. Each of these explanations is conjecture, and further work would be required to determine their validity. Further complicating the issue is that it is difficult to compare the severity of the lung injuries between study populations. Existing scoring systems (such as ISS or the AIS used in our study) might not be valid predictors of outcome after blunt thoracic trauma,[55] and other scoring systems for blunt thoracic injury might better characterize the severity of thoracic injury.[55,56]

Our study was subject to all the typical limitations of any retrospective study. We attempted to create an accurate reflection of our ARDS rate by directly calculating PF ratios instead of relying on a potentially poorly defined clinically based diagnosis. We searched all clinical records to assure that patients were properly assigned to treatment groups and that patients who were not appropriate for the study (those with hip fractures and those treated elsewhere first) were not included. Although all the data were collected prospectively, which might have improved the quality of the information, the study was retrospective in nature.

This report shows that low rates of ARDS and death were observed for patients with multiple traumatic injuries treated with reamed intramedullary nailing of femoral fractures even though DCO was infrequently performed. The patient demographics and, in particular, the lactate values describe the characteristics of the unusual patients that we reserved for DCO. DCO might play a lifesaving role for certain very ill patients but is an approach that is infrequently needed, even for patients with multiple traumatic injuries. Higher reported rates of ARDS at centers that practice more aggressive use of DCO coupled with earlier operative intervention for stabilization of femoral shaft fractures suggest that the safety of such aggressive treatment protocols might be less than that which we routinely use.

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EDITORIAL COMMENT

This article is another piece in the puzzle to determine the optimal orthopedic management for multiply injured patients. One issue is addressed in its title and refers to the limited use of damage control. From the orthopedic point of view, the Damage Control Orthopaedics idea should not be abused to place external fixateurs in every patient with multiple injuries. Appropriate use of the operating time is important. Patients who can be cleared for definitive surgery all should receive timely definitive treatment and appropriate access to the operating room is crucial. First, the article by Dr. O'Toole and colleagues addresses the issue of adequate resuscitation for patients who require

TABLE 1. Comparison of Publications in the Orthopedic Literature and Time of Treatment, Inclusion Criteria, and Pulmonary Complications

Author	Year of Publication	Year of Treatment	ISS	Inclusion (all Patients, Including the Ones Not Cleared)	Inclusion (Cleared for Orthopedic Fixation)	ARDS (%) Depending on Subgroup
Bosse	1997	1983–1994		—	—	2–8
Pape et al.[3]	2002	1981–1990	38	All		16–32
		1991–1992	36			11–22
		1993–2000	35			8–15
COTS[2]	2006	1995–1999	—	—	—	3.7
EPOFF[4]	2007	2000–2006	31,6		Cleared	0

—, not indicated; ISS, Injury Severity Score.

operative care, which dates back to issues stressed by Border two decades ago. Today, it is equally important and underlines the importance of a very close cooperation between general surgery and orthopedics. If resuscitation is in doubt, early definitive femoral shaft fracture fixation increases mortality.[1]

The end points of resuscitation are important: "The current end-points used to guide resuscitation are global markers that may underestimate occult tissue hypoperfusion. . . . more sensitive measures of tissue oxygenation measured by polarographic or near-infrared technologies and markers of inflammation and coagulation that better reveal the physiologic condition of a patient are likely to replace simple temporal distinctions."[1] Second, the current article is an excellent example for the importance of patient selection and outcome, namely that the reported rate of adult respiratory distress syndrome (ARDS) seems to be higher in Europe than in Northern America. The Canadian Orthopaedic Association (COTS) has discussed the reasons for these apparent differences and described a simple explanation: In North America, clearing of patients for orthopedic procedures is performed by general surgeons, whereas in Europe this is performed by the orthopedic trauma surgeon. The COTS suggests that orthopedic surgeons in Europe therefore tend to include even those patients in their studies who cannot be cleared for definitive surgery. In contrast, North American orthopedic surgeons seem to include only those that are cleared for orthopedic care, therefore selecting a subgroup of "healthier" cases.[2] Third, inclusion of patients treated within a certain decade may also play a role. The COTS article alludes to this as follows: "Pape's series, however, reports the results of a series treated in the mid-1980s, which may explain the higher rate of ARDS and the higher mortality." Likewise, the publication quoted earlier[3] summarized patients from three previous decades and the higher injury severity in the 1980s may have been another reason for a high incidence of ARDS (Table 1).

If patients from Europe are selected using similar inclusion criteria, the rates of pulmonary failure are equal or lower than in the study by Dr. O'Toole and colleagues. This supports the idea that ARDS incidences depend on patient selection and the decade of treatment (Table 1). In summary, (1) an adequate resuscitation plays a key role in the management of patients with head injuries, (2) the use of external fixateurs should be limited to those patients who are in unstable/uncertain condition, (3) an operative time for definitive orthopedic procedures should be used whenever possible. Similar to the establishment of an acute care fellowship, it may be useful for orthopedic surgeons to spend time on the trauma services in a later stage of their training for a mutual learning experience regarding the effects of trauma, blood loss, timing of surgery, and postoperative complications.

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