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Systemic effects of bilateral tibial versus bilateral femoral shaft fractures Is there a difference ?

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The authors investigated the prevalence and the difference in the severity of systemic complications following intramedullary nailing of bilateral tibial and femoral shaft fractures. A retrospective chart analysis of 12 consecutive patients with bilateral tibial shaft fractures (TF) and 14 patients with bilateral femoral shaft fractures (FF) was performed. The incidences of bilateral tibial fractures and bilateral femoral shaft fractures were 3.8% and 4.6% respectively. The median Injury Severity Score (ISS) in TF group was 13 (9-29) compared to 16 (9-34) in the FF group (p = 0.169). The mean resuscitation requirements were 4.2 (3-11) litres of colloids and crystalloids and 1.7 (0-10) units of blood in the TF group and 10.6 (6-16) litres of colloids and crystalloids and 9.2 (5-25) units of blood in the FF group (p = 0.002). In the TF group there was 1 death compared to 2 in the FF group. In the TF group, there were 2 cases of ARDS, 4 cases of deep sepsis and 3 above knee amputations. In the FF group, there were 6 cases of ARDS (p = 0.04), 1 case of deep sepsis and 1 above knee amputation. Patients with bilateral tibial shaft fractures revealed lower ISS, resuscitation requirements, ARDS, associated injuries, and mortality when compared to bilateral femoral shaft fractures. This is probably due to the anatomical difference in the morphology of the bones, volume of liberated intravascular marrow fat, organisation and layout of the venous capillary network and severity of associated injuries.

INTRODUCTION

Intramedullary nails are the accepted standard for the stabilisation of long bone fractures (*28, 35, 52*). Recent studies, especially in the past two decades have raised concern over the possible harmful systemic effects (adult respiratory distress syndrome -ARDS) of intramedullary nailing in the multiply injured if the patient is at special risk due to prolonged shock states or associated injuries (chest trauma) (*25, 37, 46*). Intravasation of intramedullary contents and immune activation under the stimulus of the cytokines and other inflammatory mediators released during canal preparation and nail insertion are presumed to be significant factors in the evolution of adverse cardiopulmonary effects (*31, 53*).

There is substantial evidence in the literature endorsing the association of intramedullary nailing and development of systemic complications in unilateral long bone fractures in selected patient groups (*7, 12, 32*). To our knowledge, systemic effects following bilateral long bone fractures has

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been given only cursory attention in the English speaking literature in a few passing references (*24, 33*). and two case reports, both involving the femur (*23, 38*). The general consensus however is that of an additive effect bestowed by the bilateralism of these fractures.

In this study therefore, we aim to investigate the prevalence of systemic complications following stabilisation of bilateral tibial and femoral shaft fractures with intramedullary nailing. In addition, we try to answer the question whether there is a difference in the severity of systemic complications following stabilisation of bilateral tibial and femoral shaft fractures with intramedullary nailing.

PATIENTS AND METHODS

Between August 1995 and July 2001, 312 consecutive adult patients with tibial fractures were treated in our institution. Among them there were 12 (3.8%) patients (3 females) with bilateral tibial shaft fractures (TF –Tibial fracture group). A retrospective chart analysis was performed. The following data was recorded : age, sex, Injury Severity Score - ISS (*2*), resuscitation requirements, intensive care unit (ICU)/ high dependency unit (HDU) stay, hospital stay, systemic and local complications, mortality and time to union. Similarly the same parameters were recorded and analysed in a group of 14 (4.8%) consecutive patients (1 female) with bilateral femoral shaft fractures (FF – Femoral fracture group) treated in our unit during the same period out of 292 femoral fractures (*24*). Associated injuries were treated accordingly. Chest injury was defined by radiological evidence of lung contusion, at least 2 fractured ribs or presence of a haemo / pneumothorax and was quantified using the Abbreviated Injury Scale – AIS (*2*).

In the TF group, all fractures were stabilised by intramedullary nails. In total 24 nails were inserted. The surgery was performed free hand with the patient supine. No tourniquet was used. In 9 patients 18 AO solid nails were inserted using an unreamed technique. Of the remaining 3 patients, one patient had the external fixators exchanged for bilateral AO hollow nails (reamed technique) 3 days after the injury and the other 2 patients had their fractures stabilised primarily with AO hollow nails, which were inserted after reaming the medullary canal. In the FF group, all patients had their femoral fractures stabilised within 24 hrs of injury. All fractures were stabilised with intramedullary nails. Twenty-eight nails were inserted in total. Sixteen femurs were reamed and 12 femurs were not reamed. AO hollow nails were used in the reamed femurs and the solid nail in the unreamed femurs. The surgery was performed with the patient supine on a fracture table. All nails were statically locked in both groups. In all patients, stabilisation of the fractures took place in the same operative setting. All surgery was performed by a senior trainee/consultant.

Following surgery, patients who developed systemic complications were treated in the intensive care unit or the high dependency unit. Adult respiratory syndrome (ARDS) was defined as a PaO_2/FiO_2 ratio less than 200 for at least 5 consecutive days and bilateral diffuse infiltrates seen in chest radiographs in the absence of pneumonia and cardiogenic pulmonary oedema (*5*). Prophylactic antibiotics (IIIrd generation Cephalosporin) were administered to all patients at induction of anaesthesia. A further 2 doses was administered post operatively. Patients with open fractures received broad-spectrum antibiotics on arrival to the accident and emergency unit. Antibiotic cover was provided for 2 weeks for this group of patients. Full active weight bearing was encouraged in all patients with intramedullary nails in both groups. All patients received thromboprophylaxis (low molecular weight heparin) post operatively until full ambulation. All patients were clinically and radiologically followed up as indicated by their general condition and progress. The mean follow up was 34 (range 18-60) months.

STATISTICS

Comparison of data between the groups was performed on a personal computer using SPSS® 11.0 for Windows®, © SPSS Inc., Chicago Illinois, USA. Wilcoxon sign rank test was performed to assess whether there was statistical difference between the two groups with respect to age, sex, ISS, presence of ARDS, presence of chest injuries and mortality. Fisher's exact test was used for categorical data, and the Wilcoxon sign rank test and Mann-Whitney U-test were used for all other data. A p value of less than 0.05 was considered statistically significant.

RESULTS

The patient demographics of the TF and FF group are shown in table I and table II respectively. The

Table I. — Patient characteristics of the TF group

Case	Age	Sex	ISS	Nail type	Blood (units)	ICU/HDU stay (days)	Chest Injury (AIS score)	Complications
1	40	Female	11	UTN	1	0	No	
2	46	Male	13	RTN	0	0	Yes (2)	
3	27	Male	9	UTN	0	0	No	
4	22	Male	10	UTN	0	0	No	
5	27	Male	13	UTN	10	5	No	
6	20	Male	29	UTN	6	8	Yes (3)	ARDS
7	19	Male	17	UTN	0	2	No	
8	29	Male	13	UTN	0	12	No	
9	79	Female	16	UTN	0	10	No	
10	60	Male	17	RTN	0	8	No	CA[b]
11	48	Female	22	RTN[a]	0	7	Yes (3)	
12	20	Male	13	UTN	3	14	No	ARDS/RF

(*CA* Cardiac arrest, *RF* Renal failure, *RTN* Reamed tibial nail, *UTN* Unreamed tibial nail).
[a] Exchange from External fixators. [b] Mortality.

Table II. — Patient characteristics of the FF group

Case	Age	Sex	ISS	Nail type	Blood (units)	ICU/HDU stay	Chest Injury (AIS score)	Complications
1	20	Male	16	RFN	5	1	No	
2	18	Male	10	UFN	6	6	Yes (3)	ARDS
3	50	Male	10	UFN	5	1	No	
4	81	Male	16	RFN	9	7	No	ARDS
5	19	Male	22	RFN	15	6	Yes (3)	ARDS
6	69	Male	34	UFN	25	4	No	
7	40	Male	18	RFN	7	2	Yes (3)	
8	30	Male	20	UFN	6	2	No	
9	35	Male	14	RFN	9	2	No	
10	45	Male	16	RFN	10	14	Yes (3)	ARDS
11	28	Male	13	UFN	5	9	No	ARDS
12	25	Male	29	RFN[a]	12	3	Yes (2)	
13	78	Female	10	UFN	9	5	No	IHD/RF[b]
14	28	Male	9	RFN	6	3	No	ARDS[b]

(*IHD* Ischaemic heart disease, *RF* Renal failure, *RFN* Reamed femoral nail, *UFN* Unreamed femoral nail).
[a] Retrograde nailing [b] Mortality.

mean age in the TF group was 36.4 (range 19-79) years and 40.4 (range 18-81) years in the FF group. No significant difference was noted between the two groups with regard to age (p = 0.875) and sex (p = 0.317). The median ISS in TF group was 13 (interquartile range 11-17) compared to 16 (interquartile range 10-20) in the FF group (p = 0.169). Six fractures were open in the TF group and 3 in the FF group. The mean resuscitation requirements were 4.2 (3-11) litres of colloids and crystalloids and 1.7 (0-10) units of blood in the TF group and 10.6 (6-16) litres of colloids and crystalloids and 9.2 (5-25) units of blood in the FF group (p = 0.002). The mean operation time was 2.3 (2-4.5) hours in the TF group and 4.5 (4-7) hours in the FF group. The mean ICU/HDU stay was 5.5 (1-14) days in the TF group and 4 (1-14) in the FF group whereas the mean hospital stay was 46 (8-148)

Table III. — Associated injuries in the TF and FF groups

Associated injuries	TF group - no of patients	FF group - no of patients
Chest	3 (25%)	5 (35.7%)
Abdominal	3 (25%)	1 (7.1%)
Craniofacial*	7 (58.3%)	2 (14.2%)
Musculoskeletal		
Femur/Tib-Fib*	1 (8.3%)	6 (42.8%)
Pelvis	1 (8.3%)	4 (28.5%)
Ankle	2 (16.6%)	5 (35.7%)
Hand	0	5 (35.7%)
Wrist	3 (25%)	6 (42.8%)
Other	6 (50%)	10 (71.4%)

* $p < 0.014$.

days in the TF group and 36.3 (5-108) days in the FF group, ($p > 0.05$). In the TF group there was 1 death compared to 2 in the FF group, ($p > 0.05$). The average length of stay in the TF group was higher as 5 patients in this group needed longer rehabilitation and social support.

Associated injuries are shown in table III. The mean AIS (Abbreviated Injury Scale) of the patients with chest injuries were 2.66 and 3.2 in the TF and FF groups respectively. In the TF group, there were 2 cases of ARDS and 4 cases of deep sepsis. In the FF group, there were 6 cases of ARDS ($p = 0.04$) and 1 case of deep sepsis. Comparison of the parameters under review is shown in table IV. Three patients in the TF group and 1 patient in the FF group developed compartment syndromes requiring fasciotomies. Of the six open fractures in the TF group 5 patients required soft tissue reconstruction (3 local fasciocutaneous flaps and 2 musculocutaneous free flaps) compared to none in the FF group. Three patients had above knee amputation in the TF group ; 2 were due to deep sepsis while the third was due to failed vascular reconstruction. In the FF group, one patient had above knee amputation due to osteomyelitis. The mean time to union was 29 (range 16-96) weeks in the TF group and 24.5 (range 12-37) weeks in the FF group, ($p > 0.05$).

DISCUSSION

Bilateral long bones fractures of the lower limb are uncommon injuries and are usually associated with high-energy trauma. The overall incidence of 4.6% and 3.8% for the bilateral femoral and bilateral tibial shaft fractures respectively is similar to reports by other authors (*33, 45, 51*). While there are many accounts of unilateral injuries (*16, 22, 51*), only scattered case reports describing bilateral injuries of both the tibia and the femur are available (*3, 18, 47*). Furthermore, there is very little information in the literature describing the systemic effects of bilateral fractures (*24, 33*).

In our study there was no significant difference in the ISS between the two groups. However, we are aware that with musculoskeletal injuries, the scoring systems tend to ignore the compounding effects of other associated injuries. The ISS limits the total number of contributing injuries to only 3, one each from the 3 most injured regions. This may result in underscoring the degree of trauma sustained if a patient has more than one significant injury in either one region or more than three

Table IV. — Analysis of data from the TF and the FF group

Parameter	TF group	FF group	p- value
ISS	13 (9-29)	16 (10-20)	> 0.05
Intravenous fluids (l)	4.2 (3-11)	10.6 (6-16)	**0.03***
Blood transfusion (units)	2.5 (0-10)	8.6 (4-30)	**0.002***
ICU/HDU stay (days)	5.5 (0-14)	4 (1-14)	> 0.05
Hospital stay (days)	46 (8-148)	36.3 (4-210)	> 0.05
ARDS (no. of patients)	2 (16%)	6 (42.8%)	**0.04***
Mortality (no. of patients)	1 (8.3)	2 (14.2%)	> 0.05

* $p < 0.05$.

regions (*13, 14, 19*). Further more, the ISS takes into account only one injury per body region resulting in inability to account for multiple injuries to the same body region. Therefore patient's overall anatomic injury severity is often underestimated particularly in penetrating trauma. Additionally it does not take into account physiologic variables and gives equal weight to each body region, ignoring two more severe injuries in one body region in favour of a less severe injury in another body region. This fact impairs its ability to predict short-term mortality (*13, 19*).

The resuscitation requirements were significantly higher in patients with bilateral femoral shaft fractures reflecting the severity of the associated injuries and probably due to the fact that they experienced more blood loss. Nonetheless, in both groups they were significantly higher compared to patients with unilateral fractures (*16, 21, 36*).

In this study the incidence of local complications by means of open fractures and requirement of soft tissue reconstruction was higher in the TF group. This relates to the anatomic predisposition of the tibia to open fractures. Five of 6 patients with open fractures in this group required soft tissue reconstruction (3 fasciocutaneous flaps and 2 muscle free flaps) compared to none in the FF group. Furthermore, there was a higher incidence of deep sepsis (4 in the TF and 1 in FF group) and amputation (3 in the TF group and 1 in the FF group). This higher incidence of local complications could be attributed to the poor soft tissue coverage of the tibia especially in the anteromedial aspect predisposing it to an increased risk of infection and healing problems.

There is clear evidence that early stabilisation of long bone fractures significantly reduces the risk of pulmonary complications (*4, 8, 27*). However, systemic complications have been reported with the use of intramedullary nails in patients at special risk and have been noted to be a significant factor of morbidity and mortality (*18, 22, 54*). The current evolution of 'damage control orthopaedic surgery' clearly recommends early (initial) temporary stabilisation followed by secondary definitive osteosynthesis of major fractures in patients at high risk of developing systemic complications (*40*). In our series, all fractures in both groups were stabilised within 24 hrs of injury.

Intramedullary nailing is still the preferred treatment for stabilisation of diaphyseal fractures of the femur and tibia. Concerns regarding the association of intramedullary nailing of femoral fractures and fat embolisation was raised in the early 50's (*42*). Since then several studies have reported the intravasation of fat from the medullary canal as the main cause for the pulmonary insufficiency after reamed intramedullary nailing (*15, 20*). A transient rise in ThromboxaneA2, B2 and prostacyclins has been observed during reaming and unexpected fatal complications have been cited (*23, 25, 26, 32, 39, 46*). Animal studies also support disturbances in the cardio pulmonary circulation during intramedullary reaming which may predispose to the development of ARDS (*44*). The difference in the amount of fat mobilised into the vascular system and different degrees of pulmonary dysfunction by different types of reamers has also been investigated (*39*). Various theories were proposed to explain the toxic effects of the liberated fat and intramedullary contents such as the release of humeral mediators (thromboxane), the theory of toxic effects, the theory of coagulation disturbances, and the colloidal theory (*1, 10, 11, 34, 46*).

On the basis of these studies, there was a rise in the use of unreamed nails in an attempt to eliminate the problem of reaming. Subsequent studies have shown that there is significant fat embolisation even after unreamed nail insertion, but to a lesser extent (*29, 31*). The maximal embolisation of the marrow contents as shown by echocardiography occurs during nail insertion independent of the changes in the intramedullary pressure (*17, 30, 53*).

The influence of the reaming technique in the development of ARDS is debatable and its primary role in development of ARDS has been challenged (*7, 9, 12*). It has been established that reaming of the medullary canal causes an additive surgical impact and can cause clinically relevant side effects if cofactors (e.g., thoracic trauma, severe shock, and polytrauma) are present that set the individual up for postoperative complications (*37, 41*). In this study, we are unable to make any recommendations on the relationship of reaming and development of ARDS due to the small number of patients studied.

Co-existing thoracic trauma has been proven to be a major contributor in the development of ARDS, irrespective of the treatment used (*7, 9*). Two studies, in particular have indicated that it was not the method of treatment, but the associated chest injury which led to an increase in the pulmonary complications and mortality (*6, 7*). In our study, half of all patients who developed ARDS in both the groups had concomitant chest injury (AIS scores of 3 in both groups). The pathological events leading to the development of ARDS is complex and many factors have been implicated. There is no doubt that primary lung injury by itself could predispose the development of ARDS. Subsequent intramedullary nailing especially using the reamed technique has been shown to cause bone marrow fat embolisation and increased immune activation (*32, 44, 46*). The interaction of the activated leucocytes and endothelial cells under the stimulus of the released cytokines and other inflammatory mediators released during reaming may further contribute to the development of ARDS in the already injured lung (*23*).

The incidence of ARDS in the TF group was significantly less than in the FF group ($p = 0.04$). In the TF group, 2 patients developed ARDS. Both the patients were treated with unreamed nails and one patient had coexisting chest injury. Among the 6 patients who developed ARDS in the FF group, 3 had concomitant chest injuries ; in 2 of the cases the femoral fractures were stabilised using reamed intramedullary nails and in the third case the fracture was treated with solid nails inserted with the unreamed technique.

The increased incidence of systemic complications, in the FF group compared to the TF group suggests a quantitative event, which predisposes to ARDS. These effects seem to be systemic as there are no increased local complications in the FF group. It has been previously established that there is a sufficient amount of fat in the long bones to account for the phenomenon of fat embolism. The average fat content in the adult femur and tibia are 152 gms and 108 gms respectively (*43*). Of great interest is the distribution of the fat within the long bones. The tubular diaphysis does not contain the major store of bone fat as assumed. Instead, the spongy metaphysis with its greater volume contains more than 60% of the fat (*43*). This variation is due to the differences in the volume of the fat rather than the concentration. There is very little fat in the distal tibial metaphysis compared to the supracondylar region of the femur, as it is relatively small. The unique rich venous drainage system present in the supracondylar region of the femur is also absent in the distal tibia (*50*). There is a high intramedullary pressure directed distally towards the supracondylar region during reaming and ante grade nail insertion (*48, 49*). We believe that these factors may predispose the femur to a higher degree of intravasation of intramedullary contents after stabilisation with intramedullary nails and thus explains the higher incidence of systemic complications when compared to tibial fractures.

In conclusion, watchful expectancy for systemic complications from associated injuries is mandatory in patients with bilateral fractures to reduce the associated morbidity and mortality. The current scoring systems fail to qualify the associated injuries. Although the systemic effects and pulmonary complications are less in patients with bilateral tibial shaft fractures when compared to their counterparts with femoral fractures, it is extremely important to be aware of such complications associated with these injuries. Early fracture stabilisation tailored to the individual patient after accounting for the associated injuries seems appropriate in the current climate of 'damage control orthopaedic surgery'

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