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Demographics, Mechanism Of Injury, Injury Severity, And Associated Injury Profiles Of Patients With Femoral And Tibial Shaft Fractures: A Study Of The National Trauma Databank

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Demographics, mechanism of injury, injury severity, and associated injury profiles of patients with femoral and tibial shaft fractures: a study of the National Trauma Databank

A Thesis Submitted to the
Yale University School of Medicine
in Partial Fulfillment of the Requirements for the
Degree of Doctor of Medicine

by
Nidharshan Subra Anandasivam
2019

Abstract

Introduction:

Traumatic injuries, such as fractures, are known for having defined associated injury patterns. These can alter management and affect outcome if not promptly recognized and managed. There are limited large-scale studies of demographics, mechanism of injury, and injuries associated with femoral and tibial shaft fractures.

Objectives:

1. To determine the demographics, mechanism of injury, injury severity score, and associated injuries in those with femoral and tibial shaft fractures in a large national sample.
2. To determine the relationship between associated injuries and in-hospital mortality.

Methods:

In two separate studies, patients in the 2011 and 2012 National Trauma Data Bank were analyzed for demographics, mechanism of injury, injury severity score, and associated injuries. Using ICD-9 diagnosis codes, the first study examined patients with tibial shaft fractures, while the second study examined patients with femoral shaft fractures. Descriptive analyses were performed for each of the cohorts, and multivariate regression was utilized to understand relationships between associated injuries and in-hospital mortality.

Results:

A total of 26,357 adult patients with femoral shaft fractures were analyzed. The primary mechanisms of injury for these fractures were motor vehicle accidents and falls (predominantly in those above 65 years of age). Generally, those with motor vehicle accidents tended to be younger males with more associated injuries. Associated injuries tended to concentrate based on proximity to the femoral shaft fracture. The highest frequencies of associated injuries are the following: upper extremity (22.4%), thoracic organ (19.5%), spine (16.8%), and intracranial (13.5%).

A total of 27,706 adult patients with tibial shaft fractures were analyzed. There was a bimodal age distribution with peaks at 20 and 50 years of age. Falls were the most common mechanism in the older age groups, while motor vehicle accidents dominated the younger age groups. Overall, 59.6% of patients had at least one associated injury. The highest frequencies of associated injuries are the following: upper extremity (16.3%), spine (14.0%), thoracic organ (12.9%), and intracranial (11.3%). The presence of an associated injury correlated with mortality (odds ratio = 12.9).

Conclusion:

Overall, the current study describes the cohorts of patients who sustain femoral and tibial shaft fractures. The significant incidences and patterns associated with these fractures are described. Furthermore, the significantly increased odds of mortality associated with these injuries underscores the importance of recognizing and managing associated injures in the trauma population.

Acknowledgements

This work would not have been possible without the generous contributions of several individuals. First, I would like to extend a warm thank you to Dr. Jonathan Grauer who has been an inspirational mentor to me and a formative part of my orthopaedic education at the Yale School of Medicine. In addition, I thank my colleagues who are a part of the clinical research team of Dr. Grauer. The collegial atmosphere created here is like no other, and I am grateful for my opportunities to collaborate in the works of several esteemed individuals, including Dr. Daniel Bohl and Dr. Andre Samuel.

I am also grateful for the mentorship of the Yale orthopaedics faculty including Dr. Brian Smith and Dr. Michael Baumgaertner, as I really appreciate the support they have provided during my time at the Yale School of Medicine.

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Introduction to Thesis

Femoral and tibial shaft fractures are relatively common injuries, with incidences of 10.3 and 21.5, respectively, per 100,000 people per year.[1,2] Furthermore, these injuries are associated with several complications and significant costs.[3,4] The average incremental direct cost increase during the six months after a polytrauma with a long bone fracture was estimated to be $39,041, with absenteeism and short-term disability costs amounting to an additional $7,200.[3]

The orthopaedic trauma population can present with isolated injuries or defined patterns of associated injuries. For example, there is a known correlation between clavicle fractures and thoracic injuries, as well as a known correlation between calcaneus fractures and lumbar spine injuries.[5,6] By appreciating these known associations, orthopaedic traumatologists are able to conduct a more focused evaluation for these injuries.

Although associated injuries have been examined in patients with femoral and tibial fractures, these studies are limited because they involve small sample sizes and do not examine all associated bony and internal organ injuries. For example, Bennett et al. focused on femoral shaft fractures and only associated ipsilateral femoral neck fractures in a total of only 250 patients.[7] As another example, Jung et al. examined 71 patients with tibial shaft fractures to determine the frequency of concomitant ankle injuries.[8] Although these studies provide useful information about specific associated injuries, they lack the statistical power to determine common associated injury patterns in patients with femoral and tibial shaft fractures.

In light of this dearth of knowledge, the current thesis utilizes a large national sample from the National Trauma Data Bank (NTDB) to examine associated injuries in patients with femoral and tibial shaft fractures. The NTDB was constructed and is currently maintained by the American College of Surgeons, and is a database that utilizes registrar-abstracted data from over 900 US trauma centers and contains over five million cases.[9,10,11] Because of its volume and national representation, it was specifically chosen to obtain an adequate study sample to analyze these fracture patients on a large scale.

Section 1 of this thesis examines demographics, mechanism of injury, injury severity, associated injuries, and mortality in adult patients with femoral shaft fractures. Section 2 examines demographics, mechanism of injury, injury severity, associated injuries, and mortality in adult patients with tibial shaft fractures This information will be essential in guiding the orthopaedic traumatologist and emergency medicine physician in deciding when to have a low threshold for suspecting associated injuries.

Section I

Analysis of Bony and Internal Organ Injuries Associated with 26,357 Adult Femoral Shaft Fractures and Their Impact on Mortality.

This section was published as follows:
Anandasivam NS, Russo GS, Fischer JM, Samuel AM, Ondeck, NT, Swallow MS, Chung SH, Bohl DD, Grauer JN. Analysis of Bony and Internal Organ Injuries Associated with 26,357 Adult Femoral Shaft Fractures and Their Impact on Mortality. Orthopedics 2017;40(3): 506-512. PubMed ID: 28358976

Introduction

Femoral shaft fractures are common following major traumas, such as motor vehicle accidents.[1] In fact, a femoral shaft fracture occurs in approximately one in every ten road injuries.[2] A recent study estimated that the incidence of femoral shaft fractures is about 1 to 2.9 million per year worldwide.[2] The preferred treatment option of these severe injuries is intramedullary nails.[3-5] This surgery has been shown to have good healing and recovery.[6]

Oftentimes fractures are not isolated injuries, and identifying associated injuries is important for patient care, especially in the seriously injured patient.[7] For given injuries, there are often specific known patterns of associated injuries that can help direct patient workups and management. For example, such patterns of associated injuries have been described for calcaneus fractures (known association with lumbar fractures)[8,9] and clavicle fractures (known association with lung injuries).[10] Along with comorbidities and the patient's general condition, associated injuries can impact the fracture management, time to surgery, and outcomes.

Given that femoral shaft fractures typically result from major trauma, they are frequently seen in polytrauma patients.[11] However, to the best of our knowledge, no study has identified the associated injury profile for femoral shaft fractures.

To address the lack of literature in this area, the current study sought to utilize the National Trauma Data Bank (NTDB), the largest multi-center trauma repository, to define a large cohort of patients with femoral shaft fractures and assess associated injury profiles. Furthermore, in order to assess the impact of such associated injuries, the correlations of such associated injuries with mortality were defined and compared to other factors believed to affect mortality in this patient population.

Methods

The NTDB, created by the American College of Surgeons, is the largest national, multi-center trauma database and includes registrar abstracted and administratively coded data.[12] It was established as a "repository of trauma related data voluntarily reported by participating trauma centers."[13] The current study utilized the NTDB to identify adult (18 years of age and older) patients with femoral shaft fractures from 2011 and 2012. This was based on International Classification of Disease, 9th Revision (ICD-9) codes for either open or closed femoral shaft fractures (821.01, 821.11).

Patient age, gender, and comorbidities were characterized. Age was stratified into the following groups: 18 – 39 years old, 40 – 64 years old, and 65+ years old. The following comorbidities contained in NTDB were used to calculate a modified Charlson Comorbidity Index (CCI): hypertension, alcoholism, diabetes, respiratory disease, obesity, congestive heart failure, coronary artery disease, prior cerebrovascular accident, liver disease, functionally dependent status, cancer, renal disease dementia, and peripheral vascular disease. These variables were used to calculate CCI based on a previously described algorithm.[14] Of note, this modified CCI did not include an age component, and any mention of "CCI" in this paper always refers to this modified Charlson Comorbidity Index.

Mechanism of injury was then determined from ICD-9 e-codes. Patients were categorized into "fall", motor vehicle accident ("MVA"), or "other." Patients with a fall mechanism of injury were determined based on the following ICD-9 e-code ranges: 880.00 – 889.99, 833.00 – 835.99, 844.7, 881, 882, 917.5, 957.00 – 957.99, 968.1, 987.00 – 987.99. These primarily contained falls from standing height, ladders, buildings, and sports. Patients with an MVA mechanism of injury were determined based on the following ICD-9 e-code ranges: 800-826, 829-830, 840-845, 958.5, and 988.5. These included patients who were involved in accidents as motor vehicle drivers, motorcyclists, bicyclists, and pedestrians. All other e-codes were counted as "other". These included firearm and machinery-related injuries, among others.

Injury severity score (ISS) and mortality were data elements directly abstracted from NTDB. Associated injuries were identified by ICD-9 codes. The diagnosis codes that were used to identify associated bony and internal organ injuries are shown in Appendices 1 and 2 (which have been used for a previously submitted associated injuries study).[15]

For analysis, Adobe® Photoshop® CS3 was used to visually demonstrate the associated injury frequencies by shadings on the skeleton and internal organ figures. The range of shadings from white to black represented increasing injury frequency. Multivariate logistic regression was used to determine the association of age, modified CCI, and various associated injuries with mortality. All statistical analyses were conducted using Stata® version 13.0 statistical software (StataCorp LP, College Station, TX). All tests were two-tailed and a two-sided α level of 0.05 was taken as statistically significant. A waiver for this study was issued by our institution's Human Investigations Committee.

Results

Patient demographics

For 2011 and 2012, the NTDB included 26,357 adult patients (16,717 males and 9,640 females) who had femoral shaft fractures. The age distribution of all adult femoral shaft fracture patients is shown in Figure 1. The highest incidences were between the ages of 18 and 39. The primary incidence peak was around 20 years of age. It was found that the younger patients were predominantly male (10,448 males and 3,220 females in the 18-39 age group), while the older patients were predominantly female (3,823 females and 1,586 males in the 65+ age group). The middle group (ages 40-65) contained 4,683 males and 2,597 females.

Comorbidity index and injury severity

The medians of modified Charlson Comorbidity Index (CCI) for age categories 18-39, 40-64, and 65+ were all 0 (Table 1). However, comorbidity burden did generally increase with age for this cohort.

The medians of Injury Severity Score (ISS), for these three categories were between 10-19 for the first two, and between 0-9 for ages 65 and over (Table 2). This is consistent with decreasing injury severity with increasing age for this cohort.

Mechanism of Injury

Mechanism of injury distribution by age group is shown in Figure 2. Younger adults sustaining femur fractures and had predominantly been involved in MVAs, while older adults had predominantly been involved in falls. The middle age category (40-64) had a distribution more similar to the younger adults than the older adults, with MVAs dominating the distribution.

Associated Injuries by Age

On average, younger adults (ages 18-39, who as a group had a predominate MVA mechanism of injury) sustained higher frequencies of bony and internal organ associated injuries across the board compared to the older adults (65+ years of age). The middle age group (40-64 years of age) had associated injury frequencies more comparable to the younger group (ages 18-39) than the older age group (age 65+ years old). Table 3 summarizes the associated injury frequencies by age category.

Figures 3 and 4 show the associated bony and internal organ injury profiles for the total adult femoral shaft fracture population (18 years of age and older). The darker shadings correspond to higher frequencies. Overall, among associated bony injuries, the top three were tibia/fibula (20.5%), rib/sternum (19.1%), and non-shaft femur (18.9%, of which 5.8% of the total cohort were femoral neck) fractures. Among associated internal organ injuries, the top three were lung (18.9%), intracranial (13.5%), and liver (6.2%) injuries. In general, the most common associated injuries were found in the thoracic area (lungs and ribs) and in the lower extremity, especially near the femoral shaft fracture.

Effects of associated injuries on mortality

The overall mortality after femoral shaft fractures was 4.3%. Multivariate analysis was used to determine the independent effects of age, modified CCI, and specific associated injuries on mortality (Table 4).

With regards to age (while controlling for modified CCI and associated injuries), compared to the 18-39 year old reference group, the 40-64 age group had a 1.92 times increased odds of death and 65+ age group had a 4.29 increased odds of death. With regards to modified CCI (while controlling for age and associated injuries), values of 2 and above all had increased odds of death compared to a modified CCI of zero. Both age and modified CCI had a statistically significant correlation with mortality ($p<0.05$).

Lastly, the effects of associated injuries (by anatomic region) on the odds of death were assessed (while controlling for age and modified CCI). These are shown in order of increasing odds of mortality in Table 4. The associated injuries by anatomic area that correlated with the greatest increase in odds of death were thoracic organ injuries (adjusted odds ratio [AOR]=3.53), head injuries (AOR=2.93), abdominal organ injuries (AOR=2.78), and pelvic fractures (AOR=1.80).

Discussion

Femoral shaft fractures are relatively common injuries that can result from high-energy trauma. Noting that there can be associated injuries with femoral shaft fractures, traditional teaching demands a thoughtful evaluation of the femoral neck, as the incidence of this concomitant injury with femoral shaft fractures has been documented anywhere from 2.5% to 9%.[16-19] However, to our knowledge, there has been no reported compelling data defining the likelihood of the overall spectrum of injuries that can be associated with femoral shaft fractures.

The current study utilized the NTDB to identify a cohort of 26,357 adult femoral shaft fractures patients. This is a much large sample size than those found in previous femoral shaft studies.[20,21] That said, the demographics of the identified cohort were in line with the prior studies. For example, the majority of these femoral shaft fractures occurred in patients between 18 and 39 years of age, which is comparable to previously identified peak incidences between 15 and 24 years of age.[21] As another example, the identified cohort had a male-to-female ratio of 1.7:1, which is comparable to a previously reported ratio of 1.4:1.[20] Furthermore, consistent with what would be anticipated, modified CCI was found to increase with age, and the predominant mechanism of injury was found to transition from MVAs to falls with increasing age.

ISS gives us an overview of the severity of both the femoral shaft fracture and associated injuries. In our study, ISS was found to be higher in younger patients than older patients, consistent with the expected higher energy mechanisms and greater overall injury level for younger patients.[22] However, importantly, ISS alone does not define the specific injuries associated with femoral shaft fractures, which was the focus of our work.

Specific associated injuries were evaluated and results are presented in tabular and graphic formats in the current paper.

As an example of a specific associated injury, femoral neck fractures have been reported to be associated with femoral shaft fractures with an incidence ranging from 2.5%-9%. This was confirmed by our analysis, which showed that 5.8% of femoral shaft fractures had concomitant femoral neck fractures (completely in line with prior reports).[16,23] This is clearly of clinical importance for the treating surgeon, who should be aware of this when managing patients with this combination of injuries.

From our analyses of bony injuries associated with femoral shaft fractures, it was found that 38.1% had other lower extremity fractures (notably 20.5% had tibia/fibula fractures), while 22.4% had upper extremity fractures. These high incidences suggest that the extremities need to be thoroughly assessed for concomitant injuries and that there should be a low threshold for imaging any area of question.

In addition, spinal injuries were relatively common in this population (16.8% of patients with femoral shaft fractures had a concomitant spinal fracture). This is notable since this incidence is comparable to that of patients with a known spine fracture who also have a non-contiguous spinal fracture (reported ranges from 6.4% to 19%).[24,25] For patients with a spine fracture, conventional teaching promotes a low threshold to evaluate for non-contiguous fractures. The same appears to be true for the need to evaluate for any spine fracture in the femoral shaft fracture patient as well.

From our analysis of internal organ injuries associated with femoral shaft fractures, it was found that thoracic injuries (19.5%), abdominal injuries (14.2%), and intracranial injuries (13.5%) were quite common. This suggests a higher incidence than a previous study that showed concomitant thoraco-abdominal injuries (10.9%) with femoral shaft fractures.[21] The high incidence of internal organ injuries identified underscores the importance of the "pan scan" for patients with high energy injuries when clinically appropriate to ensure that such associated internal organ injuries are not missed.

Finally, multivariate analysis showed that increasing age, increasing modified CCI, and many of the associated injuries (most notably thoracic organ, head, and abdominal organ injuries) had significant associations with higher risk of mortality. This underscores the importance and impact of associated injuries, highlighting the clinical importance of appreciating the associated injuries defined in the current study.

The major limitation of the current study deals with the data acquired from NTDB. Since NTDB focuses on trauma patients, the studied population may be biased towards femoral shaft fractures that occur in the setting of more severely injured patients than the general population. Also, because NTDB is a "convenience sample," the data "may not be representative of all hospitals."[13] It is important to note that trauma victims who die before transport to a hospital are not included in the NTDB, and so this study does not represent those femoral shaft fractures that result in immediate death.[13] Lastly, although we gathered all femoral shaft fracture patients in the NTDB by ICD-9 diagnosis coding, it is crucial that we emphasize the potential variability within this group, as fracture classification was not available in the data set.

Tables

Table 1: Distribution of modified Charlson comorbidity index (CCI)

CCI	Age			
	18-39	**40-64**	**65+**	**Total**
0	93.7%	77.8%	56.5%	81.7%
1	5.6%	15.5%	25.4%	12.4%
2	0.6%	3.6%	10.0%	3.3%
3	0.1%	1.7%	4.2%	1.4%
>=4	0.0%	1.4%	3.9%	1.2%
Total	100%	100%	100%	100%

Note: Underlined values represent median CCI values for each age group.

Table 2: Distribution of Injury Severity Score (ISS)

ISS	Age			
	18-39	**40-64**	**65+**	**Total**
0-9	30.7%	41.0%	73.0%	42.2%
10-19	40.1%	33.9%	18.7%	34.0%
20-29	16.6%	14.5%	5.4%	13.7%
30+	12.6%	10.6%	3.0%	10.1%
Total	100%	100%	100%	100%

Note: Underlined values represent ISS ranges containing median values for each age group.

Table 3: Percent Incidence of Injuries for Each Age Group

	18-39	40-64	65+	Total
Head Injury	26.2	21.4	7.0	21.0
Skull Fracture	14.9	11.2	3.0	11.4
Intracranial Injury	16.5	14.3	5.0	13.5
Spinal Injury	18.1	20.9	7.7	16.8
Cervical Spine	5.4	6.5	2.9	5.2
Thoracic Spine	5.3	6.7	2.4	5.1
Lumbar Spine	9.5	11.6	3.8	8.9
Sacral Spine	4.6	4.8	1.4	4.0
Ribs/Sternum	18.9	26.5	9.7	19.1
Pelvic Fracture	15.6	15.2	5.8	13.5
Acetabulum	8.4	7.1	2.4	6.8
Pubis	5.9	6.2	2.7	5.4
Ilium	2.0	2.4	0.7	1.8
Ischium	0.5	0.6	0.3	0.5
Upper Extremity Fracture	25.8	24.5	10.8	22.4
Clavicle	4.2	4.2	1.6	3.7
Scapula	3.6	3.5	1.0	3.0
Humerus	5.8	6.6	3.5	5.5
Proximal Humerus	1.6	2.6	2.0	2.0
Humeral Shaft	2.7	2.5	0.8	2.2
Distal Humerus	1.4	1.5	0.7	1.3
Radius/Ulna	12.7	12.2	5.0	11.0
Proximal Radius/Ulna	2.9	2.7	0.8	2.4
Radial/Ulnar Shaft	4.3	3.6	1.1	3.4
Distal Radius/Ulna	6.1	6.4	3.0	5.6
Hand	7.3	5.9	2.3	5.8
Lower Extremity Fracture	38.0	47.1	26.2	38.1
Other Femur Fracture	15.1	25.6	19.5	18.9
Proximal Femur	9.5	16.1	10.5	11.6
Femoral Neck	5.8	6.8	4.5	5.8
Distal Femur	5.4	10.3	8.7	7.5
Patella	5.8	5.0	1.8	4.8
Tibia/Fibula Fracture	22.1	26.6	8.4	20.5
Proximal Tibia/Fibula	6.5	10.9	3.4	7.1
Tibial/Fibular Shaft	8.8	10.6	2.7	8.1
Ankle	8.5	9.8	3.3	7.8
Foot	10.1	10.2	2.4	8.6
Thoracic Organ Injury	25.3	18.6	6.0	19.5
Heart	0.8	1.2	0.4	0.8

Lung	24.7	17.8	5.7	18.9
Pneumothorax	15.1	12.6	4.3	12.2
Diaphragm	0.8	1.0	0.2	0.7
Abdominal Organ Injury	18.4	14.2	3.6	14.2
GI Tract	4.7	4.5	0.9	3.8
Liver	8.7	5.0	1.4	6.2
Spleen	7.9	5.5	1.1	5.9
Kidney	3.7	2.0	0.5	2.6
Pelvic Organ Injury	1.5	1.4	0.2	1.2

Note: All values are percentages.

Table 4: Multivariate Mortality Analysis

Outcome: Mortality	Adjusted Odds Ratio	95% CI*	P-value
Age (reference=18-39)			<0.001
40-64	1.92	1.65-2.23	
65+	4.27	3.55-5.16	
Modified CCI (reference=0)			<0.001
1	0.70	0.56-0.88	
2	1.45	1.04-2.03	
3	2.88	1.95-4.27	
4+	2.69	1.78-4.07	
Associated Injuries (in increasing order of odds of mortality)			
Lumbar Spine	0.72	0.60-0.86	<0.001
Lower Extremity	0.96	0.84-1.10	0.541
Thoracic Spine	1.11	0.90-1.36	0.342
Upper Extremity	1.30	1.13-1.50	<0.001
Cervical Spine	1.40	1.15-1.70	0.001
Pelvic Fracture	1.80	1.55-2.08	<0.001
Abdominal Organ	2.78	2.39-3.23	<0.001
Head	2.93	2.54-3.38	<0.001
Thoracic Organ	3.53	3.01-4.14	<0.001

* CI = Confidence Interval

Figures

Figure Captions

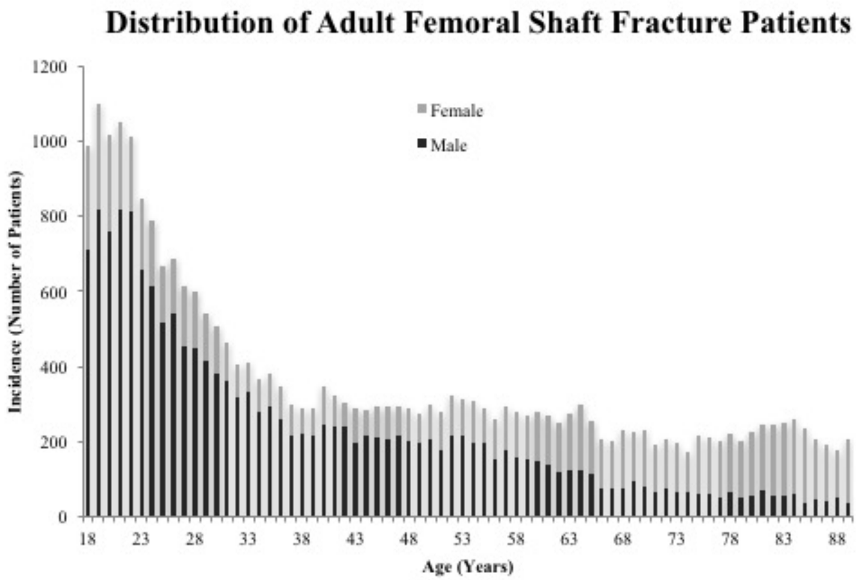
Figure 1: Distribution of ages of femoral shaft fracture patients by gender.

Figure 2: Distribution of femoral shaft fracture patients by mechanism of injury and age groups.

Figure 3: Schematic representation of percentages of adult (18 years and older) femoral shaft fracture patients with incidence of associated bony injuries in different regions of the skeleton. Darker shadings in grayscale correspond to higher frequencies of associated injuries.

Figure 4: Schematic representation of percentages of adult (18 years and older) femoral shaft fracture patients with incidence of associated internal organ injuries in different regions of the body. Darker shadings in grayscale correspond to higher frequencies of associated injuries.

Figure 1



Distribution of Adult Femoral Shaft Fracture Patients
1200
1000
800
600
400
200
0
Female
Male
Incidence (Number of Patients)
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
Age (Years)

Figure 2

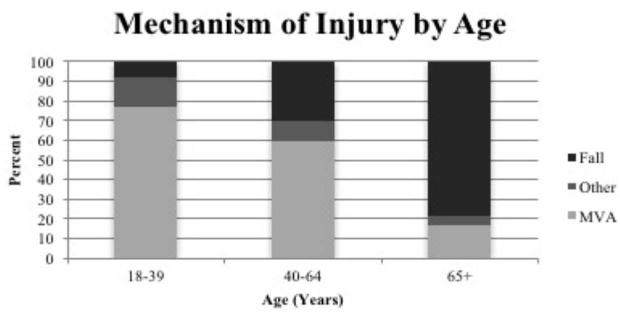

Mechanism of Injury by Age
Percent
100
90
80
70
60
50
40
30
20
10
0
18-39
40-64
65+
Age (Years)
Fall
Other
MVA

Figure 3

Bone Injuries Associated with Femoral Shaft Fractures

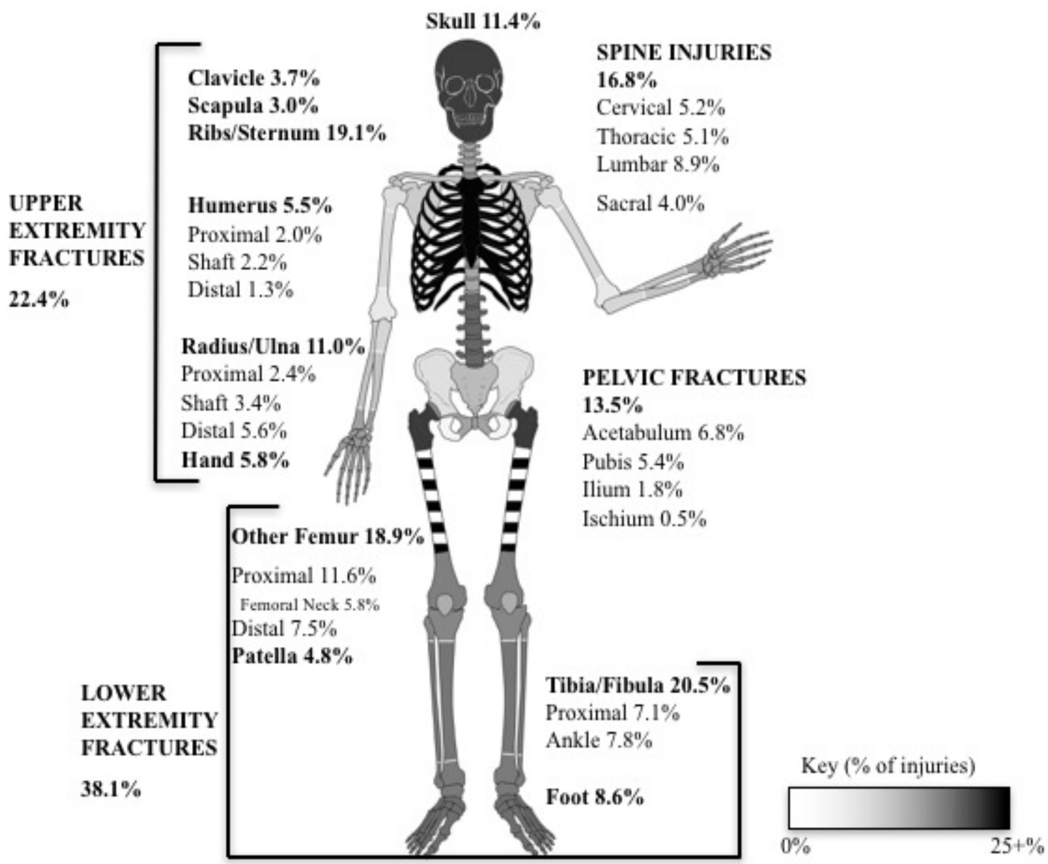
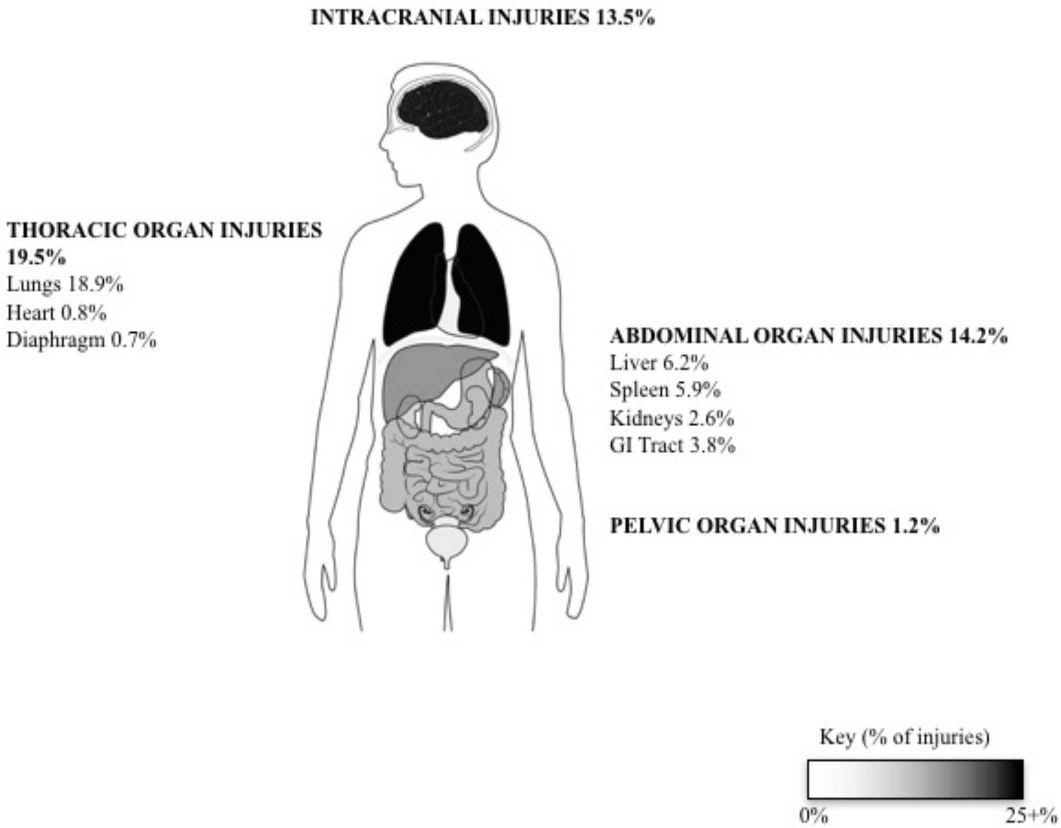


Figure 4

Internal Organ Injuries Associated with Femoral Shaft Fractures



Appendices

Appendix 1: International Classification of Disease, Ninth Revision (ICD-9) diagnosis codes for skeletal injuries associated with femoral shaft fracture

Injury	ICD-9 diagnosis codes
Skull fracture	800.00 - 804.99
Spinal injury (cord or vertebrae)	All subcategories listed below
Cervical spine injury	805.00 - 805.19, 806.00 - 806.19, 952.00 - 952.09
Thoracic spine injury	805.2, 805.3, 806.20 - 806.39, 952.1
Lumbar spine injury	805.4, 805.5, 806.4, 806.5, 952.2
Sacral spine injury	805.6, 805.7, 806.60 - 806.62, 806.69, 806.70 - 806.72, 806.79, 952.3, 952.4
Rib/Sternum injury	807.0, 807.00 – 807.19, 807.1, 807.2, 807.3, 807.4
Pelvic fracture	808.40 - 808.59, 808.8, 808.9 + All subcategories listed below
Acetabulum fracture	808.0, 808.1
Pubis fracture	808.2, 808.3
Ilium fracture	808.41, 808.51
Ischium fracture	808.42, 808.52
Upper extremity fracture	818.0, 818.1, 819.0, 819.1 828.0, 828.1 + All subcategories listed below
Clavicle fracture	810.00 - 810.19
Scapula fracture	811.00 - 811.19
Humerus fracture	812.2, 812.3 + All subcategories listed below
Proximal humerus fracture	812.00 - 812.19
Midshaft humerus fracture	812.21, 812.31
Distal humerus fracture	812.40 - 812.59
Radius/Ulna fracture	813.80 - 813.83, 813.90 - 813.93 + All subcategories listed below
Proximal radius/ulna fracture	813.00 - 813.19
Midshaft radius/ulna fracture	813.20 - 813.39
Distal radius/ulna fracture	813.40 - 813.59
Hand fracture	814.00 - 817.19
Lower extremity fracture	819.0, 819.1, 827.0, 827.1, 828.0, 828.1 + All subcategories listed below
Femur fracture	821.00, 821.10 + All subcategories listed below
Proximal femur fracture	820.00 - 820.99 (Femoral neck fracture: 820.00 - 820.19, 820.8, 820.9)
Distal femur fracture	821.20 - 821.39
Patella fracture	822.0, 822.1
Tibia/fibula fracture	823.80, 823.81, 823.82, 823.90, 823.91, 823.92 + All subcategories listed below
Proximal tibia/fibula fracture	823.00 - 823.19
Midshaft tibia/fibula fracture	823.20 - 823.39
Ankle fracture	824.0 - 824.9
Foot fracture	825.20, 825.26 - 825.29, 825.30, 825.36 - 825.39 + All subcategories listed below

Appendix 2: International Classification of Disease, Ninth Revision (ICD-9) diagnosis codes for non-skeletal injuries associated with femoral shaft fracture

Injury	ICD-9 diagnosis codes
Intracranial injury	850.00 - 854.19
Thoracic organ injury	862.10 - 862.99 + All subcategories listed below
Heart injury	861.00 - 861.19
Lung injury	861.20 - 861.39 + 860.0 - 860.5 (Pneumothorax)
Diaphragm injury	862.0, 862.1
Abdominal organ injury	868.00 - 868.19 + All subcategories listed below
Liver injury	864.00 - 864.19
Spleen injury	865.00 - 865.19
Kidney injury	866.00 - 866.19
GI tract injury	863.00 - 863.99
Pelvic organ injury	867.00 - 867.99

Section II

Tibial Shaft Fracture: A Large-scale Study Defining the Injured Population and Associated Injuries

This section was published as follows:
Anandasivam NS, Russo GS, Swallow MS, Basques BA, Samuel AM, Ondeck NT, Chung SH, Fischer JM, Bohl DD, Grauer JN. Tibial shaft fracture: A large-scale study defining the injured population and associated injuries. Journal of Clinical Orthopaedics and Trauma. 2017; 8(3): 225-231. PubMed ID: 28951639

Introduction

Tibial shaft fractures occur with an incidence of 16.9/100,000/year.[1] They are associated with significant short- and long-term morbidities,[2] ranging from acute compartment syndrome to chronic leg and knee pain.[3] Furthermore, tibial shaft fractures in working-age adults have been shown to have a significant financial impact, both in terms of direct medical costs and lost productivity.[4]

As with other orthopaedic injuries, several studies have characterized patients with tibial shaft injuries in terms of age, gender, mechanism of injury (MOI) and fracture type. One such study by Larsen et al. found that men have a higher frequency of fractures while participating in sports activities, while women have a higher frequency while walking and during indoor activities.[1] Another study by Court-Brown et al. found that the majority of tibial shaft fractures were caused by falls from height and road-traffic accidents.[5] However, both of these studies may be limited by their population sizes (both under 600) or regional factors (both done at single institutions).

In the orthopaedic trauma assessment, it is helpful to know the likelihood of associated injuries in order to optimize evaluations and ensure appropriate management. For example, in the setting of a calcaneus fracture, the strong association with vertebral column injury is often considered.[6] Similarly, with open clavicle fractures, pulmonary and cranial injuries are important to suspect and recognize early.[7] Although a few studies have examined injuries associated with tibial shaft fractures such as ankle, posterior malleolus, and ligamentous injuries,[8-11] no previous study has characterized overall bony and internal organ injuries that are associated with tibial shaft fractures.

The aim of the present study is to use a large, national sample of adult trauma patients with tibial shaft fractures in order to characterize the patient population, comorbidity burden (modified Charlson Comorbidity Index [CCI]), MOI, injury severity score (ISS), and specific associated injuries for adult patients with tibial shaft fractures. It is believed that a better understanding of such variables would help health care providers optimize patient evaluation and management.

Methods

Patient Cohort

The National Trauma Data Bank Research Data Set (NTDB RDS) was used to identify patients for this study. This database is compiled from several hundreds of trauma centers around the US and contains administrative and registrar-abstracted data on over five million cases.[12] Data files are processed through a validation phase to ensure reliability and consistency of the data used for research.[12]

The inclusion criteria for patients in this study were: (1) hospital admission during years 2011 and 2012, (2) over 18 years of age, and (3) an International Classification of Disease, 9th Revision code for tibial shaft fracture (823.20, 823.22, 823.30, 823.32). A waiver was issued for this study by our institution's Human Investigations Committee.

Patient Characteristics

Age was directly abstracted from the database. After evaluation of the age distribution, subsequent analyses were done with age groups defined based on clusters in the population (18 – 39 years, 40 – 64 years, 65+ years).

The following comorbidities were directly extracted from the database: hypertension, alcoholism, diabetes, respiratory disease, obesity, congestive heart failure, coronary artery disease, prior cerebrovascular accident, liver disease, functionally dependent status, cancer, renal disease dementia, and peripheral vascular disease. From these patient characteristics, a modified CCI[13] that has been shown to have comparable predictive value to the original CCI was calculated.[14] Modified CCI was computed based on an algorithm previously described by an earlier study by Samuel et al.[15]

Injury Characteristics

ISS is an overall assessment of body trauma severity based on the Abbreviated Injury Scale.[16] This is a variable that was directly abstracted from the NTDB RDS data set.

The categorizations for MOI were "fall", motor vehicle accident ("MVA"), or "other". Patients with a fall mechanism of injury were determined based on the following ICD-9 e-code ranges: 880.00 – 889.99, 833.00 – 835.99, 844.7, 881, 882, 917.5, 957.00 – 957.99, 968.1, 987.00 – 987.99. Patients with an MVA mechanism of injury were determined based on the following ICD-9 e-code ranges: 800-826, 829-830, 840-845, 958.5, and 988.5. Patients included in this MVA category were involved in accidents as motor vehicle drivers/passengers, motorcyclists, bicyclists, or pedestrians. All other e-codes were counted as "other".

For associated injuries, ICD-9 diagnosis codes that were used to identify associated bony and internal organ injuries. It is important to note that based on this data set, it could not be distinguished whether proximal and distal tibia associated injuries were contiguous (extensions of the same fracture line) or indicative of segmental injuries.

Thus, these were not included as "associated injuries" because it could not be determined if they were separate from the primary injury.

Mortality data was obtained directly from NTDB RDS. This was based on whether the patient died in the emergency department or the hospital prior to discharge.

Data Analysis

Adobe® Photoshop® CS3 (Adobe Systems Incorporated, San Jose, California) was used to illustrate the associated injury frequencies by shadings on the skeleton and internal organ figures. In these figures, darker shadings represent higher frequencies of associated injury.

All statistical analyses were conducted using Stata® version 13.0 statistical software (StataCorp LP, College Station, TX). Multivariate logistic regression was used to determine the association of age, modified CCI, and various associated injuries with mortality. Chi-square statistics for associations with mortality were obtained from Wald tests by using the "test" command following logistic regression on Stata. All tests were two-tailed and a two-sided α level of 0.05 was taken as statistically significant.

Results

Patient Characteristics

A total of 27,706 adult patients (19,312 males and 8,394 females) with tibial shaft fractures were identified. There were 16,896 (61.0%) closed fractures and 10,810 (39.0%) open fractures.

The distributions of open and closed fractures are shown by age in Figure 1. This distribution overall appeared bimodal with peaks at around 20 and 50 years of age. Based on this age distribution noted for these injuries, the decision was made to analyze the population by age categories (18-39, 40-64 and 65+). More young adults (18-65) were males, while more older adults (65+) were females as shown in Table 1. The medians for modified CCI were 0, 2, and 4 for ages 18-39, 40-64, and 65+, respectively (Table 2).

Injury Characteristics

The median ranges for ISS were in the 0-9 range for the three age categories (Table 3). In terms of mechanism of injury distributions, it is noted that ages 18-39 predominantly suffered MVAs, while the elderly (65+) primarily suffered falls (Figure 2).

Frequencies of associated injuries were analyzed by age group (Table 4). The frequencies were overall similar across the ages for all associated injuries, although there was a slight general decline in associated injury frequency as age increased. For example, head injury frequency declined as age increased (18.09% for 18-39; 16.79% for 40-64; 14.33% for 65+). However, ribs/sternum injury frequency showed the opposite trend, with some increase with increased age.

Because similar frequencies of associated injuries were found across the age groupings, the population was considered as a whole to graphically represent the frequencies of bony (Figure 3) and internal organ (Figure 4) injuries that accompany tibial shaft fractures. It was found that the three most common bony injuries outside of the tibia/fibula shaft region are ankle (16.58%), ribs/sternum (14.56%), and spine (14.0%) fractures. The two most common internal organ injuries were lung (12.52%) and intracranial (11.3%) injuries. Overall, 59.6% of tibial shaft fracture patients had at least one associated injury (58.2% of patients had at least one other bony fracture, and 16.7% of patients had at least one internal organ injury).

To determine the impact of associated injuries versus patient factors (age and CCI) on inhospital mortality, a multivariate regression analysis was conducted (Table 5). Mortality was more associated with the presence of an associated injury (chi-squared = 268.3) than age (chi-squared = 86.0) or CCI (chi-squared = 0.2). In fact, controlling for age and CCI, the odds of mortality with at least one associated injury is over 12-fold compared to without any associated injuries.

Discussion

Tibial shaft fractures are common injuries. While several studies have been done regarding the optimal method of treatment for tibial shaft injuries, little work has explored the rate and impact of tibial shaft fracture associated injuries.

Due to distraction, associated injures can be missed on preliminary trauma surveys if not specifically considered. Rapid identification and treatment of such injuries is important to optimize patient care. Thus, the primary goals of this study were to define patient characteristics, MOI, and associated injuries for a large patient population sustaining tibial shaft fractures. The secondary goal of the study was to evaluate the impact of such associated injuries on an important clinical endpoint--inhospital mortality--relative to other patient factors.

Our research sample from the National Trauma Database (NTDB) included 27,706 tibial shaft fracture patients. Overall, the age distribution of our population was bimodal, with peaks at ages 21 and 47 years of age (Figure 1). There were nearly twice as many male patients than female patients, with the younger population especially favoring male over female subjects (Table 1). Furthermore, there were few elderly subjects past age 65. Based upon the bimodal and nonuniform age distribution, age categories of 18-39, 40-64, and 65+ were created, as it was suspected that these different categories may be representing distinct patient populations.

Our suspicions were confirmed when analyzing MOI (Figure 2), as the older population tended to suffer injury predominantly from falls, whereas the younger populations were mostly injured from motor vehicle accidents. This trend may be explained by the loss of bone strength typically exhibited in elderly patients. Whereas a tibial shaft fracture in a young patient would characteristically require a high-energy fall, relatively lower energy falls can cause the injury in an elderly person.

To further gain an understanding of our subject population, the individual comorbidities were extracted, along with the Injury Severity Score (ISS) for each patient. Comorbidities were converted to the modified Charlson comorbidity index (CCI), a single value that could be used in multivariate analysis (Table 2). CCI was an effective means to control for the relative health of the subjects while analyzing different variables for their effect on patient morbidity. For our population, CCI increased linearly with increasing age.

ISS was also recorded as a tool to convert the severity of associated injuries for the population into a single variable. For our study, all three age categories tended to exhibit patients with mostly ISS values of 0-9 (Table 3), indicating that most patients have few severe associated injuries. However, a slight increase in frequency of higher ISS values was found in the younger population, suggesting that younger patients are more likely to suffer from extra-tibial injuries.

Similar to the trend with ISS, the rate of associated injuries did not show any significant or abrupt changes based upon age category (Table 4). A slight decrease in associated injuries occurred as age increased, but even this trend was not present throughout this study, as seen by the increasing rate of rib fractures in elderly patients. Because there were no drastic differences in associated injuries based upon age group, the entire population's associated injury data were transformed into a single visual format

(Figures 3 and 4). Darker shades on respective body parts correlate with higher rates of associated injuries. The most common bony injuries were ankle fractures. Although the high rate of ankle fractures may be expected based on proximity to the primary injury (tibial shaft fracture), other bony injuries of note that were further from the tibia include spine injuries (13.99%), skull fractures (9.39%), and upper extremity fractures (16.33%). Even though approximately 1/5 of tibial shaft fractures have an accompanying upper extremity fracture, there was no specific upper extremity bone that was most commonly injured. The most common soft tissue injuries found with tibial shaft fractures were lung (12.52%) and intracranial injuries (11.3%). Of the lung injuries, a majority of the subjects suffered from pneumothorax (8.19%).

In order to gauge the importance of associated injuries, a multivariate regression analysis was conducted to determine their effects on tibial shaft fracture mortality rates. Age and comorbidities have previously been linked in determining a patient's mortality rate for inpatient orthopaedic surgeries,[18] but this study focused on how associated injuries affected patient morbidity. Overall, the presence of an associated injury had the largest effect (odds ratio = 12.9) on mortality compared to age and CCI. This demonstrates the importance of associated injuries in predicting important aspects of patient outcomes. This data implies that when assessing the mortality of a trauma patient with a tibial shaft fracture, associated injuries may be more important to examine than age or CCI.

One major limitation of this study stems from the data collected by the NTDB. Since the patient data collected by the NTDB comes from hospitals that "have shown a commitment to monitoring and improving the care of injured patients" and voluntarily submit data to the NTDB, this data may not be representative of all hospitals and trauma centers.[12] Further, specific fracture and associated injury information was limited to ICD-9 level coding.

Tables

Table 1: Age and Gender Distribution

	Male	Female	Total
18-39	9,724	3,121	12,845
40-65	8,144	3,598	11,742
65+	1,444	1,675	3,119
Total	19,312	8,394	27,706

Table 2: Distribution of Modified Charlson Comorbidity Index (CCI)

CCI	Age			
	18-39	**40-64**	**65+**	**Total**
0	93.41%	3.85%	0%	44.94%
1	5.73%	38.70%	0%	19.06%
2	0.64%	35.54%	0%	15.36%
3	0.11%	14.95%	26.55%	9.37%
4	0.03%	4.42%	42.16%	6.63%
>=5	0.09%	2.55%	31.29%	4.64%
Total	100%	100%	100%	100%

Note: Underlined values represent median CCI values for each age group.

Table 3: Distribution of Injury Severity Score (ISS)

ISS	Age			
	18-39	**40-64**	**65+**	**Total**
0-9	<u>57.28%</u>	<u>59.95%</u>	<u>65.5%</u>	59.33%
10-19	25.61%	23.37%	19.27%	23.94%
20-29	10.07%	9.94%	9.49%	9.95%
30+	7.05%	6.75%	5.74%	6.77%
Total	100%	100%	100%	100%

Note: Underlined values represent median ISS values for each age group.

Table 4: Percent Incidence of Injuries for Each Age Group

	18-39	40-64	65+	Total
Head Injury	18.09	16.79	14.33	17.12
Skull Fracture	10.26	9.32	6.06	9.39
Intracranial Injury	11.61	11.13	10.68	11.3
Spinal Injury	12.58	15.45	14.3	13.99
Cervical Spine	3.54	5.25	5.87	4.53
Thoracic Spine	3.67	5.16	4.62	4.41
Lumbar Spine	6.89	8.22	6.32	7.39
Sacral Spine	3.38	3.48	3.56	3.44
Ribs/Sternum	11.07	17.4	18.24	14.56
Pelvic Fracture	9.25	9.88	9.27	8.48
Acetabulum	4.31	4.33	2.85	4.16
Pubis	3.75	4.63	5.26	4.3
Ilium	1.19	1.5	1.64	1.37
Ischium	0.28	0.32	0.26	0.29
Upper Extremity Fracture	16.26	16.64	15.45	16.33
Clavicle	2.76	3.49	3.75	3.18
Scapula	3.01	3.71	2.66	3.27
Humerus	3.95	4.52	4.71	4.28
Proximal Humerus	1.4	2.38	2.92	1.99
Humeral Shaft	1.73	1.32	1.06	1.48
Distal Humerus	0.75	0.88	0.71	0.8
Radius/Ulna	7.05	6.69	5.96	6.77
Proximal Radius/Ulna	1.74	1.75	1.06	1.67
Radial/Ulnar Shaft	2.6	2.34	2.05	2.43
Distal Radius/Ulna	3.13	3.13	2.92	3.1
Hand	4.34	4.05	3.46	4.12
Lower Extremity Fracture	39.73	48.98	46.3	44.39
Other Femur Fracture	11.55	10.02	9.84	10.71
Proximal Femur	2.48	3.33	3.24	2.92
Femoral Shaft	7.57	4.95	3.43	5.99
Distal Femur	2.55	3.53	4.1	3.14
Patella	2.2	2.11	2.02	2.14
Tibia/Fibula Fracture	27.88	39.48	37.83	33.92
Proximal Tibia/Fibula	10.41	18.56	17.95	14.71
Ankle	14.33	18.57	18.34	16.58
Foot	9.97	10.01	7.02	9.65
Thoracic Organ Injury	13.87	12.27	11.51	12.93
Heart	0.32	0.6	0.45	0.45

Lung	13.55	11.8	11.03	12.52
Pneumothorax	8.19	8.19	8.14	8.19
Diaphragm	0.45	0.52	0.55	0.49
Abdominal Organ Injury	9.99	8.21	6.41	8.83
GI Tract	2.38	2.29	1.51	2.25
Liver	4.43	2.75	1.99	3.44
Spleen	4.15	3.03	1.92	3.43
Kidney	2.13	1.42	0.96	1.7
Pelvic Organ Injury	0.95	0.96	0.67	0.92

Table 5: Multivariate Analysis of Effects of Associated Injuries on Mortality

Outcome: Mortality	Multivariate Odds Ratio	95% CI	Chi-square statistic*	P-value
Age (reference = 18-39)			86.01	<0.05
40-64	1.32	1.13-1.55		
65+	3.01	2.46-3.67		
CCI (reference = 0)			0.17	0.68
1	0.65	0.51-0.82		
2	0.81	0.52-1.25		
3	1.36	0.80-2.31		
4	0.70	0.22-2.24		
5+	2.33	1.27-4.26		
Associated Injuries (reference = No Associated Injuries)			268.31	<0.05
Presence of At Least One Associated Injury	12.93	9.53-17.54		

*The Chi-statistics were determined from Wald tests (using the "test" command on Stata after multivariate logistic regression), which were used to determine the relative strengths of the independent associations of three variables (age, CCI, and the presence of any associated injury) with mortality.

Figures

Figure Captions

Figure 1: Distribution of open and closed tibial shaft fracture patients by age.

Figure 2: Mechanism of injury distribution of tibial shaft fracture patients by age.

Figure 3: Schematic representation of percentages of adult (over 18 years old) tibial shaft fracture patients with incidence of associated bony injuries in different body regions. Darker shadings in grayscale correspond to higher frequencies of associated injuries.

Figure 4: Schematic representation of percentages of adult (over 18 years old) tibial shaft fracture patients with incidence of associated internal organ injuries in different body regions. Darker shadings in grayscale correspond to higher frequencies of associated injuries.

Figure 1

Distribution of Closed and Open Tibial Shaft Fracture Patients by Age

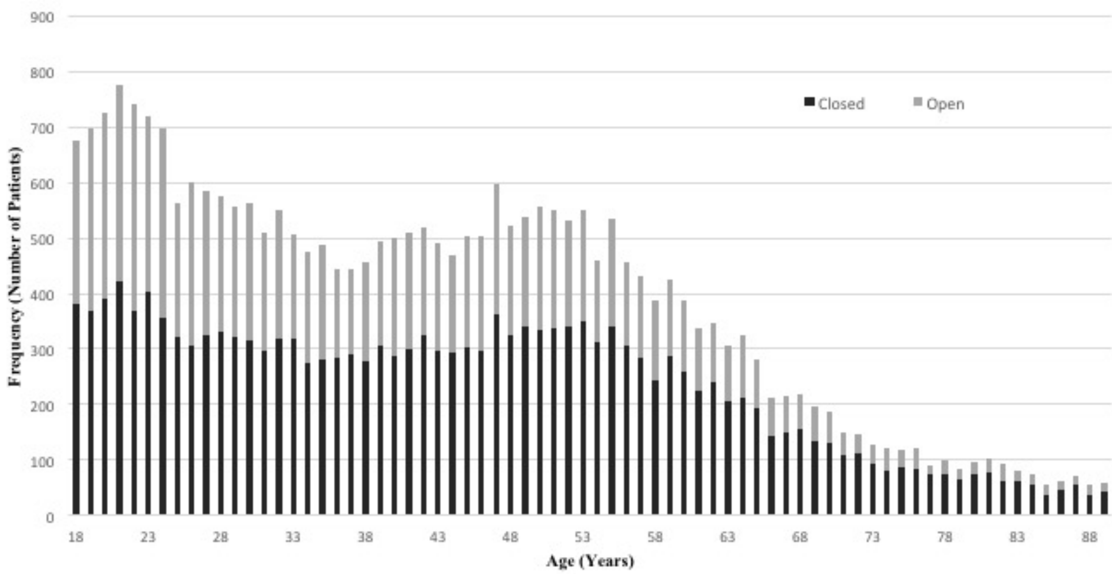


Figure 2

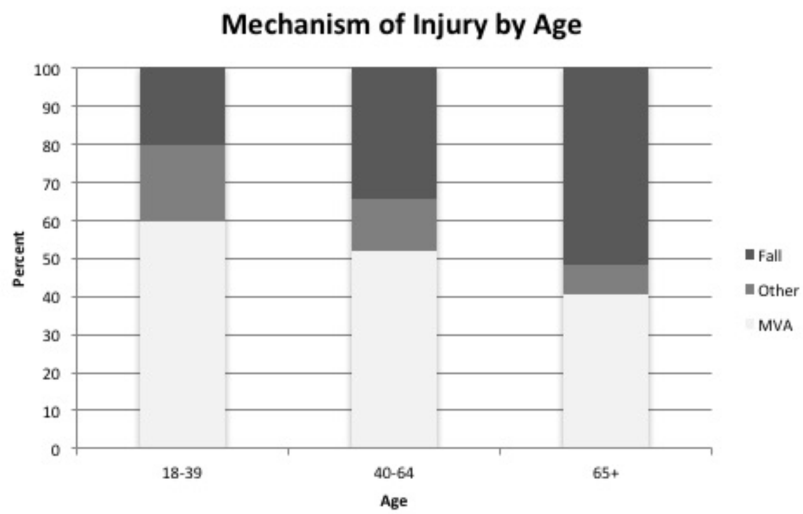

Mechanism of Injury by Age
100
90
80
70
60
50
40
30
20
10
0
Percent
18-39
40-64
65+
Age
Fall
Other
MVA

Figure 3

Bone Injuries Associated with Tibial Shaft Fractures

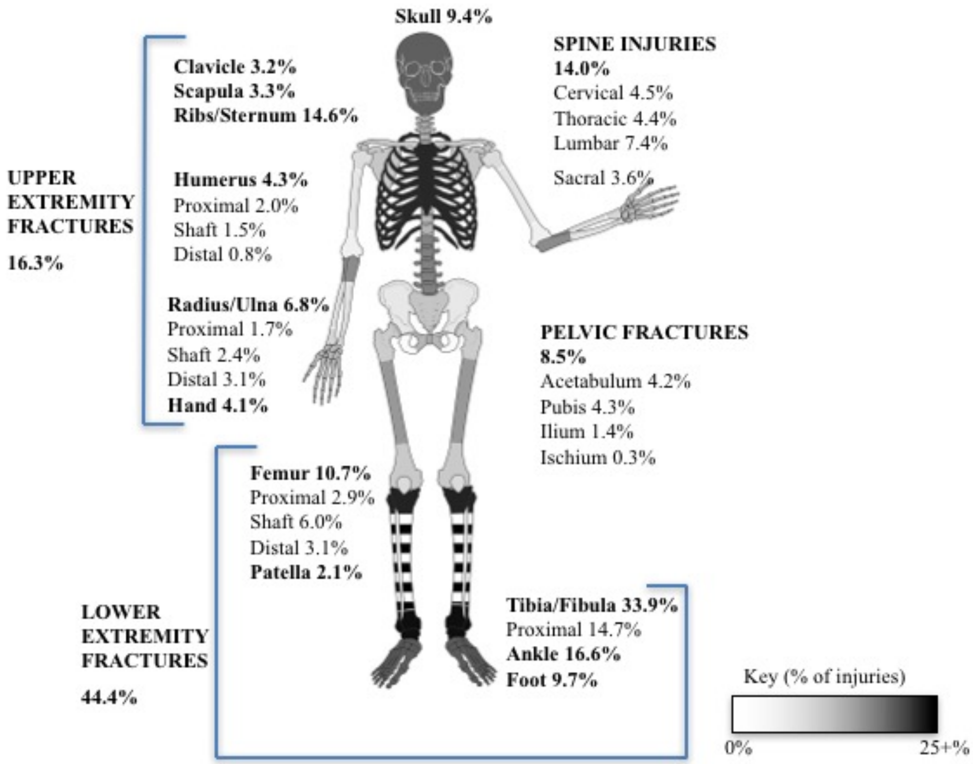
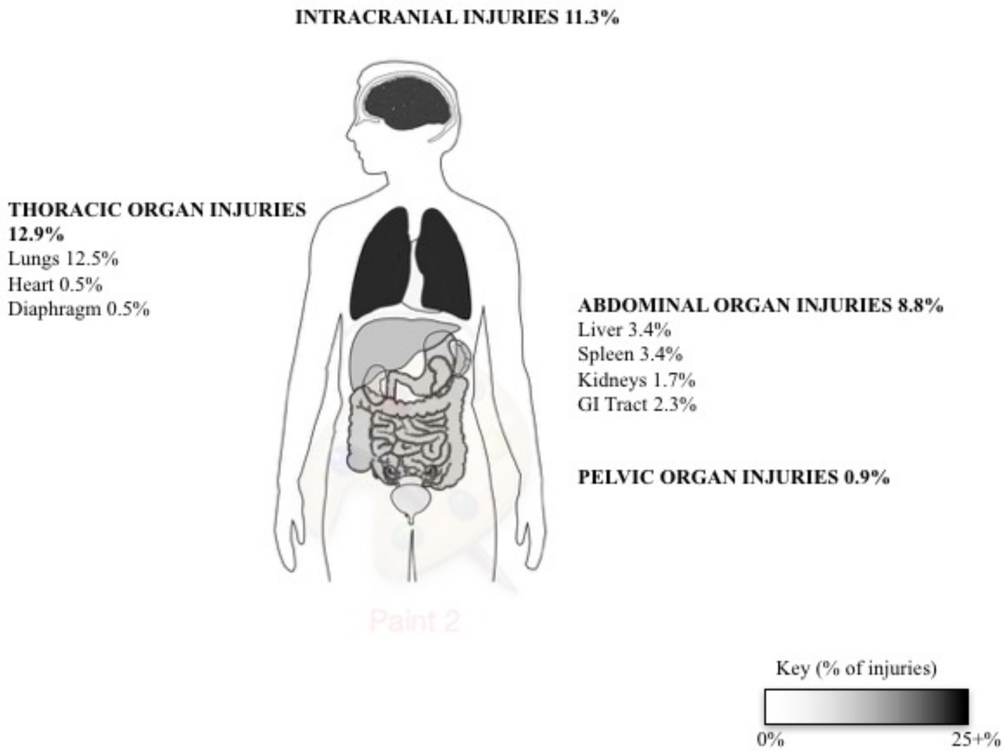


Figure 4

Internal Organ Injuries Associated with Tibial Shaft Fractures



Appendices

Appendix 1: International Classification of Disease, Ninth Revision (ICD-9) diagnosis codes for skeletal injuries associated with tibial shaft fracture

Injury	ICD-9 diagnosis codes
Skull fracture	800.00 - 804.99
Spinal injury (cord or vertebrae)	All subcategories listed below
Cervical spine injury	805.00 - 805.19, 806.00 - 806.19, 952.00 - 952.09
Thoracic spine injury	805.2, 805.3, 806.20 - 806.39, 952.1
Lumbar spine injury	805.4, 805.5, 806.4, 806.5, 952.2
Sacral spine injury	805.6, 805.7, 806.60 - 806.62, 806.69, 806.70 - 806.72, 806.79, 952.3, 952.4
Rib/Sternum injury	807.0, 807.00 – 807.19, 807.1, 807.2, 807.3, 807.4
Pelvic fracture	808.40 - 808.59, 808.8, 808.9 + All subcategories listed below
Acetabulum fracture	808.0, 808.1
Pubis fracture	808.2, 808.3
Ilium fracture	808.41, 808.51
Ischium fracture	808.42, 808.52
Upper extremity fracture	818.0, 818.1, 819.0, 819.1 828.0, 828.1 + All subcategories listed below
Clavicle fracture	810.00 - 810.19
Scapula fracture	811.00 - 811.19
Humerus fracture	812.2, 812.3 + All subcategories listed below
Proximal humerus fracture	812.00 - 812.19
Midshaft humerus fracture	812.21, 812.31
Distal humerus fracture	812.40 - 812.59
Radius/Ulna fracture	813.80 - 813.83, 813.90 - 813.93 + All subcategories listed below
Proximal radius/ulna fracture	813.00 - 813.19
Midshaft radius/ulna fracture	813.20 - 813.39
Distal radius/ulna fracture	813.40 - 813.59
Hand fracture	814.00 - 817.19
Lower extremity fracture	819.0, 819.1, 827.0, 827.1, 828.0, 828.1 + All subcategories listed below
Femur fracture	821.00, 821.10 + All subcategories listed below
Proximal femur fracture	820.00 - 820.99
Midshaft femur fracture	821.01, 821.11
Distal femur fracture	821.20 - 821.39
Patella fracture	822.0, 822.1
Tibia/fibula fracture	823.80, 823.81, 823.82, 823.90, 823.91, 823.92 + All subcategories listed below
Proximal tibia/fibula fracture	823.00 - 823.19
Ankle fracture	824.0 - 824.9
Foot fracture	825.20, 825.26 - 825.29, 825.30, 825.36 - 825.39 + All subcategories listed below
Calcaneus fracture	825.0, 825.1
Talus fracture	825.21, 825.31
Navicular fracture	825.22, 825.32
Cuboid fracture	825.23, 825,33
Cuneiform fracture	825.24, 825.34
Metatarsal fracture	825.25, 825.35
Phalanx fracture	826.0, 826.1

Appendix 2: International Classification of Disease, Ninth Revision (ICD-9) diagnosis codes for non-skeletal injuries associated with tibial shaft fracture

Injury	ICD-9 diagnosis codes
Intracranial injury	850.00 - 854.19
Thoracic organ injury	862.10 - 862.99 + All subcategories listed below
Heart injury	861.00 - 861.19
Lung injury	861.20 - 861.39
Diaphragm injury	862.0, 862.1
Abdominal organ injury	868.00 - 868.19 + All subcategories listed below
Liver injury	864.00 - 864.19
Spleen injury	865.00 - 865.19
Kidney injury	866.00 - 866.19
GI tract injury	863.00 - 863.99
Pelvic organ injury	867.00 - 867.99

Conclusion to Thesis

Several studies have examined specific associated injuries in patients with femoral and tibial shaft fractures. These studies have small sample sizes and are not nationally representative. Because of the lack of knowledge and limited studies on injuries associated with femoral and tibial shaft fractures, this thesis utilized the NTDB to examine these fracture patients for associated injuries on a large scale.

Section 1 examined 26,537 femoral shaft fracture patients from the NTDB. Age, comorbidities, mechanism of injury, injury severity score, and associated injuries were described. The most common mechanisms of injury were motor vehicle accidents (primarily in younger patients) and falls (primarily in older patients). The four most frequent associated injuries were tibia/fibula (20.5%), ribs/sternum (19.1%), non-shaft femur (18.9%), and lung (18.9%) injuries. This demonstrates associated injuries occurring in proximity to the femoral shaft fracture, as well as in the upper body. Mortality was shown to correlate more with associated injuries than with age or comorbidities.

Section 2 examined 27,706 tibial shaft fracture patients from the NTDB. Age distributions, patient characteristics, mechanism of injury, injury severity score, and associated injuries were described. The most common mechanisms of injury were motor vehicle accidents and falls. The four most frequent associated injuries were ankle (16.6%), ribs/sternum (14.6%), spine (14.0%), and lung (12.5%) injuries. This study also shows a concentration of injuries in proximity to the primary injury, as well as a significant frequency of upper body injuries. Mortality was found to be more correlated with associated injuries than age or comorbidity burden.

These two studies are the first to comprehensively characterize bony and internal organ associated injuries using a large national sample of patients with femoral and tibial shaft fractures. In this era of cost containment and reduction of unnecessary imaging, the data provided here will be valuable in helping establish guidelines for managing the initial workup of the orthopaedic trauma patient.

Database studies are limited by the variables contained within. For example, the tibial shaft fracture study in this thesis does not distinguish between proximal and distal tibial shaft fractures because of the lack of granularity of ICD-9 coding. Perhaps newer classification systems such as ICD-10 will be able to add granularity to reach more meaningful conclusions. Furthermore, although overall injury severity is given by the NTDB, a closer look at the injury severity of each associated injury would provide useful information for patient workup. Newer databases could improve by including CPT codes and other variables to link injuries to the surgery the patient received, along with outcomes. A future direction building on this thesis includes examining associated injuries by mechanism of injury, as this would assist in determining which associated injuries to suspect and check for based on mechanism.

Overall in this study, as expected, high frequencies of associated injuries were found in proximity to the primary shaft fracture. It is important to note that high percentages of associated upper body injuries were found as well, including upper extremity, spine, thoracic organ, and intracranial injuries. This supports the notion that a thorough secondary assessment should be performed on patients with lower extremity fractures. In addition, imaging may be warranted to search for occult fractures as patients may not be able to communicate all signs and symptoms during a traumatic situation. Furthermore, the importance of associated injuries is demonstrated by its correlations with mortality.

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