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Authors

Saiz, Augustine M
Wellman, Alexandria C
Stwalley, Dustin
et al.

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The Incidence and Risk Factors Associated With the Need for Fasciotomy in Tibia and Forearm Fractures: An Analysis of the National Trauma Data Bank

Augustine M. Saiz, Jr, MD, Alexandria C. Wellman, MS,† Dustin Stwalley, MA,‡ Philip Wolinsky, MD,* and Anna N. Miller, MD, FACS§*

Objective: The aims of this study were to analyze a large national trauma database to determine the incidence of, risk factors for, and outcomes after a fasciotomy of the lower leg or forearm after fracture.

Methods: Data from the National Trauma Data Bank for the years 2004–2016 were analyzed, and we identified 301,351 patients with forearm fractures and 369,237 patients with tibial fractures. Risk factors, length of stay (LOS), and mortality were assessed to determine associations with an injury that required a fasciotomy.

Results: A total of 1.22% of the forearm fractures and 3.79% of the tibial fractures had a fasciotomy. Patients with a fasciotomy were more likely to have invasive procedures ($P < 0.0001$); have injuries resulting from machinery, motor vehicle collisions, and firearms ($P < 0.0001$); and smoke, use drugs, and/or alcohol ($P < 0.05$) compared with patients who did not undergo fasciotomies. Fasciotomy procedures were associated with longer LOS and higher mortality rate ($P < 0.05$).

Conclusions: The incidence of a fasciotomy is less than 5% in tibia or forearm fractures. Patients who underwent fasciotomy have higher energy injuries, increased alcohol or drug use, higher rates of surgical interventions, and increased LOS. Furthermore, having a fasciotomy is associated with increased mortality rate. When counseling patients and evaluating surgeon/hospital performance, fasciotomies can serve as an indicator and modifier for a more complex trauma pathology.

Key Words: fasciotomy, compartment syndrome, forearm fracture, tibial fracture

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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From the *Department of Orthopaedic Surgery, Davis Medical Center, University of California, Sacramento, CA; †School of Medicine, Southern Illinois University, Springfield, IL; ‡Department of Medicine, Washington University in St. Louis, St. Louis, MO; and §Department of Orthopaedic Surgery, Washington University in St. Louis, St. Louis, MO.

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Reprints: Anna N. Miller, MD, FACS, Department of Orthopaedic Surgery, Washington University in St. Louis, 660 S. Euclid Avenue, Campus Box 8233, St. Louis, MO 63110 (e-mail: milleran@wustl.edu).

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INTRODUCTION

Developing an acute compartment syndrome (CS) that requires a fasciotomy is a well-known sequela of extremity trauma and most commonly occurs in conjunction with a fracture.[1] Tibia and forearm fractures have the highest incidence of an American College of Surgeons (ACS) that requires a fasciotomy when compared with other long bone fractures.[2–4] However, the overall incidence and prevalence of ACS and fasciotomy for these fractures varies widely in the literature.[5] This is likely due to lack of objective data for diagnosing an ACS.[5–7] Once the diagnosis is made, a fasciotomy is indicated as failure to treat leads to significant comorbidities.[8–12] Most studies to date are based on data from single-institution, retrospective reviews.

Patients who require a fasciotomy of the tibia or forearm have higher morbidities, complications, and increased hospital costs, when compared with those who do not need a fasciotomy.[13–16] Identifying risk factors that may be used to predict which patients will require fasciotomies is difficult, given the paucity of large-scale studies. In addition, information on the immediate, in hospital, outcomes after fasciotomy are scarce.

The aim of this study was to document the incidence of, risk factors for, comorbidities associated with, and injury mechanisms associated with a fasciotomy after tibia and forearm fractures. We also analyzed the effect of a fasciotomy on hospital length of stay (LOS), intensive care unit (ICU) LOS, days on a ventilator, and mortality. The goal of our investigation was to provide surgeons with awareness of which patients are at higher risk for fasciotomy and the effect of injury patterns that required a fasciotomy on inpatient outcomes.

METHODS

Prospectively collected data for the years 2002–2016 contained in the National Trauma Data Bank (NTDB) were reviewed. The ACS established the NTDB, the largest repository of trauma data in the United States, in 1997, as a public service to be a repository of trauma-related data voluntarily reported by participating trauma centers.[17] The database is structured as a national probability sample from Level I, II, III, and IV trauma centers in the United States. It currently contains more than 7 million cases from 747 contributing trauma centers, and current data sets date back to 2002. The NTDB is the only national trauma database, and it enables the analysis of trauma-specific information such as mechanism of injury (MOI), injury severity score (ISS), operations/procedures performed, and inpatient outcomes/complications for a large number of trauma patients that includes all payers. The data are extracted from the medical record, using established definitions, by a trained data abstractor. The database contains demographics, discharge status, and ICD-9/10 procedure and diagnosis codes. Each year, the NTDB releases an Annual Report, which is an updated analysis of the data as well as commentary recognizing changes and modifications to improve the registry. All data provided by the NTDB are deidentified and subjected to quality screening for consistency and validity. Hence, our study was waived for review by our Institutional Review Board.

Inclusion criteria for this study consisted of patients greater than 17 years of age with a diagnosis code or Abbreviated Injury Score code for a fracture of the tibia with or without a fibula fracture or a radius and ulna fracture. Patients were identified using the International Classification of Diseases, Ninth Revision, Clinical Modification codes (ICD-9 CM) for injuries and procedures. ICD-9 codes included for the forearm fractures included 813, followed by 3 (Monteggia, closed), 8 (proximal both bone, closed), 13 (Monteggia, open), 18 (proximal both bone forearm, open), 21 (radius shaft, closed), 22 (ulna shaft, closed), 23 (both bone forearm, closed), 31 (radius shaft, open), 32 (ulna shaft, open), and 33 (both bone forearm, open). ICD-9 codes for the tibial fractures included 823, followed by 0 (closed fracture of upper end of tibia alone), 2 (closed fracture of upper end of tibia with fibula), 10 (open fracture of upper end of tibia alone), 12 (open fracture of upper end of tibia with fibula), 20 (closed fracture of tibia shaft alone), 22 (closed fracture of tibia shaft with fibula), 30 (open fracture of tibia shaft alone), and 32 (open fracture of tibia shaft with fibula). All of these patients had a tibia or forearm fracture and a diagnosis of a compartment syndrome and a Current Procedural Terminology (CPT) code for a fasciotomy of the forearm or calf. The ICD-9 codes 950.91 for upper extremity or 950.92 for lower extremity are specific for the diagnosis of a traumatic compartment syndrome, and the CPT codes designate the location of the fasciotomy. Patients were excluded if they had both a tibia and a forearm fracture to avoid confusion regarding fasciotomy site and compartment syndrome.

The data set for patients with fractures of the tibia and forearm with and without fasciotomies was analyzed. Patients were divided into 2 groups: group 1, those with a tibia or forearm fractures and fasciotomy, and group 2, those with a tibia or forearm fracture that did not have a fasciotomy. ISS, external cause of injury codes (Ecode), and comorbidities were recorded for both groups. Treatments, including fracture fixation, skin grafting, surgical flap coverage, operative debridement, transfusion, embolization, and angiography were recorded. The primary outcome was patient mortality. Secondary outcomes included hospital LOS, ICU days (ICU LOS), and ventilator days.

Outcome data, except for mortality, and ISS are presented as counts with 95% confidence intervals (CIs). Mortality along with the Ecode, comorbidities, and treatments rendered are presented as percentages along with relative risks (RRs) and associated 95% CI. Clinical characteristics were compared between the respective tibia/forearm fasciotomy and nonfasciotomy groups using the *t* test for continuous symmetrically distributed variables, the Mann–Whitney test for continuous asymmetrically distributed variables, and chi-square. Two-sided *P*-value of 0.05 was used to determine statistical significance. Statistical significance was considered when the *P* value was 0.05. All analyses were performed using SAS.

RESULTS

We identified 301,351 patients with a forearm fracture who did not have a concomitant tibial fracture. Of those, 1.22% (3672) had a fasciotomy of their forearm. There were 369,237 patients with a tibial fracture without a concomitant forearm fracture. Of those, 3.79% (13,990) had a calf fasciotomy. There were a total of 33,399 patients with a forearm fracture and a tibial fracture. A total of 4.57% (1525) of those underwent a fasciotomy; however, because we could not reliably determine the site of the fasciotomy, these patients were not included in the data analysis.

Demographics/Comorbidities/MOI

Patients who underwent fasciotomy tended to be younger, male, and have a higher ISS than those without a fasciotomy (Table 1). Multiple comorbidities, including smoking, drug use, and alcohol use, were associated with an increased risk of having a fasciotomy (see **Table, Supplemental Digital Content 1**, http://links.lww.com/JOT/A928). Conversely, chronic medical conditions, such as diabetes, congestive heart failure, hypertension, chronic obstructive pulmonary disease, renal failure, cerebrovascular disease, and cancer were associated with a significantly lower risk of having a fasciotomy.

A variety of MOIs were associated with an increased risk of undergoing a fasciotomy (see **Table, Supplemental Digital Content 2**, http://links.lww.com/JOT/A929). The majority had a higher energy MOI, including motor vehicle collisions, transport injuries, machinery, and gunshot wounds. Cutting/piercing trauma was associated with the need for an upper extremity, but not a lower extremity, fasciotomy. An iatrogenic MOI (ie, extravasation after arterial blood draws, casting) was also significantly associated with need for fasciotomy. Conversely, ground-level falls were associated with decreased likelihood of need for fasciotomy.

Mortality Rate

The inpatient mortality rate was significantly higher for patients who had a fasciotomy than for those who did not have a fasciotomy (Table 2). A total of 2.12% of patients who required a forearm fasciotomy died during their hospitalization compared with 1.36% of patients with forearm fractures that did not undergo a fasciotomy (RR 1.56, CI 1.30–1.87, $P < 0.0001$). A total of 4.95% of the patients with a tibial fracture that had a fasciotomy died during their hospitalization compared with 4.13% of patients with a tibial fracture that did not have a fasciotomy (RR 1.20 CI 1.09–1.32, $P < 0.0003$).

In-Patient Hospital Stay

Patients who underwent fasciotomy had an increased hospital LOS, an increased ICU LOS, and an increased number of days on a ventilator ($P < 0.0001$) (Table 2). When analyzing the subgroup of patients who had been in the ICU or on a ventilator (as opposed to all patients), patients with a fasciotomy spent more time in the ICU ($P < 0.0001$) and more time on a ventilator ($P < 0.002$) than nonfasciotomy patients.

In-Hospital Treatment Interventions

Patients with forearm fractures and tibial fractures who had a fasciotomy were more likely to have external and/or internal fixation performed than those with fractures that did not have a fasciotomy ($P < 0.0001$) (Table 3). Having a fasciotomy was associated with an increased need for soft-tissue operative procedures, including operative debridement, skin grafting, and/or surgical flap coverage ($P < 0.0001$). Furthermore, fasciotomy patients needed more treatment interventions including blood transfusions, angiography, and embolization ($P < 0.0001$).

DISCUSSION

To the best of our knowledge, this is the largest data set analyzed to determine the fasciotomy rate, risk factors for undergoing a fasciotomy, and inpatient outcomes after a fasciotomy. 1.22% of forearm fractures and 3.79% of tibial fractures had a fasciotomy. Both incidences are lower than those reported in case series, but similar to another larger extremity fracture study.[11,18,19] We believe that our study provides the best estimate of the incidence of fasciotomy after a tibial or forearm fracture. Previous studies have reported rates that range between 1% and 29%—a huge range that is not clinically helpful.[5,8,13,25,27] In addition, this is the first multicenter study to determine the effect of fasciotomy on inpatient outcomes. Patients requiring fasciotomy had a significantly higher mortality rate: 2.12% after a fasciotomy/fracture of the forearm and 4.95% after a fasciotomy/fracture of the tibia. This is likely due to higher energy MOI in these patients, as reflected by the significantly higher ISS of that group.[11,20] The need for fasciotomy reflects the higher energy transfer to the patient at the time of injury, a "marker" of a more serious injury. Patients who had a fasciotomy required more inpatient procedures, including fixation, angiography, embolization, and soft-tissue procedures. Furthermore, patients who had a fasciotomy of either their calf or forearm had an increased hospital and ICU LOS, and more days on a ventilator, all of which are associated with increased hospital costs and a decreased quality of life.[13]

Diagnosing an ACS can be difficult, and a high level of suspicion is needed to make a timely diagnosis. Delayed fasciotomies lead to increased morbidity and mortality.[21,22] Identifying fasciotomy risk factors would be helpful for clinicians to pick out higher risk patients. Patients who required a fasciotomy tended to be younger and male and had a higher energy MOI (interaction with machinery, motor vehicle collisions, pedestrian collisions, transportation injuries, being a pedestrian struck, or having a gunshot wound). Cutting/piercing mechanisms were associated with a higher risk of forearm, but not leg, fasciotomy. Interestingly, iatrogenic

TABLE 1. Demographics Associated With the Presence or Absence of Fasciotomy

	Forearm				Tibia			
	Fasciotomy	No Fasciotomy	Difference in Mean Values (CI)	P	Fasciotomy	No Fasciotomy	Difference in Mean Values (CI)	P
Age	37.03	49.24	12.21 (11.71–12.71)	0.0001	40.35	45.53	5.19 (4.93–5.45)	0.0001
Sex	1.92	0.47	4.06 (3.72–4.43)	0.0001	5.14	2.01	2.56 (2.46–2.67)	0.001

Mean differences in demographic variables among patients with and without fasciotomy/compartment syndrome.
CI, 95% confidence interval.

TABLE 2. Outcomes of Patients With and Without a Fasciotomy

	Forearm				Tibia			
	Fasciotomy	No Fasciotomy	Difference in Mean Values (CI)	*P*	Fasciotomy	No Fasciotomy	Difference in Mean Values (CI)	*P*
Mortality	2.12%	1.36%	1.56 (1.30–1.87)	0.0001	4.95%	4.13%	1.20 (1.09–1.32)	0.0003
ISS	13.64	11.91	1.73 (1.38–2.08)	0.0001	11.89	10.56	1.33 (1.17–1.49)	0.0001
LOS	13.24	6.13	7.10 (6.67–7.53)	0.0001	15.14	7.62	7.52 (7.28–7.75)	0.0001
ICU days	3.92	1.65	2.28 (2.00–2.56)	0.0001	3.46	1.60	1.86 (1.74–1.99)	0.0001
Ventilator days	2.30	0.86	1.44 (1.23–1.65)	0.0001	1.87	0.86	1.00 (0.90–1.10)	0.0001
ICU days among ICU patients	8.90	6.38	2.52 (1.98–3.06)	0.0001	8.49	7.15	1.34 (1.08–1.61)	0.0001
Ventilator days among ventilated patients	8.45	7.49	0.96 (0.33–1.60)	0.002	8.18	7.28	0.90 (0.53–1.26)	0.0001

Mean differences in certain continuous variables among patients with and without fasciotomy/compartment syndrome.
CI, 95% confidence interval.

injuries also place patients at high risk of a fasciotomy.[23] In our study, burn injuries of the forearm were more likely to need fasciotomy than burns to the leg. Patients who present with these MOI should be carefully evaluated for an ACS. Conversely, lower-energy mechanisms such as ground-level falls were not associated with an increased risk of a fasciotomy.

Patients who used alcohol, drugs, or were smokers were more likely to undergo fasciotomy of both the leg and forearm. This may be due to these patients having decreased sensorium, which can make the diagnosis of an ACS diagnosis difficult; it may also be from vasoconstriction of smaller vessels; and this leads to decreased perfusion and earlier myonecrosis.[24]

Our study has all the limitations associated with research performed using data obtained from a large database, particularly the lack of specificity to the data and inherent potential for error in coding or documentation. However, CPT codes are used by a variety of regulatory agencies in the United States as well as insurers so represent the most accurate data point for procedures performed, and NTDB data are extracted by trained data analysts. The database does not contain more detailed information, such as the presence or absence of ACS symptoms or intracompartment pressures. Therefore, it is possible that fasciotomies were performed for prophylaxis, for other diagnosis, for a misdiagnosis, and/or that some ACS were missed. Furthermore, the actual energy level of any specific injury is not known, because the MOIs are grouped into general categories without any additional specific information. There may also be reporting bias of the individual facilities that participate in the NTDB. Single-institution case series tend to come from Level 1 trauma centers, which may skew the incidence of ACS requiring fasciotomy, while the NTDB data include information on patients from Level II and III centers as well. Bearing all these caveats in mind, this data set represents the largest number of fracture patients with fasciotomies from trauma centers across the United States ever extracted and has all the advantages of looking at a large number of patients to determine the endpoints of our study.

Future studies could examine longer-term outcomes after these injuries, including infection, nonunion, loss of limb, functional outcomes, and the need for additional procedures. Because of the fact that data capture for the NTDB stops at the time of hospital discharge, this will require large, multicenter studies with prospective longitudinal data capture. Expanding this study to incorporate regression analyses with weighted propensities to identify the most

TABLE 3. Procedures Needed for Patients With and Without a Fasciotomy

	Forearm				Tibia			
	Fasciotomy Rate	No Fasciotomy Rate	RR (CI)	*P*	Fasciotomy Rate	No Fasciotomy Rate	RR (CI)	*P*
Fixation	2.02	0.73	2.76 (2.58–2.95)	0.0001	4.81	2.80	1.72 (1.66–1.78)	0.0001
Skin graft	20.67	0.88	23.41 (21.99–24.92)	0.0001	30.58	2.97	10.30 (9.98–10.63)	0.0001
Flap coverage	9.98	1.23	8.09 (7.06–9.26)	0.0001	13.15	3.88	3.39 (3.14–3.67)	0.0001
Debridement	4.88	1.28	3.80 (2.76–5.24)	0.0001	6.12	3.56	1.72 (1.66–1.78)	0.0001
Transfusion	3.01	1.17	2.58 (2.37–2.81)	0.0001	9.18	3.48	2.64 (2.54–2.74)	0.0001
Angiography	4.27	1.18	3.63 (3.31–3.99)	0.0001	12.50	3.54	3.53 (3.39–3.68)	0.0001
Embolization	7.56	1.21	6.24 (5.56–7.00)	0.0001	16.39	3.82	4.29 (4.02–4.58)	0.0001

Rates of fasciotomy/compartment syndrome.

specific and sensitive predictors for the development of an ACS and need for fasciotomy is planned for a subsequent study.

The major strength of our study is the inclusion of a very large number of injuries: over 650,000 forearm and tibial fractures from multiple trauma centers. Large population data are needed to appropriately power evaluations of traumatic injuries at a national level. The National Trauma Data Bank (NTDB), headed by the American College of Surgeons, was designed to improve our understanding of traumatized populations to improve care. Using this large amount of data, we were able to determine the effects of having a fasciotomy of the calf or forearm on inpatient outcomes. We found that having a fasciotomy is a marker of an injury with a higher mortality rate, higher need for ICU stay, a longer ICU stay, more days on a ventilator, and a higher hospital LOS. This information is useful for the treating physician, patients, and their family regarding inpatient expectations and outcomes. This study reflects aggregated data at a national level and eliminates the variability and bias that may in present in studies based on the experience of a single institution. Finally, our analysis of the NTDB allowed us to establish a baseline incidence of fasciotomy after fracture, a relatively infrequent sequela, and correlate it with risk factors and outcomes.

In conclusion, patients with tibia and forearm fracture patients who undergo fasciotomy have higher inpatient mortality rates than patients who have not had a fasciotomy. In addition, physicians should have a high level of suspicion in younger, male patients with higher energy MOI and a history of alcohol or drug use. In addition, it is helpful for surgeons to know that these patients may require more invasive procedures and have longer hospital stays. When counseling patients and evaluating surgeon/hospital performance, fasciotomies can serve as an indicator and modifier for a more complex trauma pathology.

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