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Original Article

Geographic variation in fasciotomy during operative management of tibia fractures

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ABSTRACT

Background: Diagnosis and treatment of acute or impending compartment syndrome (ACS) remains a clinical challenge. ACS is a clinical diagnosis, and may be associated with variation in its definition, as well as individual threshold for fasciotomy. We examined regional and state variation in rates of lower extremity fasciotomy associated with operatively managed tibia fractures.

Methods: A total of 313,344 surgically treated tibia fractures were identified via Current Procedural Terminology (CPT) codes using PearlDiver, a private-payer medical record database. Data from the PearlDiver database was compared to the National Trauma Data Bank trauma registry data to corroborate calculated fasciotomy rates.

Results: The aggregate United States fasciotomy rate derived from PearlDiver was 2.57%. State fasciotomy rates were wide-ranging (0.03%–11.86%) with an average state rate of 2.22% (n = 47, SD = 2.27).

Conclusions: There was significant state-to-state variation in the use of fasciotomy during operative management of tibial fractures. Various factors may have contributed to the observed difference of state fasciotomy rates.

Level of evidence: This is a Level III epidemiological study retrospectively comparing geographic rates of fasciotomy during operative management of tibia fractures.

1. Introduction

Diagnosis and treatment of acute or impending compartment syndrome (ACS) continues to be a debated topic among orthopedic surgeons. Tibia fractures are one of the most common long-bone injuries, with 492,000 reported per year in the United States.[1] Compartment syndrome has been cited in the literature as occurring in 1–10% of all tibia fractures.[2] Consensus for treatment of ACS is emergent fasciotomy, but there is still discordance regarding diagnosis of this condition. Diagnosis can be complex due to widely varying injury patterns and confounding comorbidities, and is often made using a combination of clinical symptoms and/or intra-compartmental pressure monitoring[3,4]. A missed or delayed diagnosis potentially results in deleterious consequences such as ischemic contracture, neurological sequelae, infection and ultimately amputation.[5] Alternatively, unnecessary fasciotomy carries noted morbidity. Patients who have undergone an open fasciotomy can develop complications of residual pain, altered sensation, wound morbidity and long-term functional deficit.[5] Diagnosis and management of ACS remains challenging for orthopedic surgeons, who must avoid a missed diagnosis, but also minimize the risk of an unnecessary surgical procedure with significant morbidity.

Variation in the diagnosis rate of ACS among individual surgeons has been noted and highlights the difficulty of diagnosing compartment syndrome in clinical practice[3]. The concept that procedure rates vary more widely than what can be explained by regional differences in prevalence of injury or disease has long been recognized, but to our knowledge, there is a paucity in the literature regarding the geographic variation of fasciotomy. The purpose of this study was to examine the geographical variation of fasciotomy during operative management of tibia fractures. Our hypothesis was that we would find substantial geographic variation in fasciotomy rates, suggesting that there may be underlying confounders that influence the decision to perform fasciotomy during surgical treatment of tibia fractures.

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2. Methods

This study utilized publicly available, aggregated data from two separate databases to identify surgically treated tibia fractures by means of Current Procedural Terminology (CPT) codes. Fasciotomy rates were calculated by dividing the total number of patients recorded as undergoing a lower extremity fasciotomy and surgery for a tibia fracture by the total of operatively managed tibia fractures. Patients recorded as having an operatively managed tibia fracture – open reduction internal fixation (ORIF) or intramedullary nailing of both proximal and distal tibia shaft fractures – were identified by CPT codes 27535, 27536, 27756, 27758, and 27759 (Appendix Table 1). Fasciotomy for a primary diagnosis of tibial compartment syndrome among patients that also underwent surgery for a tibia fracture were obtained by identifying fasciotomy procedures on any lower extremity compartment, multiple compartments, with or without debridement (CPT codes 27600, 27601, 27602, 27892, and 27894) in conjunction with the above codes.

The primary database utilized, PearlDiver (PearlDiver Technologies Inc. Warsaw, IN, USA; www.pearldiverinc.com) is a commercially available and Health Insurance Portability and Accountability Act (HIPAA) compliant national insurance database containing information from more than two billion de-identified Medicare and private payer patient records. A multitude of incidence and demographic studies of orthopedic injury have been used the PearlDiver database since 2010.[6–17] PearlDiver provided state totals of operatively managed tibia fractures and state totals of patients who have had both a lower extremity fasciotomy and an operatively managed tibia fracture from 2007 to 2011. State procedure volumes less than eleven were censored by PearlDiver to protect patient privacy. States with missing values were imputed with a weighted average of the difference in total volumes for the respective states.

To corroborate that PearlDiver data represented generally accurate procedure counts, this study also utilized data from the National Trauma Data Bank (NTDB). The NTDB is the current largest aggregation of U.S trauma registry data. The NTDB research dataset used in this study is based on the 2012 admission year and consists of 773,299 records from 747 facilities.[18] The NTDB identified individuals by CPT code from participating trauma registries. State rates were unable to be calculated using this database, but US region of the hospital where procedures were performed was provided, allowing for the calculation of a total US fasciotomy rate as well as a regional rate to substantiate the general accuracy of PearlDiver data (refer to Appendix Table 2 for states included in each US region).

Comparison of fasciotomy rates between data sources for each region was done using Pearson's Chi-square test. Comparisons of median fasciotomy rates of states within each region were done using the Kruskal–Wallace test. Change in aggregated fasciotomy rates over the study time period was done using the Cochran-Armitage trend test. To describe the central tendency of the fasciotomy rates, descriptive statistics including mean, standard deviation, and skewness were computed. Spearman correlation was used to assess the association between total volume of operatively managed tibia fractures and fasciotomy rates as well as the association between fasciotomy rates and population. All tests were performed using a significance level of 0.05. There was no external funding source for this study.

3. Results

3.1. Results found using PearlDiver database data

A total of 47 US states were included in the analysis. Due to missing data, North Dakota, Alaska, and Delaware were excluded.

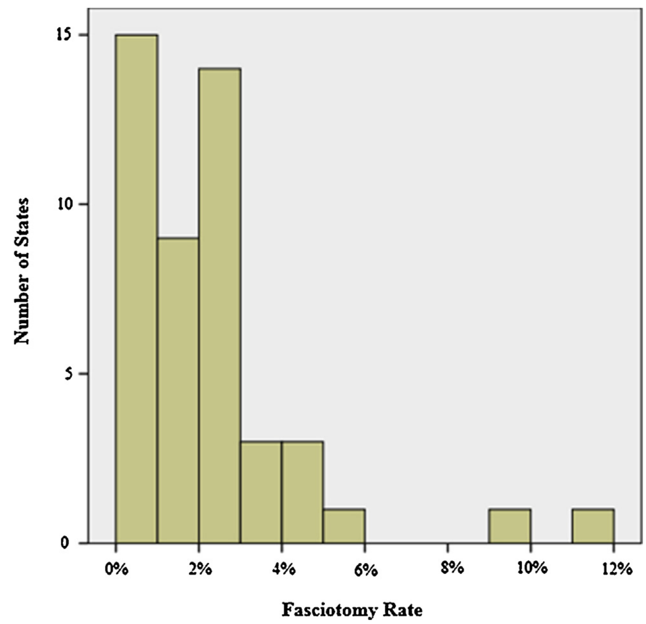

Fig. 1. Histogram for state fasciotomy rate. Data are displayed for 47 US states.

Considerable variation in state fasciotomy rates were noted (0.03%–11.86%) with an average rate of 2.22% ($n = 47$, SD = 2.27). Sizable variance and skewness values indicate the distribution of the data is clustered between 0.03% and 3.00%. A majority of the state rates ($n = 20$, 42.6%) were less than 1.5% with two outliers at 11.90% and 9.52% (Fig. 1).

Fig. 2 illustrates the geographic distribution of fasciotomy rates in the U.S (averaged from 2007 to 2011).

There was a significant trend of US fasciotomy rates increasing over the study time period ($p < 0.0001$) (Fig. 3).

The states with the five highest fasciotomy rates were Vermont (11.90%), Idaho (9.53%), Maryland (5.05%), Washington (4.83%), and Massachusetts (4.69%). Alternatively, the states with the five lowest fasciotomy rates (all less than 1%) were West Virginia, Kansas, Nebraska, Montana, and Wyoming (Table 1). The Spearman's rho revealed a statistically significant negative relationship between state fasciotomy rates and the total volume of operatively managed tibia fractures in each state ($r_s[47] = -0.499$, $p < 0.0001$). States with higher the volumes of operatively managed tibia fractures were associated with lower fasciotomy rates. There was also a statistically significant negative relationship between state fasciotomy rates and the total population of each state ($r_s[47] = -0.429$, $p = 0.003$). States with larger populations were associated with lower fasciotomy rates.

3.2. Results using National Trauma Data Bank data

Dividing the contiguous US states into four broad regions: North Eastern, Southern, West, and Mid-Western, there was no statistically significant variation of fasciotomy rates among operatively managed tibia fractures between regions ($p = 0.170$) (Appendix Table 2 identifies the states included in each region). There was no significant difference between the two datasets when comparing fasciotomy rates by region (Table 2), although the US PearlDiver rate overall was 2.57% (N = 313,344) was different than the US rate of 3.44% (N = 16,896) derived from the National Trauma Data Bank data ($p < 0.0001$).

Distribution of state fasciotomy rates (grouped by region) is right skewed with two outlier states in the North Eastern and in the Western region of the US respectively (Fig. 4).

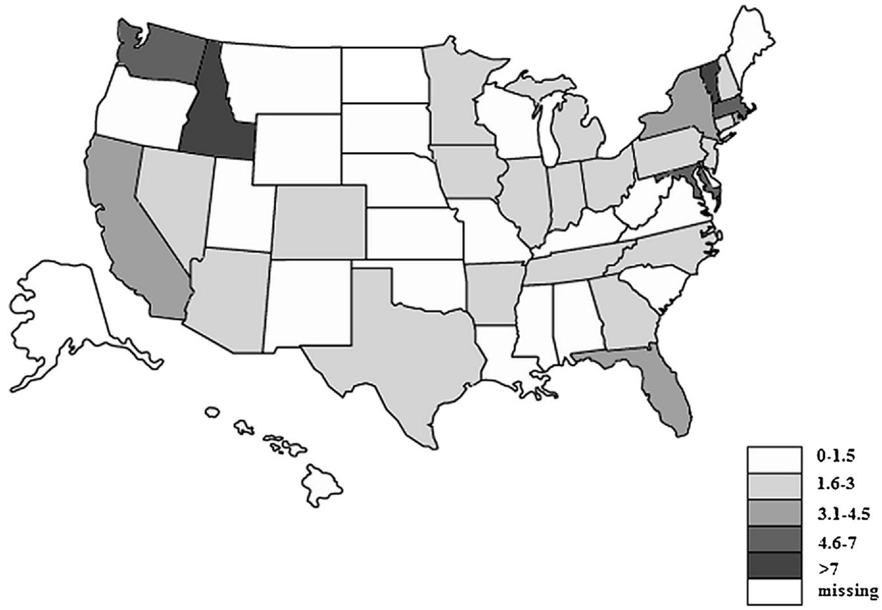

Fig. 2. Geospatial map showing the yearly average rates of fasciotomy among operatively managed tibia fractures.

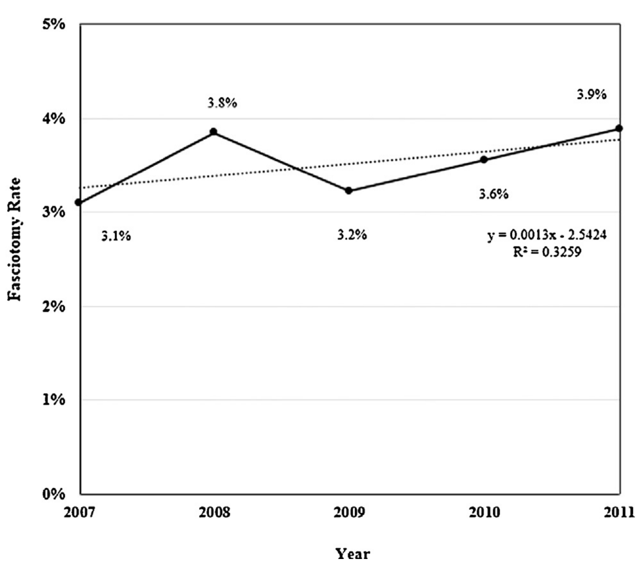

Fig. 3. Scatterplot of US fasciotomy rate over the study time period.

4. Discussion

To our knowledge there have been no epidemiological studies exploring the geographical variation of fasciotomy among operatively managed tibia fractures by broad US region or by state. Upon examination of the geographic variation of rates of lower extremity fasciotomy associated with surgically treated tibia fractures, we found substantial variation state to state, but not by US region. Several limitations should be considered when evaluating the conclusions drawn by the results of this study. ACS has been defined as present in any patient whose attending surgeon has stated the patient had compartment syndrome and therefore performed a fasciotomy, which makes it difficult to distinguish an ACS diagnosis from treatment by fasciotomy.[3] Therefore it is unclear how many fasciotomies were done prophylactically. This study also did not investigate or address the definition or incidence of compartment syndrome. There is no established “true” rate of ACS in the literature, making a comparison of determined rates to an accepted rate challenging. Additionally, data derived from the PearlDiver database was extrapolated using incidence rates from respective data sets and applying those rates to the national population. This provided us with state procedure totals that may not be 100% accurate; to address this potential problem, we compared rates from two

Table 1
States with the highest and lowest fasciotomy rates and their respective yearly average volumes of operatively managed tibia fractures and per capita rate of operatively managed tibia fractures.

State abbreviation	Fasciotomy %	Average yearly volume of operatively managed tibia fractures (2007–2011)	Per capita rate of operatively managed tibia fractures	2010 US census state population
VT	11.90%	133	2.13E-04	625,741
ID	9.53%	338	2.16E-04	1,567,582
MD	5.05%	928	1.61E-04	5,773,552
WA	4.83%	1445	2.15E-04	6,724,540
MA	4.69%	1147	1.75E-04	6,547,629
WV	0.03%	676	3.65E-04	1,852,994
KS	0.04%	527	1.85E-04	2,853,118
NE	0.09%	263	1.44E-04	1,826,341
MT	0.11%	223	2.25E-04	989,415
WY	0.16%	145	2.57E-04	563,626

Table 2
Average regional fasciotomy rate for PearlDiver and National Trauma Data Bank databases.

Database		Mid-West	North East	South	West
PearlDiver	Fasciotomy %	1.89	3.27	2.2	3.3
	Operatively managed tibia fractures	n = 68478	n = 60854	n = 123087	n = 60473
National Trauma Data Bank	Fasciotomy %	2.98	4.63	2.67	4.9
	Operatively managed tibia fractures	n = 4626	n = 2699	n = 6777	n = 2974
		p = 0.56	p = 0.31	p = 0.18	p = 0.66

independent data sources that used different data collection methodology.

Although the US fasciotomy rate calculated using the PearlDiver dataset was statistically significantly different than the rate derived from the National Trauma Data Bank, these rates were relatively similar and the difference between the rates by region was not found to be statistically significant. This supports the notion that data from both datasets represent generally accurate procedure counts for lower extremity fasciotomy decompression and operatively managed tibia fractures.

O'Toole et al found significant variation of the diagnosis of compartment syndrome by comparing individual surgeons in the same hospital system with an essentially identical patient population.[3] Studies addressing best practice for diagnosing acute compartment syndrome suggest that surgeons should not depend on single measurements, as this method is likely to lead to overtreatment.[4] Alternatively, continuous intra-compartmental pressure monitoring for patients at risk for ACS can be considered with the knowledge that a significant false positive rate has been associated with compartment pressure checks regardless of the pressure criteria used.[3,4] The sensitivity and specificity of the key signs for compartment syndrome are limited.[19] Because there is no "true" rate of acute compartment syndrome, a finding of significant variation in fasciotomy rates suggests that some fasciotomies may have been unnecessary.[3] Due to the varied onset and development of ACS, it is important that clinicians obtain a thorough patient history and base the diagnosis of compartment syndrome on patient presentation, mechanism of injury, and vigilant repetitive clinical evaluation performed over time.[20–22] It is unknown how many fasciotomies may been unneeded because of the difficulty of accurately measuring the false-negative rate of missed compartment syndrome.[23]

It is widely reported that ACS is a surgical emergency that has the potential to cause morbidity and irreversible muscle damage.

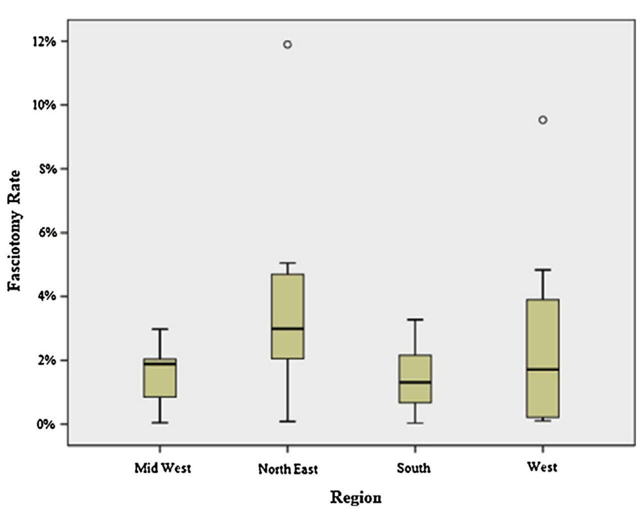

Fig. 4. Boxplot distribution of fasciotomy rate by US region. The median is identified by the line inside the box and the length of the box is the interquartile range (IQR). Values more than 1.5 IQR's but less than 3 IQR's from the end of the box are labeled as outliers (◦). Whiskers show high/low values.

Appropriate and timely use of fasciotomy is advised to be the most effective way to avoid sequelae.[20] Some have even suggested that the morbidity of fasciotomy is preferable to the outcome of missed ACS and that the risk should be weighted slightly toward false positives rather than false negatives.[4,2] Alternatively, it may be advantageous to thoughtfully consider the risks of fasciotomy, such as exposure of ischemic tissue to microbial flora leading to possible infection, the decreased rate of fracture union, and the need for subsequent skin-grafting.[19] Findings from Williams et al support the notion of a conservative and deliberate approach to performing fasciotomy, stating that limb salvage can still achieved with good functional outcome even when compartmental decompression is more than 36 h after injury.[21]

In addition to considering the medical consequences of missed ACS vs. unnecessary fasciotomy, defensive medicine may affect clinical decision making.[19] Although relatively uncommon for individual surgeons, orthopedic surgery is consistently among the subspecialties with the highest malpractice claim rates, and malpractice claims for ACS have been reported to result in a high rate of indemnity payments.[19,24] There is a need for reliable data on orthopedic risk management.[19] Early diagnosis is emphasized and has been reported as associated with improved patient outcome and decreased risk of indemnity.[25]

Many factors may contribute to the geographic variation within broad regions (from state to state), including differences between intra-compartmental pressure monitoring practices as well as the possible influence on medical decision-making by the substantial clinical and medico-legal consequences of failing to diagnose compartment syndrome.[19] Waters et al found that medical schools that are outliers for malpractice lawsuits against their graduates in one decade are likely to retain their outlier status in the subsequent decade, suggesting that the malpractice claims experiences of physicians who graduated from the same medical school are strongly related to each other.[26] The same reasoning used to explain why certain medical schools and hospitals are outliers for malpractice claims could also be used to justify the sizable variance and skewness of state rates found by this study. Geographic rates (both regional and state rates) were consistent over the study time period and the US rate generally increased from 2007 to 2011. This could indicate a future trend in the increase of fasciotomies performed on operatively managed tibia fractures. This trend may also be affected by the changing medico-legal climate for orthopedic surgeons. An additional factor influencing state to state variation of fasciotomy rates may be differences in patient population. The inability to ensure clinical follow up of patients in certain circumstances might affect the threshold for fasciotomy.

Further work is needed to better define and diagnose compartment syndrome to balance timely treatment of every impending compartment syndrome with avoidance of unnecessary surgery, additional costs, extra surgical procedures for wound closure, and morbidity.

Conflicts of interest

All authors have none to declare.

Appendix

Appendix table 1
Current procedural terminology code definitions.

CPT code	Definition
27535	Open treatment of tibial fracture, proximal (plateau); unicondylar, includes internal fixation, when performed
27536	Open treatment of tibial fracture, proximal (plateau); bicondylar, with or without internal fixation
27756	Percutaneous skeletal fixation of tibial shaft fracture (with or without fibular fracture) (eg, pins or screws)
27758	Open treatment of tibial shaft fracture (with or without fibular fracture), with plate/screws, with or without cerclage
27759	Treatment of tibial shaft fracture (with or without fibular fracture) by intramedullary implant, with or without interlocking screws and/or cerclage
27600	Decompression fasciotomy, leg; anterior and/or lateral compartments only
27601	Decompression fasciotomy, leg; posterior compartment(s) only
27602	Decompression fasciotomy, leg; anterior and/or lateral, and posterior compartment(s)
27892	Decompression fasciotomy, leg; anterior and/or lateral compartments only, with debridement of nonviable muscle and/or nerve
27894	Decompression fasciotomy, leg; anterior and/or lateral, and posterior compartment(s), with debridement of nonviable muscle and/or nerve

Appendix table 2
States Included within each defined region.

Region	States included
Midwest	IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI
Northeast	CT, MA, ME, NH, NJ, NY, PA, RI, VT
South	AL, AR, FL, GA, KY, LA, MD, MS, NC, OK, PR, SC, TN, TX, VA, WV
West	AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY
Missing	ND, NE, AK, DC

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