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The Influence of Procedure Delay on Resource Utilization: A National Study of Patients with Open Tibial Fracture

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Abstract

Background—The purpose of this study is to 1) understand national variation in delay of emergency procedures in patients with open tibial fracture at the hospital level and 2) compare length of stay (LOS) and cost in patients cared for at the best and worst performing hospitals for delay.

Methods—We retrospectively analyzed the 2003 – 2009 Nationwide Inpatient Sample. Adult patients with primary diagnosis of open tibial fracture were selected for inclusion. We calculated hospital probability of delay of emergency procedures beyond the day of admission (day 0). Multilevel linear regression random effects models were created to evaluate the relationship between the treating hospital's tendency for delay (in quartiles) and the log-transformed outcomes of LOS and cost, while adjusting for patient and hospital variables.

Results—The final sample included 7,029 patients from 332 hospitals. Adjusted analyses demonstrate that patients treated at hospitals in the fourth (worst) quartile for delay were estimated to have 12% (95% CI 2–21%) higher cost compared to patients treated at hospitals in the first quartile. In addition, patients treated at hospitals in the fourth quartile had an estimated 11% (CI 4–17%) longer LOS compared to patients treated at hospitals in the first quartile.

Conclusions—Patients with open tibial fracture treated at hospitals with more timely initiation of surgical care had lower cost and shorter LOS than patients treated at hospitals with less timely

initiation of care. Policies directed toward mitigating variation in care are not only beneficial for patient outcomes, but may also reduce unnecessary waste.

Level II (Prognostic)

Keywords

amputation; debridement; emergent procedures; lower extremity reconstruction; lower extremity trauma; open tibial fracture; practice variation; treatment delay

The rising cost of healthcare in the United States has spurred innovations in quality assessment of healthcare practices. While many cost-containment strategies entail a trade-off between cost and quality, strategies that minimize cost while improving quality represent a rare bargain. Curbing inefficient practice patterns among hospital systems reduces excess resource utilization. In addition, reducing inefficiencies in patient care follows the concept of continuous quality improvement by addressing at least one of the triad of quality measures, which include structure, process and outcome (1, 2).

Open tibial fracture is an injury that is both common and costly (3–5). Despite the widely accepted practice of prompt debridement and fracture stabilization of patients presenting with open tibial fracture (6, 7), two national studies have demonstrated that approximately 24–30% of patients with open tibial fracture have delay of emergency surgical intervention beyond the day of admission (8, 9), even when controlling for injury severity. In addition, amputation is more likely to occur in patients having delayed surgical intervention (9). This variation in timing of surgical care is a potential inefficient practice in the process of healthcare delivery that can adversely affect outcomes and result in higher healthcare costs in this patient population. Several studies have demonstrated that delays to surgical intervention increase resource utilization in the form of cost or length of stay (LOS) for patients with other traumatic conditions such as hip fracture (10–12) and spine fracture (13–17). Most prior studies primarily focus on delay of care at the individual level, which makes these studies more sensitive to confounding by unmeasured severity. The relationship between timing of care at the hospital level and influence on LOS and cost is not clearly understood.

The impact of hospital tendency for delay of surgical interventions as it relates to resource utilization in patients with open tibial fracture has not been studied. The purpose of this study is to 1) understand national variation in delay of emergency procedures in patients with open tibial fracture at the hospital level and 2) compare resource utilization in the form of LOS and cost in patients cared for at the best and worst performing hospitals for delay in performing emergency procedures. We hypothesize that hospitals having greater probability of delay of emergency procedures will use relatively greater resources to care for patients with open tibial fracture, even when controlling for individual patient risk factors. By accounting for delay at the hospital level as opposed to the individual level, we sought to minimize the role of unmeasured confounding at the individual level and more accurately characterize the role of systematic delays. These individual variations would have more of a direct impact on surgical timing at the individual level if timing were considered at the patient level. By considering timing practices at the hospital level, the impact of patient-

level variation on timing of procedures is minimized because these variations have a less direct influence on the hospital's overall mean time to perform emergency procedures.

METHODS

Data Source

We retrospectively analyzed discharge data from the 2003 – 2009 Nationwide Inpatient Sample (NIS), Health Care Utilization Project, Agency for Healthcare Research and Quality (18). The NIS is a stratified probability sample of approximately 20% of all U.S. non-federal hospitalizations from the majority of states (44 in 2009). The NIS is the largest all-payer inpatient care database, containing roughly 8 million discharges from approximately 1,000 hospitals annually (19). This study was assigned nonregulatory status from the Institutional Review Board.

Patient Selection

Adult patients with primary diagnosis of open tibial fracture who were admitted to an acute care hospital where definitive management was performed were selected for inclusion in this study. International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes were used to identify patients with primary diagnosis of open tibial fracture (ICD-9-CM = 823.10, 823.12, 823.30, 823.32, 823.90 or 823.92). Because our analysis focused on timing of emergency procedures, patients without documented emergency procedures were excluded. We included only emergency, urgent, and trauma center admission types to avoid including patients being readmitted for complications after prior admissions for open tibial fracture. The full inclusion and exclusion criteria are outlined in Figure 1.

Predictor and Outcome Variables

The predictor variable of interest was the hospital's probability of delay in performing emergency procedures in patients with open tibial fracture (Figure 2). The NIS database contains ICD-9-CM procedure codes and timing of procedures measured in days from admission. Timing of initial emergency procedures was noted and included operative debridement, vascular repair, external fixator placement, open reduction internal fixation, and amputation. Procedures were identified by ICD-9-CM procedure codes (Figure 2). Delay was defined as emergency procedures performed after the day of admission (hospital day [HD] = 1), whereas non-delay was defined as timing of emergency procedures on the day of admission (HD 0). Hospitals with few patients in the sample will have less reliable estimates for probability of delay. In this case, the reliability of measuring a hospital's probability of delay is increased four fold with measurement of delay in 5 patients compared to measurement of delay in only 1 patient per hospital. Thus, hospital-level probabilities for delay were calculated from hospitals in which procedure-timing data were available for at least 5 patients. We calculated hospital probability of delay by dividing the total number of patients with delay by the total number of open tibial fracture cases within each hospital. Hospital probabilities of delay were grouped into quartiles in order to stratify the best and worst performing hospitals. Hospitals with the lowest delay were assigned to the first

quartile (best performing), and hospitals with the highest probability of delay were assigned to the fourth quartile (worst performing).

The outcomes of interest were patient LOS and cost. LOS was measured in days from admission. Total hospital charges data were available for each patient. Patient hospital cost was calculated by multiplying total charges by cost/charge ratios supplied by NIS (Figure 2). All costs were adjusted to 2009 U.S. dollars at a 3% annual rate of inflation. Observations that were outside of 3 standard deviations from the mean for cost or LOS were considered outliers and were excluded. In addition, patients having in-hospital death and patients discharged against medical advice were excluded because these circumstances would bias both cost and LOS outcomes.

Control Variables

Control variable categories included hospital characteristics, patient demographic data, economic characteristics, comorbidities, injury, and treatment characteristics (Figure 2). Hospital characteristics included trauma center status, urban/rural location, bed size, teaching status, and facility volume of open tibial fractures per year in quartiles. Demographic data included patient age, gender, and race. Economic characteristics included primary insurer and median household income for the patient's ZIP code. Patient comorbidities include congestive heart failure, hypertension with complications, peripheral vascular disease, diabetes with and without complications, liver disease, and renal disease. Patients with congestive heart failure, hypertension with complications, and peripheral vascular disease were grouped into a single category of cardiac disease. Patients having diabetes with and without chronic complications were grouped into a single category of diabetes. Injury and treatment characteristics included weekend admission, mechanism of injury, associated injuries, associated procedures, and overall injury severity score (ISS). Using external cause of injury codes (E-codes) (Figure 2), we divided mechanism of injury into categories of blunt, sharp/penetrating, and other/unspecified. Associated injuries and procedures included arterial injury, complicated open wound, transfusion of blood products, fasciotomy, and mechanical ventilation, which were identified using ICD-9-CM diagnosis and procedure codes (Figure 2). Overall injury severity scores were calculated for each patient using the ICDMAP-90 software (Tri-Analytics, Baltimore, MD) (20) in order to stratify mortality risk after trauma.

Missing Data

Missing data were accounted for by creating "missing" categories within variables when greater than 1% of data were unspecified. Race, income, and mechanism of injury had separate "missing" categories created for unspecified values in order to include these observations in the final analysis.

Data Analysis

We evaluated the relationship between the treating hospital's probability of delay of performing emergency procedures and the outcomes of patient LOS and cost. LOS and cost outcomes both had right-skewed distributions. Thus, both were log-transformed in order to permit parametric statistical analysis. Bivariate comparisons were used to evaluate

differences between control variables among quartiles of hospital delay of emergency procedures. Kruskal-Wallis and chi-squared tests were used for continuous and categorical variables respectively. ANOVA was used to perform bivariate comparisons of log-transformed LOS and cost outcomes between quartiles of hospital delay. Multilevel linear regression random effects models were created to evaluate the relationship between the treating hospital's tendency for delay of emergency procedures and the log-transformed outcomes (dependent variable), while adjusting for control variables. Separate models were created for log-transformed cost and log-transformed LOS. Regression coefficients represent the proportional change in outcome per unit change of the independent variable when linear regression is performed on log-transformed outcomes. For example a coefficient of 0.10 represents a 10% increase in outcome for a unit change of the associated independent variable.

We performed a sensitivity analysis by changing the cutoff for delay from beyond HD 0 to beyond HD 1. Timing of procedures and admission are documented based on calendar days. Thus, a patient admitted before midnight who has a procedure at 5am the following calendar day would be considered to have delay. Thus, we also performed the same analyses to evaluate the relationship between hospital delay and outcomes when delay was defined as timing of procedures on HD 2 or later.

Source of Funding

The funding sources did not play a role in the investigation.

RESULTS

Hospital Quartiles of Delay

We calculated hospital probability of delay of emergency procedures from 7,777 patients from 354 hospitals. The mean hospital probability of delay among all included hospitals was 0.23 (SD 0.16). Mean hospital probability of delay in the first quartile was 0.04 (SD 0.05); whereas mean hospital probability of delay in the fourth quartile was 0.43 (SD 0.10) (Table 1). When HD 2 is used as the cutoff for delay, the mean probability of delay among all included hospitals was 0.09 (SD 0.11).

Final Sample Characteristics

The final sample evaluating the relationship between calculated hospital probability of delay and patient resource utilization consisted of 7,029 patients from 332 hospitals. Patient and hospital characteristics among hospital quartiles of delay are described in Table 2 and Table 3 respectively. Hospitals in the first (best performing) quartile of delay treated 14.4% (n=1,013) of patients in the total sample. In addition, hospitals in the first quartile of delay treated fewer patients with the greatest level of injury severity score (4.0%; n=40) (Table 2). A greater proportion of patients in the first quartile for delay were treated at rural hospitals (13.8%; n=140), nonteaching hospitals (63.4%; n=642), and hospitals that treat relatively lower volume per year of open tibial fracture compared to patients in the other quartiles (Table 3). Table 4 demonstrates the distribution of initial emergency procedures coded. 67% had debridement coded at first surgical intervention. If debridement was not coded at the

initial operation, we examined additional procedures that could have been documented during the first surgical intervention. 8.7% had external fixation coded, 23% had ORIF coded, and <1% had arterial repair or amputation as the first intervention coded. 23% of all patients had delay of initial procedure, with 7% occurring HD 2 or later. 2% of patients treated in the first quartile hospitals (best performing) had initial procedure performed HD 2 or later, whereas 11% of patients treated in the fourth quartile hospitals (worst performing) had initial procedure performed HD 2 or later (Table 4).

Hospital Probability of Delay and Patient Resource Utilization

Mean cost of patients treated at hospitals in the first (best performing) quartile of delay was lower (\$23,317; SD 18,304; $p<0.001$) compared to patients treated at hospitals in the fourth (worst performing) quartile of delay (\$29,030; SD 23,185; $p<0.001$) (Table 5). Mean LOS for patients treated at hospitals in the first quartile was also less (6.3 days; SD 5.7; $p<0.001$) compared to patients treated at hospitals in the fourth quartile of delay (7.9 days; SD 6.9, $p<0.001$) (Table 5).

In analyses adjusted for patient and hospital control variables, patients had proportionally higher cost (Table 6) and LOS (Table 7) as the treating hospital's probability of delay increased. Patients treated at hospitals in the fourth (worst performing) quartile of delay were estimated to have 12% (95% CI 2–21%) higher cost compared to patients treated at hospitals with the lowest quartile of delay, even when adjusting for injury severity and associated procedures among other control variables. In addition, patients treated at hospitals in the fourth quartile for delay were expected to have 11% (95% CI 4–17%) longer LOS compared to patients treated at hospitals in the first quartile. We saw a similar relationship in the adjusted analyses when the cutoff for delay was changed to hospital day 2 or later. For this sensitivity analysis, patients in the fourth quartile for delay were estimated to have 18% (CI 10–26%) higher cost and 19% (CI 14–24%) longer LOS compared to patients treated at hospitals in the first quartile.

DISCUSSION

Patients treated at hospitals with more timely initiation of surgical care had lower cost of care and shorter LOS than patients treated at hospitals with less timely initiation of care, even when accounting for a wide variety of patient risk factors. The difference between hospitals with the shortest and longest delays was substantial, with 12% higher cost and 11% longer LOS in patients treated at hospitals with the greatest probability of delay. As expected, increase in cost and LOS was seen with presence of injury characteristics such as arterial injury, need for mechanical ventilation, and increased injury severity. Efforts to reduce the time to initiate surgical management have the potential to not only improve patient outcomes (9), but also to reduce the cost of care.

There is a long-held belief that patients with open tibial fracture should have immediate surgical debridement, which will lead some surgeons to assume that all patients are receiving timely care. However, two previous national studies have demonstrated that not all patients have immediate surgical intervention (8, 9). We have previously found that delays to emergency treatment are associated with an increased risk of in-hospital amputation in

patients with open tibial fracture (9). Our current findings strengthen the argument against delay by showing that hospitals with a greater tendency to delay surgery also have higher resource utilization.

This study has limitations common to all studies using administrative data, such as the limited availability of detailed clinical data and the retrospective nature of the analysis. Timing of initial emergency procedures was recorded in days from admission rather than hours. However, in our previous study (9), we were able to demonstrate that approximately 30% of patients with open tibial fracture had delay of initial surgery beyond the day of admission. Thus within this group, it is important to understand the impact of delay that is beyond the standard of care. In addition, we were limited to using ICD-9-CM diagnosis and procedure codes to control for associated injuries and overall injury severity. Thus, patients were unable to be stratified according to the Gustilo grading system (7) for open tibial fractures and additional complex reconstructive procedures were unable to be characterized. However, we were able to control for presence of arterial injury and complex open wounds, which accounts for the most severe type of injuries. We attempted to limit the impact on cost and LOS outcomes of traumatic injuries outside of the lower extremity by including only patients with primary diagnosis of open tibial fracture. In addition, we attempted to minimize the effect of type of procedures performed for individual patients by studying the relationship of hospital delay with patient resource utilization. In order for procedure type to impact patient resource utilization in our analysis, all of the hospitals in each group would need to systematically have a different preference for performing certain procedure types compared to hospitals in one of the other groups. These systematic differences at the level of groups of hospitals are certainly possible, but less likely than differences at the individual or surgeon level.

A similar relationship between resource utilization and timing of interventions at the patient level has been demonstrated in the literature in conditions such as hip fracture (10–12), ankle fracture (21, 22), spine fracture (13–17), and laryngeal trauma (23). Delay of emergency procedures can theoretically be attributed to medical stability of patients, provider deviations from standards of care, or systems limitations, such as availability of surgeons or operating rooms. Few studies have evaluated the impact of hospital level delay of emergency procedures as it relates to resource utilization. Much of the work evaluating timing of care in relation to resource use has evaluated timing of surgery at the individual patient level. A study by Orosz et al. (24) examined the reasons for delay in timing of surgical repair in patients with hip fracture treated at four hospitals. The authors found that among patients having delay between 25 and 48 hours, 41% were delayed due to unavailability of the operating suite or surgeon and 52% were delayed for routine medical clearance. Patients delayed beyond 48 hours were more likely to have unstable medical conditions, but 63% of these patients were also delayed in part because of routine medical clearance and 44% were delayed in part due to unavailability of the surgeon or operating room. Thus, systems factors played a large role in delaying surgical intervention for patients in this study.

Individual providers, hospital systems, and health plans are often evaluated for practice variation during quality improvement. Prompt initiation of surgical treatment of patients

with open tibial fracture is a process measure of quality of care, with delay resulting in increased risk of amputation (9) and higher resource utilization. Strategies to improve surgical quality at the hospital level include creation of centers for excellence, pay-for-performance, and pay-for-participation programs. Both pay-for-performance and pay-for-participation incentives could be helpful to improve variation in the timing of emergency procedures in patients with open tibial fracture. Although pay-for-performance programs have potential for rapid improvements (25), these programs may put the lowest performing hospitals at a further disadvantage if they are penalized and resources are reduced further. Pay-for-participation programs allow several hospital systems to collaborate and develop a system of gathering quality data that is fed back to surgeons and hospitals regularly. Participants are compensated for participation in these collaborative activities, allowing hospitals to learn from one another rather than compete for incentives. Creation of centers for excellence is likely unrealistic in patients with open tibial fracture, because these are common injuries. In addition, it may be counterproductive to transport patients to centers for excellence, because these acutely injured patients may be put at risk for increased complications as a result of delaying care.

Hospitals should enact policies to facilitate prompt initiation of surgical intervention on the day of admission unless patients have a clear medical contraindication to surgery. Systems limitations that interfere with prompt intervention in stable patients must be improved in order to optimize patient outcomes, decrease LOS, and decrease cost. Policies directed toward improving global variation in care are not only beneficial to improve patient outcomes, but may also decrease unnecessary waste in hospital resource utilization.

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Study Sample Selection Criteria	
Inclusion Criteria	
Primary diagnosis open tibia fracture	
Patients ≥ 18 years of age	
Admission to acute care hospital	
Admission types: emergency, urgent, and trauma center	
Hospitals with emergency procedure timing data available for at least 5 patients	
Exclusion Criteria	
Transfer in or out to another hospital	
No emergency procedure documented	
Procedure documented with date prior to admission of record (readmission)	
Patient did not survive to discharge*	
Patient discharged against medical advice*	

Figure 1. Study sample selection criteria

*Criteria applied to sample selection for analysis of LOS and cost outcomes only

Study Variable Specifications	
Predictor Variables	
Operative debridement	ICD-9-CM procedure codes: 79.6, 79.60, 79.65, 79.66, 79.67, 79.68, 79.69, 77.6, 77.60, 77.65, 77.66, 77.67, 77.68, 77.69, 86.2, 86.22, or 86.28 (procedure timing supplied by NIS)
Additional emergency procedures (arterial/vein repair, placement external fixator, ORIF, and amputation)	ICD-9-CM procedure codes: 39.30, 39.31, 39.32, 78.17, 78.57, 79.36, 84.13, 84.14, 84.15, or 84.16 (procedure timing supplied by NIS)
Hospital probability of delay of above procedures (quartiles)	Determined from data supplied by NIS; calculated from hospitals having timing of above procedures documented for at least 5 patients
Outcome Variables	
Length of stay	Supplied directly by NIS
Cost*	Cost = Charges x GAPICC; Charges and group average all-payer inpatient cost/charge ratios (GAPICC) supplied directly by NIS
Control Variables	
Patient age	Supplied directly by NIS
Patient gender	Supplied directly by NIS
Patient race	Supplied directly by NIS
Patient primary insurer	Supplied directly by NIS
Median household income for patient's ZIP code (in quartiles)	Supplied directly by NIS
Patient comorbidities	Supplied directly by NIS (congestive heart failure, hypertension with complications, peripheral vascular disease, diabetes with and without chronic complications, liver disease, and renal disease included in analyses)
Weekend admission	Supplied directly by NIS
Mechanism of injury	Clinical Classification System** (CCS) E-Codes supplied by NIS CCS E-Codes for blunt mechanism: 2603, 2606, 2607, 2608, 2609, 2610, or 2614 CCS E-Codes for sharp mechanism: 2601, 2605
Arterial injury (popliteal, anterior tibial, or posterior tibial)	ICD-9-CM diagnosis codes: 904.41, 904.51, or 904.53
Complicated open wound	ICD-9-CM diagnosis codes: 891.1 or 891.2
Transfusion of blood products	ICD-9-CM procedure codes: 99.0 or 99.00, 99.01, 99.02, 99.03, 99.04, 99.05, 99.06, 99.07, 99.08, or 99.09
Fasciotomy	ICD-9-CM procedure codes: 83.14
Mechanical ventilation	ICD-9-CM procedure codes: 96.70, 96.71, or 96.72
Overall injury severity score (ISS)	Supplied by ICDMAP-90 software
Trauma center status	Supplied directly by NIS
Hospital urban/rural location	Supplied directly by NIS
Hospital bed size	Supplied directly by NIS
Hospital teaching status	Supplied directly by NIS
Hospital volume open tibial fractures per year (in quartiles)	Determined by data supplied by NIS, using codes for open tibial fracture (ICD-9-CM diagnosis codes: 823.10, 823.12, 823.30, 823.32, 823.90 or 823.92)

Figure 2. Study variable specifications

*Cost from 2003 – 2008 adjusted to 2009 dollar at 3% annual rate of inflation; **CCS software accompanies NIS database to allow external cause of injury (E-Codes) to be grouped into limited categories.

Table 1

Mean Hospital-level Probability of Delay and Timing of Emergency Procedures*

	<u>All Hospitals</u>		<u>1st quartile</u>		<u>2nd quartile</u>		<u>3rd quartile</u>		<u>4th quartile</u>	
	n	%	n	%	n	%	n	%	n	%
TOTAL	354	100	88	24.9	68	19.2	105	29.7	93	26.3
Hospital level probability of delay 1 day										
Mean (SD)	0.23	(0.16)	0.04	(0.05)	0.16	(0.02)	0.25	(0.04)	0.43	(0.10)
Hospital day of first procedure										
Mean (SD)	0.46	(0.5)	0.18	(0.15)	0.31	(0.25)	0.48	(0.31)	0.92	(0.65)

* Mean hospital-level probabilities grouped into quartiles; probability cutoffs for quartiles are as follows: 1st quartile <13%, 2nd quartile 13–19%, 3rd quartile 20–33%, 4th quartile >33%

Table 2

Patient Characteristics Grouped by Quartile of Delay* of Emergency Procedures at Treating Hospital

	All patients		1st quartile		2nd quartile		3rd quartile		4th quartile		P
	n	%	n	%	n	%	n	%	n	%	
TOTAL	7,029	100	1,013	14.4	1,394	19.8	2,781	39.6	1,841	26.2	
Age											0.162
Mean (SD)	40.6	(16.3)	41.2	(16.3)	41.0	(16.4)	40.6	(16.3)	40.1	(16.2)	
Gender											0.732
Male	5,218	74.2	761	75.1	1,020	73.2	2,067	74.3	1,370	74.4	
Female	1,811	25.8	252	24.9	374	26.8	714	25.7	471	25.6	
Race											<0.001
White	3,758	53.5	591	58.3	740	53.1	1,485	53.4	942	51.2	
Black	1,010	14.4	100	9.9	167	12.0	425	15.3	318	17.3	
Hispanic	613	8.7	50	4.9	82	5.9	262	9.4	219	11.9	
Other	314	4.5	41	4.1	33	2.4	129	4.6	111	6.0	
Unspecified	1,334	19.0	231	22.8	372	26.7	480	17.3	251	13.6	
Insurance											<0.001
Uninsured	2,328	33.1	353	34.9	463	33.2	992	35.7	520	28.3	
Medicare	585	8.3	107	10.6	131	9.4	211	7.6	136	7.4	
Medicaid	722	10.3	83	8.2	131	9.4	263	9.5	245	13.3	
Private insurance	3,394	48.3	470	46.4	669	48.0	1,315	47.3	940	51.1	
Median household income											<0.001
1st quartile	2,175	30.9	303	29.9	360	25.8	884	31.8	628	34.1	
2nd quartile	1,824	26.0	265	26.2	384	27.6	780	28.1	395	21.5	
3rd quartile	1,551	22.1	229	22.6	321	23.0	615	22.1	386	21.0	
4th quartile	1,197	17.0	182	18.0	290	20.8	402	14.5	323	17.5	
Unspecified	282	4.0	34	3.4	39	2.8	100	3.6	109	5.9	
Weekend admission	2,450	34.9	352	34.8	512	36.7	979	35.2	607	33.0	0.159

	All patients		1st quartile		2nd quartile		3rd quartile		4th quartile		P
	n	%	n	%	n	%	n	%	n	%	
TOTAL	7,029	100	1,013	14.4	1,394	19.8	2,781	39.6	1,841	26.2	
Mechanism of injury											<0.001
Blunt	5,975	85.0	877	86.6	1,206	86.5	2,389	85.9	1,503	81.6	
Sharp/penetrating	518	7.4	61	6.0	91	6.5	208	7.5	158	8.6	
Other	326	4.6	45	4.4	67	4.8	123	4.4	91	4.9	
Unspecified	210	3.0	30	3.0	30	2.2	61	2.2	89	4.8	
Associated injuries/procedures											
Arterial injury	126	1.8	**	**	26	1.9	67	2.4	25	1.4	0.003
Complicated open wound	301	4.3	30	3.0	47	3.4	140	5.0	84	4.6	0.010
Fasciotomy	339	4.8	34	3.4	72	5.2	141	5.1	92	5.0	0.133
Blood transfusion	812	11.6	101	10.0	164	11.8	321	11.5	226	12.3	0.323
Mechanical ventilation	296	4.2	32	3.2	72	5.2	116	4.2	76	4.1	0.113
Injury severity score (ISS)											<0.001
<10	4,885	69.5	743	73.4	92	71.2	1,821	65.5	1,329	72.2	
10–20	1,766	25.1	230	22.7	332	23.8	778	28.0	426	23.1	
>20	378	5.4	40	4.0	70	5.0	182	6.5	86	4.7	
Comorbidities											
Cardiac	1,257	17.9	171	16.9	244	17.5	510	18.3	332	18.0	0.741
Diabetes	398	5.7	46	4.5	66	4.7	168	6.0	118	6.4	0.063
Liver disease	60	0.9	10	1.0	16	1.2	24	0.9	10	0.5	0.291
Renal failure	65	0.9	**	**	14	1.0	25	0.9	18	1.0	0.945

* Mean hospital-level probabilities grouped into quartiles; probability cutoffs for quartiles are as follows: 1st quartile <13%, 2nd quartile 13–19%, 3rd quartile 20–33%, 4th quartile >33%

** Number of individual patients in group cannot be displayed (because n<10) per NIS guidelines

Table 3

Hospital Characteristics Grouped by Quartile of Delay* of Emergency Procedures at Treating Hospital

	<u>All patients</u>		<u>1st quartile</u>		<u>2nd quartile</u>		<u>3rd quartile</u>		<u>4th quartile</u>		P
	n	%	n	%	n	%	n	%	n	%	
TOTAL PATIENTS	6,375	100	838	13.2	1,887	29.6	1,877	29.4	1,773	27.8	
Admission type											<0.001
Trauma center	896	12.8	85	8.4	234	16.8	311	11.2	266	14.5	
Nontrauma center	6,133	87.2	928	91.6	1,160	83.2	2,470	88.8	1,575	85.6	
Location											<0.001
Urban	6,626	94.3	873	86.2	1,209	86.7	2,750	98.9	1,794	97.5	
Rural	403	5.7	140	13.8	185	13.3	31	1.1	47	2.5	
Bed size											<0.001
Small	138	2.0	77	7.6	17	1.2	27	1.0	17	0.9	
Medium	1,542	21.9	198	19.6	323	23.2	467	16.8	554	30.1	
Large	5,349	76.1	738	72.9	1,054	75.6	2,287	82.2	1,270	69.0	
Teaching status											<0.001
Nonteaching	1,810	25.7	642	63.4	373	26.8	547	19.7	248	13.5	
Teaching	5,219	74.3	371	36.6	1,021	73.2	2,234	80.3	1,593	86.5	
Facility volume per year open tibial fractures											<0.001
1st quartile (5 cases/yr.)	1,011	14.4	297	29.3	192	13.8	263	9.5	259	14.1	
2nd quartile (6–15 cases/yr.)	2,056	29.3	486	48.0	468	33.6	620	22.3	482	26.2	
3rd quartile (16–30 cases/yr.)	1,941	27.6	168	16.6	482	34.6	907	32.6	384	20.9	
4th quartile (31 cases/yr.)	2,021	28.8	62	6.1	252	18.1	991	35.6	716	38.9	

* Mean hospital-level probabilities grouped into quartiles; probability cutoffs for quartiles are as follows: 1st quartile <13%, 2nd quartile 13–19%, 3rd quartile 20–33%, 4th quartile >33%

Patient-level Timing of Emergency Procedures and Initial Procedure Documented by Quartile of Delay* of Emergency Procedures at Treating Hospital

Table 4

	<u>All patients</u>		<u>1st quartile</u>		<u>2nd quartile</u>		<u>3rd quartile</u>		<u>4th quartile</u>		P
	n	%	n	%	n	%	n	%	n	%	
TOTAL	7,029	100	1,013	14.4	1,394	19.8	2,781	39.6	1,841	26.2	
Patient Level Outcomes											
Delay											<0.001
No delay (emergency procedure HD #0)	4,847	69.0	880	86.9	1,030	73.9	1,905	68.5	1,032	56.1	
HD #1	1,125	16.0	42	4.2	137	9.8	465	16.7	481	26.1	
HD #2	177	2.5	10	1.0	27	1.9	62	2.2	78	4.2	
HD #3 or greater	286	4.1	5	0.5	43	3.1	115	4.1	123	6.7	
Timing unspecified	594	8.5	76	7.5	157	11.3	234	8.4	127	6.9	
Initial emergency procedures coded**											<0.001
Debridement	4,751	67.6	658	65.0	936	67.1	1,885	67.8	1,272	69.1	
External fixation	614	8.7	69	6.8	87	6.2	288	10.4	170	9.2	
ORIF	1,615	23.0	282	27.8	363	26.0	586	21.1	384	20.9	
Arterial repair	2	0.03	0	0.0	2	0.1	0	0.0	0	0.0	
Amputation	47	0.7	4	0.4	6	0.4	22	0.8	15	0.8	

* Mean hospital-level probabilities grouped into quartiles; probability cutoffs for quartiles are as follows: 1st quartile <13%, 2nd quartile 13–19%, 3rd quartile 20–33%, 4th quartile >33%

** Procedure initially coded implies procedures listed prior were not coded in the following order: debridement, external fixation, ORIF, arterial-repair, amputation

Table 5

Patient-level Cost and Length of Stay Outcomes Grouped by Quartile of Delay* of Emergency Procedures at Treating Hospital

	All patients		1st quartile		2nd quartile		3rd quartile		4th quartile		P
	n	%	n	%	n	%	n	%	n	%	
TOTAL	7,029	100	1,013	14.4	1,394	19.8	2,781	39.6	1,841	26.2	
Cost											<0.001
Mean (SD)	28,279 (22,755)		23,317 (18,304)		27,385 (23,115)		30,037 (23,467)		29,030 (23,185)		
Length of stay											<0.001
Mean (SD)	7.7 (6.9)		6.3 (5.7)		7.1 (6.5)		8.5 (7.4)		7.9 (6.9)		

* Mean hospital-level probabilities grouped into quartiles; probability cutoffs for quartiles are as follows: 1st quartile <13%, 2nd quartile 13–19%, 3rd quartile 20–33%, 4th quartile >33%

Table 6

Adjusted Proportional Change in Cost Among Hospital Delay Quartiles and Select Control Variables

		Multiple Linear Regression of Logtransformed Cost		
		n = 7,029		
		Proportional	95% CI	P
Hospital Delay Quartile				
Mean hospital delay (quartile)				
1st quartile (<13% delay)		Reference group		
2nd quartile (13–19% delay)		0.00	–0.10 – 0.10	0.977
3rd quartile (20–33% delay)		0.07	–0.02 – 0.18	0.154
4th quartile (>33% delay)		0.12	0.02 – 0.21	0.017
Patient/Injury Characteristics				
Age (unit = 10 years)		0.03	0.02 – 0.04	<0.001
Mechanism of injury				
Blunt		Reference group		
Sharp/penetrating		–0.34	–0.39 – –0.28	<0.001
Other		–0.06	–0.12 – 0.01	0.086
Unspecified		0.15	0.07 – 0.24	<0.001
Associated injuries/procedures				
Arterial injury (popliteal, AT, PT)		0.54	0.44 – 0.64	<0.001
Complicated open wound		0.20	0.13 – 0.26	<0.001
Fasciotomy		0.39	0.33 – 0.45	<0.001
Blood transfusion		0.32	0.27 – 0.36	<0.001
Mechanical ventilation		0.50	0.43 – 0.57	<0.001
Injury severity score (ISS)				
<10		Reference group		
10–20		0.33	0.30 – 0.36	<0.001
>20		0.64	0.58 – 0.70	<0.001
Hospital Characteristics				
Admission type				

	Multiple Linear Regression of Logtransformed Cost		
	n = 7,029		
	Proportional	95% CI	P
Trauma center	0.12	0.07 – 0.17	<0.001
Nontrauma center	Reference group		
Teaching status			
Nonteaching	Reference group		
Teaching	0.01	–0.06 – 0.09	0.720
Facility volume per year open tibial fractures			
1st quartile (5 cases/yr.)	Reference group		
2nd quartile (6–15 cases/yr.)	0.21	0.15 – 0.27	<0.001
3rd quartile (16–30 cases/yr.)	0.27	0.20 – 0.35	<0.001
4th quartile (31 cases/yr.)	0.25	0.15 – 0.34	<0.001

* Grey boxes indicate nonsignificant change

[†] Controlling for hospital characteristics, patient demographics, economic characteristics, injury characteristics, associated procedures, and comorbidities

Table 7

Adjusted Proportional Change in Length of Stay Among Hospital Delay Quartiles and Select Control Variables

		Multiple Linear Regression of Logtransformed Length of Stay		
		n = 7,029		
		Proportional	95% CI	P
Hospital Delay Quartile				
Mean hospital delay (quartile)				
1st quartile (<13% delay)		Reference group		
2nd quartile (13–19% delay)		–0.01	–0.08 – 0.05	0.652
3rd quartile (20–33% delay)		0.08	0.02 – 0.14	0.006
4th quartile (>33% delay)		0.11	0.04 – 0.17	0.001
Patient/Injury Characteristics				
Age (unit = 10 years)		0.05	0.04 – 0.06	<0.001
Mechanism of injury				
Blunt		Reference group		
Sharp/penetrating		–0.20	–0.25 – 0.14	<0.001
Other		0.01	–0.05 – 0.09	0.711
Unspecified		0.16	0.07 – 0.24	<0.001
Associated injuries/procedures				
Arterial injury (popliteal, AT, PT)		0.44	0.34 – 0.55	<0.001
Complicated open wound		0.24	0.18 – 0.32	<0.001
Fasciotomy		0.45	0.38 – 0.51	<0.001
Blood transfusion		0.32	0.27 – 0.36	<0.001
Mechanical ventilation		0.41	0.34 – 0.48	<0.001
Injury severity score (ISS)				
<10		Reference group		
10–20		0.24	0.21 – 0.27	<0.001
>20		0.52	0.45 – 0.58	<0.001
Hospital Characteristics				

	Multiple Linear Regression of Logtransformed Length of Stay		
	n = 7,029		
	Proportional	95% CI	P
Admission type			
Trauma center	0.05	0.001 – 0.10	0.043
Nontrauma center	Reference group		
Teaching status			
Nonteaching	Reference group		
Teaching	0.05	–0.003 – 0.10	0.067
Facility volume per year open tibial fractures			
1st quartile (5 cases/yr.)	Reference group		
2nd quartile (6–15 cases/yr.)	0.16	0.11 – 0.22	<0.001
3rd quartile (16–30 cases/yr.)	0.21	0.14 – 0.27	<0.001
4th quartile (31 cases/yr.)	0.19	0.12 – 0.26	<0.001

* Grey boxes indicate nonsignificant change

† Controlling for hospital characteristics, patient demographics, economic characteristics, injury characteristics, associated procedures, and comorbidities