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The financial burden of musculoskeletal firearm injuries in children with and without concomitant intra-cavitary injuries☆,☆☆

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ABSTRACT

Background: Musculoskeletal pediatric firearm injuries are a clinically significant and expensive public health problem in the United States. In this retrospective cohort analysis, we sought to characterize musculoskeletal firearm injuries in children and to describe the financial burden associated with these injuries.
Methods: This study is a single center, retrospective review. Patients were identified from January 2002 – December 2015 from an institutional database using ICD-9 codes pertaining to firearm injury. Inclusion criteria were: 1) age < 18 years at injury; 2) firearm injury to an extremity, spine, or pelvis; and 3) patient received orthopedic evaluation and/or treatment. 140 patients with 142 distinct orthopedic injuries meeting inclusion criteria were analyzed (N = 142). Primary measures were demographic and situational data including intent, length of stay, follow-up, and complications; and financial outcomes including charges, costs, and net revenues.
Results: Median age was 15.3 years [IQR: 13.3, 16.4], 84% were male, and 52% were African American. 59% of the firearm injuries were of violent intent. 32% of patients were privately insured, 61% were publicly insured, and 6% were uninsured. Median length of stay was 2 days [0, 4], with 73% of patients being admitted. 43% of patients required additional hospitalizations, emergency room visits, and/or outpatient surgeries, and 93% of patients had outpatient follow-up. 42% of patients experience an injury-related or long-term orthopedic complication. Total charges for the cohort were $11.4 million, with $3.7 million in costs and $45,042 in net revenues. In the multivariable analysis, more surgeries predicted higher charges, and more secondary encounters predicted higher costs and net revenues. Only privately-insured patients had a positive median net revenue.
Conclusions: Children who sustain musculoskeletal injuries from firearms experience high rates of orthopedic complications. Institutional costs to manage these preventable injuries are excessive. Policy makers should continue to pursue measures to reduce gun violence and improve gun safety in the pediatric population.
Level of Evidence: Level III, economic/decision.

Firearm injuries are a major social and public health concern in the United States, with firearm deaths from suicide and homicide constituting the 4th and 5th leading causes of mortality due to trauma, respectively [1,2]. Furthermore, approximately twice as many non-fatal firearm injuries occur annually as fatalities [3]. Children are also affected, with homicide and suicide by firearm representing the 2nd and 5th leading causes of injury death for ages 1–18 [1]. Moreover, over 7000 total firearm injuries occurred in children per year between 2012 and 2014 [4]. Consequently, firearm injuries continue to have a significant economic impact on the healthcare system, resulting in an $17 billion in annual healthcare costs for all ages [5]. Average annual costs of $622–$734.6 million for initial admission alone have been reported, with the majority of the reimbursement burden falling on public payers (i.e. Medicare and Medicaid) [6,7].

Among injuries caused by firearms, a substantial percentage affect the extremities or spine and may require orthopedic management. A 2015 epidemiologic study of almost 100,000 patients demonstrated that 55% of primary non-fatal firearm injuries were to the arm, hand, leg, or foot [3]. Data in children are similar, with a 2012 study reporting that 49.9% of cases included an open extremity wound [8]. The frequency of firearm injuries to the musculoskeletal system is substantial, yet these studies did not even include secondary ballistic injuries or injuries to the spine. Furthermore, the mechanistic effects of bullets on

Abbreviations: ACS, American College of Surgeons; ED, Emergency Department; GSW, gunshot wound; ORIF, open reduction and internal fixation; VCH, Vanderbilt Children's Hospital; VUMC, Vanderbilt University Medical Center.

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☆☆ **Conflicts of Interest:** none.

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musculoskeletal tissue have the potential to be devastating [9,10]. Studies specific to children have reported high rates of morbidity, including infection, fracture non-union, neurological injury, compartment syndrome, and vascular injury as well as high rates of associated non-extremity injury [11–13].

The frequency and magnitude of this multidisciplinary clinical and public health problem motivated our study of the burden that musculoskeletal gunshot wounds impart on children and pediatric trauma hospitals. While previous studies have used national data samples such as the CDC's WISQARS and the National Emergency Department Sample (NEDS) to approach the issue, granular and center-specific clinical and financial data for firearm injuries in children are scarce [8,14]. In this retrospective cohort study, we mined detailed data from our institution to characterize musculoskeletal firearm injuries in children, and to describe the financial impact associated with management of these injuries. We hypothesized that these injuries would be clinically and financially burdensome on patients and the system.

1. Methods

1.1. IRB

The Vanderbilt Institutional Review Board approved all aspects of this study (#161056).

1.2. Patient Identification and Inclusion Criteria

The Monroe Carell Jr. Children's Hospital at Vanderbilt (VCH) and the Vanderbilt University Medical Center (VUMC) serve as the primary ACS-verified level 1 trauma centers for middle Tennessee, southern Kentucky, and northern Alabama. Together, these centers admit over 5000 trauma patients each year, including approximately 350 gunshot wound (GSW) victims.

Patients were identified by a query submitted to the patient information database managed by the Vanderbilt Medical Group (VMG). The query criteria were based on ICD-9 external injury codes recorded at the time of first encounter to VCH or VUMC pertaining to injury or assault by any firearm or missile. Inclusion criteria were: 1) patient was <18 years of age at the time of injury; 2) firearm injury to the extremity, spine, or pelvis; and 3) patient received orthopedic evaluation and/or treatment. At our institution, orthopedic surgery provides spine and hand services and rotates call with neurosurgery and plastic surgery, respectively; evaluation and/or treatment by any of these services for a ballistic injury to the spine or hand were considered to have met inclusion criteria. In addition to musculoskeletal injuries, some patients in this cohort had concomitant intra-abdominal, pelvic, or thoracic injuries. As long as these patients met the above inclusion criteria, they were not excluded from this analysis.

Initial queries to VMG for patients presenting during the time period of January 1st, 2002 – December 31st, 2015 yielded 655 unique medical record numbers. A total of 140 individual patients met inclusion criteria and were enrolled. Two patients were enrolled twice due to experiencing two distinct-in-time firearm injuries independently meeting selection criteria, for a total of cohort of 142. We do not consider the data from these two patients to be dependent, given that each enrollment reflects a distinct injury separated in time, and that only demographic data are similar.

1.3. Data Collection

Charts of patients meeting inclusion criteria were reviewed manually using the electronic medical record. Charts were reviewed for demographic, situational, injury-related, surgical, and hospitalization data. Financial data were obtained through a business objects report with the cooperation of the VCH Department of Finance. All available follow-up data were collected through November 2017. Study data were collected and managed using REDCap electronic data capture tools hosted at VUMC [15].

1.4. Financial Data

Financial data were adjusted for inflation and reported in 2009 dollars using the Personal Consumption Expenditure Health Price Index (PCE_Health) [16]. Total costs are defined as the sum of technical costs and professional costs, including variable direct, variable indirect, fixed direct, and fixed indirect costs. Net revenue (i.e. operating margin) is defined as total revenues minus total costs. Missing financial data were estimated using statistical data imputation with IBM SPSS v25 statistical software [17,18]. Ten imputed data sets were created using predictive mean matching (PMM). Input variables included available financial data, age, race, gender, mechanism of injury, type of encounter, initial length of stay, injury severity score, number of fractures, number of surgeries, number of complications, mortality status, and insurance status. Sensitivity analysis was performed to assess the fidelity of the imputed data set compared to the original.

1.5. Statistical Analysis

Descriptive statistics were performed on demographic and financial data, using the median and interquartile range. The Kruskal-Wallis test was applied to continuous variables. Multivariable linear regression with maximum likelihood estimation was performed to assess for predictors of each primary financial outcome variable: charges, costs, and net revenues. Linear regression assumptions were checked for each of the models resulting in the exclusion of one extreme outlier. Predictor variables were selected based hypothesized clinical significance, followed by preliminary univariable statistics (Mann–Whitney tests, $p < 0.05$). Predictors were then tested for correlation with each other (Spearman's Rho correlations) and multicollinear predictors were removed. Variables meeting these criteria were: number of secondary encounters, number of surgeries, initial length of stay, duration of outpatient follow-up, number of complications, number of fractures, payer type, injury type, disposition at initial encounter, age, and race. Regressions run with outliers included for sensitivity analysis yielded similar results. Statistical significance was set at $p < 0.05$.

2. Results

2.1. Demographics

140 patients sustained 142 independent ballistic injuries ($N = 142$; median of 10 cases per year [IQR: 7, 12.75]). There was a small increase of $M = 0.35$ in the number of GSWs per year ($R[2] = 0.14$). Median age was 15.3 years [13.2, 16.4], with patients being 84% male, 52% black/African American, and 42% white. 59% of cases were the result of a violent/intentional shooting, whereas 40% were unintentional firings. The most common weapon was a handgun (27%), although the weapon type was not documented in 47% of cases. 61% percent of patients were insured publicly (Medicaid), 32% of patients had private insurance, and 6% had no insurance. 73% of patients were admitted from the Emergency Department (ED) for an overall median length of stay of 2 days [0, 4]. 43% of patients had at least one additional encounter with the hospital (excluding outpatient follow-up), including additional ED visits, outpatient surgeries, medical admissions, admissions for surgery, and inpatient rehabilitation. Furthermore, 93% of patients had outpatient follow-up (80% with orthopedic follow-up), for a median follow-up duration of 1.9 months [0.5, 6.7] and 3 visits [1.5, 5.5] (Table 1).

Regarding injury locations in this cohort, 75% were isolated to the extremities; 11% were isolated to non-extremity locations, including the pelvis, spine, abdomen, and chest; and the remaining 14% of patients had injuries to both the extremities and elsewhere (mixed). Lower extremity injuries were most common (54% of patients) followed by

Table 1
Descriptive Data.

	N = 142
Demographics and Circumstances	
Age at time of injury, years	15.3 [13.2, 16.4]
Sex	
Male	119 (84%)
Female	23 (16%)
Race	
Black	74 (52%)
White	60 (42%)
Other/Unknown	8 (6%)
Living distance from VCH, miles*	16.0 [5.6, 46.3]
Intent	
Violent/assault	83 (59%)
Unintentional firing	57 (40%)
Suicide attempt	2 (1%)
Type of firearm	
Handgun	38 (27%)
Shotgun	11 (8%)
Automatic rifle	14 (10%)
BB/pellet gun	12 (9%)
Unknown	67 (47%)
Payer Type	
Public	87 (61%)
Private	46 (32%)
Uninsured	9 (6%)
Hospitalization and Follow-up	
Transfer to VCH from outside hospital	38 (27%)
Initial encounter	
Discharged from ED	38 (27%)
Admitted	104 (73%)
Length of stay (initial hospitalization), days	2 [0, 4]
Patients w/ ≥ 1 secondary encounter	61 (43%)
Secondary encounters	
Return to ED	21 (15%)
Outpatient surgery	31 (22%)
Inpatient surgery	14 (10%)
Medical admission	8 (6%)
Inpatient rehabilitation	4 (3%)
Total length of stay (including secondary), days	2 [1,5]
Outpatient follow-up	
Patients with orthopedic follow-up	114 (80%)
Patients with any outpatient follow-up, N (%)	132 (93%)
Number of visits per patient	3 [1.5, 5.5]
Duration of follow-up, months	1.9 [0.5, 6.7]
Injuries	
Injury type*	
Isolated extremity	107 (75%)
Isolated non-extremity (including pelvis and vertebral injuries)	15 (11%)
Mixed extremity and non-extremity	20 (14%)
Injury location	
Upper extremity	55 (39%)
Lower extremity	77 (54%)
Head/neck	3 (2%)
Chest/back	14 (10%)
Torso/pelvis	25 (18%)
Patients with ≥1 fracture	111 (78%)
Number of fractures per patient	1 [1,1]
Bones fractured	
Humerus	6 (4%)
Radius/ulna	9 (6%)
Carpal bone	9 (6%)
Vertebra	13 (9%)
Pelvis	12 (9%)
Femur	26 (18%)
Tibia/fibula	16 (11%)
Tarsal bone	13 (9%)
Other	17 (12%)
Injury severity score*	9 [4,16]
Antibiotic usage	
During initial encounter	107 (75%)
Discharge	60 (42%)
Surgeries	
Surgeries on extremities or spine	
Number of surgeries per patient	1 [0, 1]
Type of operation	
Debridement/wound care	61 (43%)

Table 1 *(continued)*

	N = 142
External fixation	4 (3%)
ORIF	38 (27%)
Ballistic fragment removal	28 (20%)
Fasciotomy	4 (3%)
Vascular repair/bypass	9 (6%)
Wound coverage/skin grafting	9 (6%)
Nerve repair	4 (3%)
Tendon repair	10 (7%)
Amputation	7 (5%)
Other	66 (47%)
Patients with abdominal and/or thoracic surgeries	17 (12%)
Total number of surgeries per patient	1 [0, 2]
Complications	
Patients with ≥1 complication	60 (42%)
Immediate/injury associated complications	
Nerve injury	30 (21%)
Vascular injury	13 (9%)
Compartment syndrome	4 (3%)
Amputation	7 (5%)
Long-term/iatrogenic complications	
Infection	14 (10%)
Reoperation – hardware removal	6 (4%)
Reoperation – other	18 (13%)
Nonunion	2 (1%)
Death	3 (2%)
Other	7 (5%)

Data reported as N (%) or median [q1, q3]. *N < 142 (Living distance, N = 123; ISS, N = 80).
* Variable categories "Non-extremity" and "Mixed" include non-musculoskeletal injuries, including intra-abdominal and thoracic injuries.

upper extremity (39%). 78% of patients sustained at least 1 ballistic fracture (max being 4) and most commonly to the femur (18%). Patients received a median of 1 surgery [0, 2] (max being 9), with 43% of patients undergoing an operative debridement/wound care procedure, 27% receiving open reduction and internal fixation (ORIF), and 20% undergoing ballistic fragment removal. 12% of patients received abdominal/pelvic and/or thoracic operations, including laparotomy and thoracotomy. 42% of patients had at least one musculoskeletal-related complication. Immediate, injury associated complications included nerve injury (including spinal cord injuries; 30 patients, 21%), vascular injury (13 patients 9%), compartment syndrome (4 patients, 3%), and amputation (7 patients, 5%). Long-term complications included injury or surgical site infection (14 patients, 10%), reoperations (24 patients, 17%), and death (3 patients, 2%; Table 1).

2.2. Financial Analysis

Financial variables used for this analysis include charges, costs, and net revenue, and were assessed on both a per-patient (N = 142) and per-encounter (N = 1016) basis. The total adjusted charges assessed for the entire cohort were $11,447,444, which were associated with total costs of $3,707,285 and net revenues of $45,042 (Table 2).

2.2.1. Per-patient

The median total charges per patient were $51,956 [IQR: $19,329, $87,653], which includes all charges assessed with initial hospitalization as well as additional encounters and outpatient follow-up. Median costs were $16,356 [$8246, $30,972], and net revenues were $441 [−$4489, $8697]. Patients with insurance experienced significantly higher costs but not charges than uninsured patients (p = 0.014 and 0.207, respectively). Patients with private insurance were the only subgroup having a median net revenue greater than 0 ($7872 [−$65, $13,304]), and uninsured patients showed the lowest median net revenue at -$2956 ([−$5540, $92]; p = 0.001; Fig. 1, Table 2).

Firearm type was associated with significantly different charges and costs (p = 0.015 and 0.001, respectively) but not net revenues (p =

Table 2
Financial Data.

	Charges		Costs		Net Revenues	
	USD	P-value	USD	P-value	USD	P-value
Total	11,447,444		3,707,285		45,042	
Per patient, N = 142						
All patients	51,956 [19,329, 87,653]		16,356 [8246, 30,972]		441 [−4489, 8697]	
Per inpatient day (initial hospitalization)	13,048 [9145, 20,597]		4399 [2937, 7319]		195 [−2171, 3336]	
Payer type		0.207		**0.014**		**0.001**
Public	52,286 [19,808, 87,653]		16,513 [15,058, 30,812]		−134 [−8917, 8098]	
Private	50,359 [19,553, 97,225]		16,401 [9646, 31,639]		7872 [−65, 13,304]	
Uninsured	13,736 [4846, 49,814]		3091 [1735, 12,589]		−2956 [−5540, 92]	
Type of firearm		**0.015**		**0.001**		0.630
Handgun	51,344 [18,446, 75,246]		15,965 [4712, 18,805]		355 [−1934, 8352]	
Shotgun	66,060 [29,504, 132,424]		25,049 [15,908, 35,281]		7557 [−1012, 11,813]	
High powered rifle	51,330 [15,856, 126,275]		17,264 [15,124, 33,383]		−177 [−9331, 11,155]	
BB or pellet gun	9061 [2772, 51,490]		3641 [845, 15,236]		30 [−117, 7970]	
Unknown	52,676 [25,572, 90,891]		16,552 [14,750, 30,780]		249 [−8154, 8694]	
Injury type		**<0.001**		**0.003**		**0.024**
Isolated extremity	40,535 [12,685, 67,077]		15,972 [4194, 19,211]		8 [−4544, 8081]	
Isolated non-extremity	44,082 [30,880, 208,203]		17,651 [12,011, 35,834]		10,083 [−1005, 22,983]	
Mixed extremity and non-extremity	88,779 [61,734, 139,724]		19,191 [16,241, 32,005]		6671 [−9960, 14,659]	
Complications		**<0.001**		**<0.001**		**0.032**
None	33,337 [10,836, 55,297]		15,504 [3906, 16,665]		−76 [−6129, 7862]	
Injury related only	58,095 [32,502, 105,067]		17,370 [15,239, 32,145]		8100 [−830, 14,921]	
Long term only	72,351 [17,355, 104,425]		30,714 [15,206, 32,118]		1721 [−1147, 15,683]	
Injury related + Long term	151,038 [74,914, 202,202]		33,218 [18,273, 61,484]		4698 [−6958, 16,126]	
Per encounter type, N = 1016		**<0.001**		**<0.001**		**<0.001**
Primary encounter – ED discharge	3715 [2920, 3799]		1221 [845, 1268]		215 [−50, 299]	
Primary encounter – hospitalization	50,342 [27,580, 64,654]		14,766 [14,638, 14,887]		1125 [−6596, 8412]	
Secondary encounter – ED visit	3730 [3488, 3794]		1213 [812, 1257]		229 [−30, 295]	
Secondary encounter – outpatient surgery	50,472 [50,223, 50,671]		14,745 [14,611, 14,846]		8229 [7961, 8433]	
Secondary encounter – hospitalization	18,936 [11,145, 40,867]		14,775 [14,682, 14,889]		−11,225 [−12,053, −7806]	
Secondary encounter – inpatient rehab	26,538 [2749, 50,410]		8606 [2532, 14,742]		3407 [−1197, 8115]	
Outpatient follow-up visit	864 [822, 901]		393 [362, 419]		−148 [−181, −110]	

Data reported as median [q1, q3]. Total number of patients = 142. Total number of encounters = 1016.

0.630), with shotgun injuries imparting the greatest costs ($25,049 [$15,908, $35,281]). Injury type was associated significantly with different charges, costs, and net revenues ($p < 0.001$, $= 0.003$, and $= 0.024$, respectively), as was complication type ($p < 0.001$, < 0.001, and $= 0.032$, respectively). The greatest costs were associated with patients sustaining mixed injury patterns ($19,191 [$16,241, $32,005]), and with both injury-related and long-term complications ($33,218, [$18,273, $61,484]; Table 2).

2.2.2. Per-encounter

Patient encounters with the healthcare system were grouped into primary encounters (discharge from the ED vs. hospitalization), secondary encounters (ED visits, outpatient surgeries, hospitalizations, and inpatient rehabilitation), and outpatient follow-up visits. As expected, significant differences were detected in charges, costs, and net revenues among different encounter types (all $p < 0.001$). Some of the greatest median charges and costs were associated with primary hospitalizations (charges: $50,342 [$27,580, $64,654]; costs: $14,766 [$14,638, $14,887]) and outpatient surgeries (charges: $50,472 [$50,223, $50,671]; costs: $14,745 [$14,611, $14,887]). Outpatient surgeries were also associated with the greatest net revenues per encounter ($8229 [$7961, $8433]). Secondary hospitalizations also carried some of the highest costs ($14,775 [$14,682, $14,889]) but the lowest net revenues (−$11,225 [$12,053, −$7806]; Table 2).

2.2.3. Predictors of Financial Burden

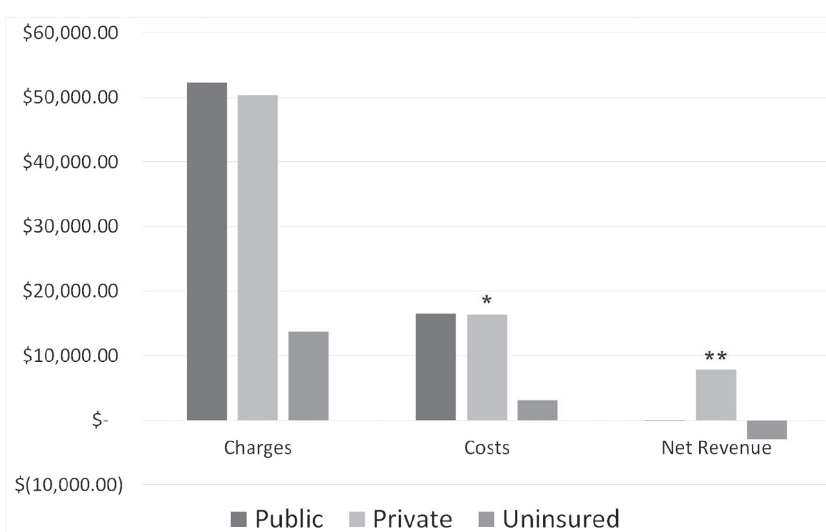
Multivariable linear regression was performed to identify predictors for charges, costs, and net revenues. For total charges, a greater number of secondary encounters, a greater number of surgeries, and a longer initial length of stay were significantly associated with higher charges (all $p < 0.001$). Patients with isolated extremity injuries had lower charges ($p < 0.001$) compared to patients with both extremity and non-extremity injuries. Number of secondary encounters ($p < 0.001$), number of surgeries ($p < 0.001$), and initial length of stay ($p = 0.007$) were also predictive of higher costs. Additionally, patients discharged from the ED at initial encounter had lower costs ($p < 0.001$). For net revenues, a higher number of secondary encounters ($p = 0.018$) and longer initial LOS ($p = 0.020$) was predictive of higher net revenues. Patients with isolated extremity injuries had lower charges ($p = 0.031$) compared to patients with both extremity and non-extremity injuries. Age, race, duration of outpatient follow-up, number of complications, number of fractures, and payer type were not significant predictors for any outcome in regression analysis (Table 3).

3. Discussion

In this study, we have demonstrated the clinical and financial impact of musculoskeletal firearm injuries on a busy pediatric trauma center over a 14-year period. This single institution cohort reflects a steady stream of injuries primarily caused by violence having high rates of admission, surgery, and complications. Furthermore, with total costs of over $3.7 million, this subset of firearm injuries represents a considerable financial item with a virtually negligible total net revenue to the institution of $45,042. Significant differences in financial outcomes were dependent on payer type, type of firearm, and injury location, and the greatest costs were incurred with hospitalizations and outpatient surgeries. The numbers of secondary encounters and surgeries and initial length of stay independently predicted higher costs, with the number of secondary encounters and length of stay also predicting a higher net revenue.

Notably, within this cohort a broad range of morbidity was observed. For example, Patient A was accidentally struck in the arm by a small projectile from a pellet rifle. The foreign body was removed at bedside and did not cause fracture or significant tissue damage, and the patient was discharged home the same day. In contrast, Patient B was the victim of a violent shooting causing multiple vertebral fractures and paraplegia. Over the course of 3.5 years, this patient had a total of 96 subsequent hospitalizations or ED visits at our center alone for a total of 352 admission days, before being lost to follow-up. The typical patient in this cohort fell somewhere in between these two examples, and our observed rates of injury-related complications, such as nerve injury, vascular injury, and amputation, were consistent with or greater than that reported in other studies [11–13].

Many of the trends in charges, costs, and net revenue seen in this study are consistent with expectations. It makes sense that the cost of injuries from a shotgun, handgun, or rifle are greater than those from a low-velocity pellet gun, and the costs of inpatient hospitalization are considerably greater than those of an ED discharge. However, it is noteworthy that the majority of this cohort fell within one of these higher-cost categories (only 9% of injuries were caused by BB/pellet guns, and 73% of patients were admitted), further underlining the overall financial impact of firearm injuries. Another significant finding of the per-encounter financial analysis is the significantly negative net revenue associated with secondary hospitalizations (median negative $11,225)



Financial values represent per-patient data. * p = 0.014, ** p = 0.001

Fig. 1. Financials by Payer Type Financial values represent per-patient data. * $p = 0.014$, ** $p = 0.001$.

Table 3
Predictors of Financial Burden (N = 141).

	Charges		Costs		Net Revenues	
	B (95% CI)	P-value	B (95% CI)	P-value	B (95% CI)	P-value
Number of secondary encounters	22,983 (16,681, 29,284)	<**0.001**	10,056 (8383, 11,729)	<**0.001**	2901 (502, 5300)	**0.018**
Number of surgeries	19,744 (14,281, 25,206)	<**0.001**	2381 (935, 3828)	<**0.001**	2039 (−35, 4113)	0.054
Initial length of stay	5871 (4175, 7566)	<**0.001**	587 (132, 1041)	**0.011**	775 (124, 1427)	**0.020**
Duration of outpatient follow-up, months	50 (−324, 424)	0.794	23 (−76, 123)	0.646	−107 (−249, 36)	0.141
Number of complications	−2395 (−7999, 3210)	0.402	−1408 (−2893, 77)	0.063	−401 (−2530, 1728)	0.712
Number of fractures	432 (−7916, 8780)	0.919	813 (−1402, 3027)	0.472	−966 (−4140, 2207)	0.551
Payer type = public	−8210 (−29,540, 13,121)	0.451	2885 (−2774, 8544)	0.318	−922 (−9035, 7191)	0.824
Payer type = private	−9986 (−31,911, 11,939)	0.379	4751 (−1141, 10,643)	0.114	5930 (−2513, 14,373)	0.169
Injury type = isolated extremity	−27,403 (−42,681, −12,124)	<**0.001**	−2328 (−6386, 1729)	0.261	−6387 (−12,201, −574)	**0.031**
Injury type = isolated non-extremity	−3614 (−25,638, 18,409)	0.749	−3181 (−9040, 2678)	0.287	2716 (−5680, 11,111)	0.526
Initial encounter = discharged from ED	3132 (−10,688, 16,952)	0.657	−8115 (−11,813, −4417)	<**0.001**	5047 (−291, 10,386)	0.064
Age at time of injury, years	399 (−1125, 1923)	0.608	43 (−361, 448)	0.833	−235 (−815, 345)	0.427
Race = black	348 (−11,410, 12,106)	0.954	−770 (−3890, 2350)	0.629	−44 (−4516, 4429)	0.985
Race = other/unknown	−12,713 (−21,349, −4077)	0.286	−3795 (−9978, 2388)	0.229	−4671 (−13,531, 4189)	0.301

Data reported as B (95% confidence interval). For continuous variables, beta represents the change in outcome associated with a one-point change in the predictor. For categorical variables, reference groups are: payer type = uninsured; injury type = mixed; initial encounter = admitted to inpatient; race = white. Adjusted R^2: charges = 0.858, costs = 0.823, net revenue = 0.354.

compared to the modest but positive net revenue of primary hospitalizations ($1125). The authors speculate that this difference is related to increased complexity of secondary hospitalizations related to complications of initial injuries, and possibly to reduction in reimbursement for readmissions. Regarding outpatient visits, despite these accounting for a large majority of total encounters (N = 718, 71%), their relative financial impact was low at only 7.6% of overall costs.

Unsurprisingly, the greatest reimbursement to the hospital was associated with private payers, with the lowest reimbursement associated with uninsured patients. It is worth noting that the percentage of uninsured patients in this cohort was significantly lower than that reported in other literature, 9% here versus 21.3–29.4% in adult firearm studies and 22.2% in one pediatric firearm study. This study also demonstrated a greater percentage of patients with private insurance: 32% versus 28.9–21.4% in adults and 26.3% in children [6–8]. Considering that only patients with private insurance generated a median net revenue greater than zero, and that the median for uninsured patients was significantly less than zero (−$2956), we conclude that other centers with different patient populations are unlikely to generate a positive net revenue in the management of musculoskeletal firearm injuries. In other words, such centers are likely to experience a greater financial burden related to firearm injuries. Despite the fact that payer type did not independently predict for differences in any of the financial outcomes in our multivariable model, the significant univariable differences seen in costs and net revenues lead us to believe that it is still an important demographic consideration in this discussion.

Of note, we found that charges and costs were lower for patients without insurance than for those with insurance (Table 2; p = 0.207 and 0.014 respectively), an unexpected observation. Upon subgroup analysis, patients without insurance in this cohort (N = 9) were more likely to have isolated extremity injuries than the cohort at large and had lower rates of fracture, admission, surgery, complication, and secondary encounters. Thus, the uninsured patients in this cohort were on average less severely injured than the cohort at large, which helps to explain this apparent discrepancy. This is consistent with the results of the multivariable analysis, which included many of these outcome variables and found differences in charges and costs between payer types to be insignificant.

This study is limited by the fact that it is a retrospective study. However, a prospective cohort study examining musculoskeletal firearm injuries in children, which may have the advantage of greater patient enrollment and improved granularity of demographic and financial data, would require many years of enrollment to achieve meaningful statistical power. There would be value in a multicenter prospective study, but firearms studies also face the difficulty of limited funding. Another limitation of this study is that due to a change in the financial systems at our institution in 2013, we did not have access to full financial data for some encounters and were required to use statistical data imputation to estimate missing data. However, given comparable results on sensitivity analysis between the original data set and the imputed data set, and that the vast majority of missing data was for outpatient follow-up, we feel that the data presented is representative. Furthermore, while this study enrolled patients with initial admit dates up to December 2015 and only examined data through November 2017, it is likely that a small number of secondary encounters and follow-up visits were omitted from the analysis. Finally, while the focus of this study was firearm-induced musculoskeletal injuries, the authors recognize the importance of other injuries related to firearms, including intra-abdominal, -thoracic, and -cranial injuries. A demographic and financial analysis of such injuries are considerations for a follow-up study, and some data on these injuries or on firearm injuries in general has been published elsewhere [4,19].

This study has broad implications for both clinical practice and public health. This cohort underscored the impact of firearms on a single surgical service at a single pediatric hospital. Certainly, the potential for morbidity of firearm injuries on the extremities, spine, and pelvis is profound, and pediatric orthopedic surgeons should be trained and familiar with their mechanisms and treatment. Yet, these injuries have a significant impact on other pediatric services as well, including critical care, trauma surgery, neurosurgery, and plastic surgery. Considering the potential projection of the clinical and financial costs found in this cohort across other urban pediatric hospitals, pediatric firearm injuries are an undeniable public health problem. Even in this study it is evident that this problem is multifaceted, with 59% of the cohort representing violent crime; 40% representing unintentional discharge, a gun-safety issue; and 1% reflecting suicide attempts, a mental health issue.

The only way to completely avoid the financial impact of firearm injuries is to prevent the injuries completely. Given that 40% of injuries in this study appeared unintentional, the authors advocate for continued social improvements in gun safety and education in homes with children. Yet, the majority of injuries in this cohort were violent, a fact that points back to a continued social problem revolving around firearm violence. It has previously been shown in our population that firearm injuries and their mortality are not evenly distributed geographically or demographically [19]. As in that study, these authors continue to support firearm injury prevention programs that are targeted to at-risk communities, a goal which requires both public support and city-specific knowledge of injury patterns. Following initial injuries, many of the medical costs associated with firearms are unavoidable (initial ED visit/hospitalization, operations). However, another goal of our healthcare system is to improve both access to and knowledge of care, thereby improving outpatient follow-up retention and reducing rates of additional ED visits, rehospitalizations, and delayed capture of complications. As demonstrated in this study, outpatient care is significantly less costly than the latter encounters, and improved follow-up has the potential to reduce overall financial burden. In conclusion, our society must continue to take strides towards addressing these issues and protecting our children, or it must be prepared to bear the clinical, social, and financial consequences.

4. Conclusions

Firearm injuries in children are a significant clinical and public health problem in the United States, and many of these patients experience injuries to the extremities. Such patients have high rates of injury-related complications such as nerve and vascular injury, and the costs to the pediatric hospitals resulting from these injuries are considerable, especially patients with long hospitalizations and protracted clinical courses. Policy makers should continue to pursue measures to reduce gun violence and improve gun safety in the pediatric population.

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