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Proximal penetrating extremity injuries—An opportunity to decrease overtriage?

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Abstract

BACKGROUND: Penetrating injuries to the extremity proximal to the elbow or knee are anatomic criteria for full trauma team activation (FFTA) by the American College of Surgeon's Committee on Trauma standards. This criterion lacks objective evidence-based support. Overtriage of trauma team activation may result in excessive costs and resource burden at trauma centers. We hypothesized that FFTA for penetrating injuries to the proximal extremities by anatomic criteria alone may lead to significant overtriage.

METHODS: A 3-year retrospective review (2013–2015) was completed of all patients evaluated at an urban Level I trauma center with isolated penetrating extremity injuries. Data included the number of full and limited trauma team activations as well as criterion met, Injury Severity Score (ISS), injury, limb characteristics, and disposition. Overtriage was defined as FFTA for an ISS of 15 or less, with a goal rate less than 50%.

RESULTS: We identified 6,335 total trauma team activations with 795 isolated penetrating extremity injuries. Of these injuries, 413 (51.9%) were injuries proximal to the joint. Within this subgroup, 71.2% of patients were discharged from the emergency department with a median ISS of 1 and no additional intervention. Only 5.3% of patients that did not meet additional FFTA criteria underwent immediate operative intervention. By comparison, 21% of FFTAs and 5.8% of limited trauma team activations underwent immediate operative intervention during the 3-year period. Of the 413 isolated penetrating proximal-extremity injuries, only one had an ISS of 15 or greater, resulting in a 99.7% overtriage rate.

CONCLUSION: Penetrating injuries to the extremities are common in urban trauma centers. Full trauma team activation based on anatomic, rather than physiologic, criteria may lead to a significant overtriage rate. Further distinction in the level of trauma team activation may be made based on hard signs of neurovascular injury.

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AUTHORSHIP

G.M. and H.H. were involved in data collection. All authors contributed to the data analysis and writing of the article.

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DISCLOSURE

There authors declare no conflicts of interest.

LEVEL OF EVIDENCE: Epidemiological study, level III; Care Management, level IV.

Keywords

Proximal-extremity injury; overtriage; trauma team activation

Full trauma team activations (FTTAs) require the response of the complete trauma team and support personnel within 15 minutes of the arrival of the patient.¹ The required minimum criterion for FTTAs as described within the American College of Surgeons Committee on Trauma (ACS COT) *Resources for Optimal Care of the Injured Patient 2014* are predominantly composed of physiologic signs and symptoms that are associated to varying degrees as predictive of severe injury.^{2–5} Penetrating injuries to the extremities proximal to the joint are included in these minimum criteria, despite a lack of evidence supporting this triage criterion.⁶ By contrast, penetrating injuries distal to the elbow or knee do not require trauma team activation and are left to the emergency medicine physician's discretion for any necessary activation.

In an effort to reduce undertriage rates of trauma patients, the ACS COT recommends an acceptable overtriage rate between 35% and 50%.⁷ These recommendations have been implemented in an effort to reduce unnecessary morbidity and mortality resulting from delays in definitive care. However, excessive overtriage may create a burden of increased costs to the patient and health-care system, as well as potentially causing undue strain on already busy trauma systems.⁸ As trauma ranks second in total health care spending in the United States, the minimization of excess cost secondary to overtriage remains of critical importance to patient safety and efficiency of health care provision.⁹

Based on previously documented rates of neurovascular injury following penetrating injuries to the proximal extremities, we hypothesized that patients with these injuries have low rates of immediate operative intervention, admission, morbidity, and mortality.^{10–13} If this hypothesis is confirmed, FTTA for patients without additional physiologic criteria may lead to significant overtriage.

METHODS

The study was completed at the University of Cincinnati Medical Center (UCMC), an urban, academic, ACS-verified Level I trauma center. This study was approved by the Institutional Review Board of the University of Cincinnati.

The UCMC trauma registry was queried for all patients who presented with isolated penetrating injuries to the extremity as defined by Abbreviated Injury Scale (AIS) score greater than 0 between January 2013 and December 2015. Medical records were reviewed to ascertain demographic data, mechanism of injury, admission laboratory values, location of injury, trauma team activation type, Injury Severity Score (ISS), hospital length of stay, operative intervention, blood product transfusion, and discharge disposition. Patients younger than 18 years and those with additional injuries were excluded from the analysis. Patients were then identified as sustaining proximal, distal, or both proximal and distal injuries (Fig. 1). Penetrating injuries to the proximal upper extremities were defined as

injuries with skin wounds from the acromioclavicular joint to the humeral medial epicondyle. Patients with borderline axillary injuries were not included in the study. Similarly, penetrating injuries to the proximal lower extremities were defined as injuries with skin wounds from the groin crease anteriorly or inferior gluteal fold posteriorly to the patella. Patients with borderline gluteal, pelvic, or abdominal injuries were also not included in the study. Within each group, patients were further identified as having lower-extremity, upper-extremity, or both upper- and lower-extremity injuries. Finally, patients were grouped by whether they had additional FTTA criteria according to the ACS COT guidelines and UCMC trauma activation criteria¹ (Tables 1 and 2). Overtriage was primarily defined as FTTA for patients with ISS less than 15. However, several separate overtriage measures were also used including need for admission, length of stay, and need for vascular operative intervention.

Two-tailed Student's *t* tests were used to make comparisons between the two groups, and analysis of variance with Tukey's posttest was used to make comparisons between three or more groups. A *p* value less than 0.05 was considered significant. All data analyses were performed with Prism 6 (GraphPad Software, La Jolla, CA).

RESULTS

A total of 795 patients were included in the analysis. The majority of patients were African American and male. (Table 3) The two most common mechanisms of injury were gunshot wounds (65.3%) followed by cut/pierce/stab injuries (29.0%). There was no in-hospital mortality for any of the injury patterns. Isolated proximal-extremity injuries were most common (*n* = 413), followed by isolated distal extremity injuries (*n* = 290), and by concomitant proximal and distal extremity injuries (*n* = 92). Patients with isolated proximal-extremity injuries and concomitant proximal and distal extremity injuries were significantly younger than patients with isolated distal-extremity injuries (27 years vs. 28 years vs. 32 years, *p* < 0.0001 and *p* = 0.0002, respectively). Those with isolated proximal-extremity injuries and those with concomitant proximal- and distal-extremity injuries had lower extremity AIS score (1 vs. 1 vs. 2, *p* < 0.0001 and *p* = 0.0004, respectively) and ISS (1 vs. 2 vs. 4, *p* < 0.0001 and *p* < 0.0001, respectively) compared with patients with isolated distal extremity injuries. Patients with proximal-extremity injuries presented with higher base deficits compared with those with concomitant proximal- and distal-extremity injuries (1.3 mEq/L vs. 0.1 mEq/L, *p* = 0.02), while patients with isolated proximal-extremity injuries presented with higher hemoglobin compared with those with isolated distal extremity injuries (14.2 g/dL vs. 13.75 g/dL, *p* = 0.025). Interestingly, patients with isolated proximal-extremity injuries presented with higher systolic blood pressures compared with isolated distal extremity injuries (141 mm Hg vs. 133 mm Hg, *p* = 0.04), but those with isolated distal extremity injuries also had lower heart rates compared with patients with isolated proximal-extremity injuries and concomitant proximal-and distal-extremity injuries (85 bpm vs. 93 bpm vs. 96 bpm, *p* < 0.0001 and *p* < 0.0001).

Of all 413 isolated proximal-extremity injury patients, 304 patients sustained isolated injuries of the lower extremity, 96 patients sustained isolated injuries of the upper extremity, and 13 had concomitant injuries to both upper and lower extremities. There were no

differences between the three groups in demographics, admission vital signs, extremity AIS scores, ISS, or admission laboratory values (Table 4).

Isolated proximal-extremity injuries were analyzed based on the presence of additional physiologic criteria that would trigger FTTA (Table 5). Of the 413 patients with isolated proximal-extremity injuries, only 18 patients (4.5%) presented with additional physiologic criteria that required FTTA, regardless of the location of the injury. Of the patients with isolated proximal-extremity injuries who met physiologic FTTA criteria, 16 sustained lower-extremity injuries and 2 sustained upper extremity injuries. On arrival, 14 patients had systolic blood pressures less than 90 mm Hg, nine patients had received a blood transfusion, and four patients had a pulseless extremity, while no patients had a Glasgow Coma Scale score less than 9, arrived intubated, or were identified as having respiratory distress. Of the four patients with a pulseless extremity, three required a vascular operative intervention, and only one presented with additional FTTA criteria (SBP < 90). Overall, 73.9% of patients with isolated proximal-extremity injuries who did not present with additional FTTA criteria were discharged from the emergency department (ED); only 5.8% of this population were either admitted to the surgical intensive care unit or proceeded directly from the ED to the operating room. Furthermore, only 1.8% of all patients with isolated proximal-extremity injuries without additional physiologic FTTA criteria required vascular operative intervention. By contrast, those patients with isolated proximal-extremity injuries who presented with additional physiologic criteria for FTTA were more likely to require admission (63.0% vs. 26.1%, $p < 0.0001$), surgical intensive care unit admission (16.7% vs. 0.3%, $p < 0.0001$), operative intervention (72.2% vs. 15.7%, $p < 0.0001$), and vascular intervention (61.1% vs. 1.8%, $p < 0.0001$). Furthermore, patients with physiologic criteria for FTTA had longer lengths of stay (3.6 days vs. 0.2 days, $p < 0.0001$) and required more blood products in the first 24 hours of admission (0 unit vs. 0 unit, $p < 0.0001$). Of the 28 isolated proximal-extremity injury patients without physiologic FTTA criteria that were admitted to the hospital but did not require operative intervention, 64.3% were discharged within 24 hours of admission and 89.3% were discharged within 48 hours of admission.

DISCUSSION

Penetrating proximal-extremity wounds generate a low threshold for trauma team evaluation; however, no data currently exist to support FTTA in response to these injuries. In this retrospective review of our own penetrating extremity trauma experience, only 4.5% of these patients presented with physiologic FTTA criteria, while only 1.8% of those without additional FTTA criteria required an immediate vascular intervention. Under current recommendations, these patients are often overtriaged, which may result in the misappropriation of valuable personnel time and hospital resources.

Our intention with this study was not to minimize the significance of a true proximal-extremity neurovascular injury, but rather to investigate the low incidence of these occurrences. Previous studies have reported that vascular injuries to the extremity account for less than 1% of all traumatic injuries.¹² Similarly, Franz et al.^{13,14} reported a 3.3% incidence of arterial injury associated with upper-extremity trauma and a 1.4% incidence of arterial injury associated with lower-extremity trauma. Our own data demonstrate that only

4.5% of patients with isolated proximal-extremity injuries required any kind of vascular intervention. Furthermore, only 1.8% of patients with isolated proximal-extremity injuries without additional physiologic FTTA criteria required urgent vascular operative intervention. Certainly, a missed neurovascular injury can result in a limb or life-threatening situation requiring activation and care from the trauma team. Because of the low rate of operative intervention and high rate of discharge from the emergency department in patients who sustain these injury patterns, we propose that these injuries, in the absence of other physiologic or anatomic criteria, be downgraded to limited trauma team activations.

Overtriage is an important quality indicator for trauma centers and is defined to capture the burden associated with unnecessary use of hospital resources for minor trauma.¹⁵ According to the ACS COT, an overtriage rate up to 50% is necessary to avoid an unacceptable undertriage.¹ Our data would indicate that overtriage secondary to FTTA for penetrating proximal-extremity injuries exceeds the 50% recommendation in several respects. First, only one (0.2%) patient in our cohort arrived with an ISS greater than 15. This patient met other FTTA physiologic criteria arriving hypotensive, receiving blood products, and with a pulseless extremity, all of which would have triggered FTTA. Second, 73.9% of patients without additional physiologic FTTA criteria did not require hospital admission, while 84.3% did not require any operative intervention. Of those patients that were admitted but did not require operative intervention, 64.3% were discharged within 24 hours of admission. Finally, only 7.5% of patients with isolated proximal-extremity injuries ultimately underwent immediate operative intervention. By comparison, 21% of FFTAs and 5.8% of limited trauma team activations underwent immediate operative intervention during the same 3-year period in our institution. These data suggest that isolated penetrating extremity injuries without abnormal physiology have an injury severity, resource utilization, and disposition more consistent with those requiring limited trauma team activation rather than FTTA.

This is the first study that has attempted to evaluate the overtriage rate of penetrating proximal-extremity injuries. While we feel these data are novel, we also recognize several limitations to this study. First, this is a single-center retrospective study that would be improved with corroborative data from other institutions. Second, we chose to focus on the immediate response to these injuries and do not report long-term functional outcomes in these patients. A small percentage of these patients may present with long-term consequences of these injuries and complications such as the development of pseudoaneurysms, which may need future intervention. We would advocate that while these patients may not require FTTA, they should undergo a trauma team evaluation with postdischarge follow-up. Third, our study did not take into account the arterial pressure index (API) of patients that presented with these injuries. At our trauma center, APIs are required for any penetrating extremity injury and performed by either the trauma team or emergency medicine physicians within no more than 30 minutes of patient arrival and should ideally be performed as soon as possible as part of a comprehensive secondary survey. Based on our data, we recommend that in the absence of physiologic criteria for FTTA, these injuries should prompt only limited trauma team activations; however, these patients should continue to undergo mandatory API testing within 30 minutes of patient arrival by the emergency medicine team. Additionally, patients with a measured API of less

than 0.9 should be upgraded to FTTA. Finally, UCMC's institutional FTTA criteria include several additional criterion that may not be in use at other trauma centers, such as a pulseless extremity either by injury or by tourniquet placement or patients receiving prehospital blood products. In our series, 75% of these patients required vascular operative intervention, but only 25% arrived with additional ACS COT physiologic criteria (SBP, < 90 mm Hg).

Penetrating proximal-extremity injuries are common injuries seen in Level I trauma centers. While potentially life-threatening, patients with these injuries are currently overtriaged and more likely to be discharged from the emergency department than admitted to the hospital or taken to the operating room. Trauma systems may benefit from less intense resource utilization for patients with isolated penetrating extremity injuries who lack additional full trauma team physiologic criteria.

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Figure 1.
Consort diagram of patients included in the study.

TABLE 1.

ACS COT's Minimum Criteria for FFTA *

1	Confirmed blood pressure less than 90 mm Hg at any time in adults and age-specific hypotension in children
2	Gunshot wounds to the neck, chest, or abdomen or extremities proximal to the elbow/knee
3	Glasgow Coma Scale score less than 9 with mechanism attributed to trauma
4	Transfer patients from other hospitals receiving blood to maintain vital signs
5	Intubated patients transferred from the scene (OR)
6	Patients who have respiratory compromise or are in need of an emergent airway <ul style="list-style-type: none"> • Includes intubated patients who are transferred from another facility with ongoing respiratory compromise (does not include patients intubated at another facility who are now stable from a respiratory standpoint)
7	Emergency physician's discretion

* Reference: Rotondo MF, Cribari C, Smith RS. (2014) Resources for Optimal Care of the Injured Patient." Committee on Trauma American College of Surgeons. (6), 37–40.

TABLE 2.

UCMC Criteria for FFTA

Systolic blood pressure < 90 mm Hg
70 years old with systolic blood pressure < 100 mm Hg
Penetrating injuries to the head, neck, torso, or extremities proximal to the knee or elbow
Glasgow Coma Scale score 13
Open or depressed skull fracture
Receiving blood products
Intubated or assisted ventilation
Respiratory rate < 10 or > 29 breaths per minute
Flail chest
Emergency medicine physician discretion
Paralysis or suspected spinal cord injury
Mechanically unstable pelvic fracture or application of pelvic binder
Two or more proximal long bone fractures
Amputation proximal to the wrist or ankle
Crushed, degloved, or mangled extremity
Pulseless extremity
Combination trauma with burns > 15% total body surface area
Positive FAST examination

TABLE 3.
Demographic Information and Admission Testing Based on the Type of Extremity Injury

	All Patients n = 795	Isolated Distal n = 290	Isolated Proximal n = 413	Concomitant Distal and Proximal n = 92
Age: median (IQR), y	28.5 (22–40)	32 (23–46) *, **	27 (21–37)	28 (22–35)
Male, %	86.9%	85.2%	88.4%	85.9%
Ethnicity, %				
Asian	0.5	0.7	0.2	1.1
African American	62.7	38.3	76.5	77.2
Hispanic	1.0	1.4	1.0	0.0
White	34.5	57.9	21.1	21.7
Other	1.3	1.7	1.2	0.0
Mechanism of injury, %				
Cut/pierce/stab	29.0	47.9	19.1	13.0
Gunshot wound	65.3	40.1	79.4	81.5
Machinery accident	3.6	8.6	0.5	2.2
Other	2.1	3.4	1.0	3.3
Admission systolic blood pressure: median (IQR), mm Hg	138 (123–150.5)	133 (120–148) †	141 (125–153)	138 (121.5–149)
Admission heart rate: median (IQR), bpm	90 (78–103.5)	85 (74–97) *, **	93 (80–105.8)	96 (83–107)
ISS: median (IQR)	1 (1–5)	4 (1–5) **	1 (1–2) *	2 (1–9)
Extremity AIS: median (IQR)	1 (1–2)	2 (1–2) **	1 (1–1.25) *	1 (1–3)
Base deficit: median (IQR), mEq/L	1.0 (–1.6 to 2.8)	0.2 (–2.1 to 2.0)	1.3 (–1.1 to 3.0) ‡	0.1 (–2.3 to 2.3)
Hemoglobin: median (IQR), g/dL	14.1 (13–14.9)	13.75 (12.8–14.8) †	14.2 (13.2–15.0)	13.9 (12.8–14.7)
INR: median (IQR)	1.1 (1.0–1.2)	1.1 (1.0–1.125)	1.1 (1.1–1.2)	1.1 (1.0–1.2)
Lactate: median (IQR), mmol/L	2.7 (1.7–4.1)	2.45 (1.6–3.45) *	2.6 (1.7–4.0) *	3.35 (1.98–5.6)
pH: median (IQR)	7.37 (7.34–7.4)	7.36 (7.33–7.4)	7.37 (7.34–7.4)	7.37 (7.33–7.4)
In-hospital mortality, %	0.0	0.0	0.0	0.0

* $p < 0.01$ compared with proximal- and distal-extremity injuries.

** $p < 0.01$ compared with proximal-extremity injuries.

$\neq$ $p < 0.05$ compared with proximal-extremity injuries.
 $\neq$ $p < 0.05$ compared with proximal- and distal-extremity injuries.
IQR, interquartile range.

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TABLE 4.

Demographic Information and Admission Testing of Proximal-Extremity Injuries

	Isolated Proximal Lower n = 304	Isolated Proximal Upper n = 96	Concomitant Upper and Lower Proximal n = 13
Age: median (IQR), y	27 (21–37.5)	27 (21–37.75)	26 (21.5–31)
Male, %	89.5	85.4	84.6
Ethnicity, %			
Asian	0.3	0.0	0.0
African American	75.7	76.1	100.0
Hispanic	1.0	1.0	0.0
Other	1.0	2.1	0.0
White	22.0	20.8	0.0
Mechanism of injury, %			
Cut/pierce/stab	14.4	35.4	7.7
Gunshot wound	84.0	63.6	92.3
Machinery accident	0.3	1.0	0.0
Other	1.3	0.0	0.0
Admission systolic blood pressure: median, (IQR), mm Hg	140 (125–151)	142 (124.8–153.3)	144 (129.5–162)
Admission heart rate: median (IQR), bpm	93 (81–105)	96 (78–109)	88 (80.5–100.5)
ISS: median (IQR)	1 (1–1)	1 (1–4)	1 (1–5)
Extremity AIS: median (IQR)	1 (1–1)	1 (1–2)	1 (1–2)
Base deficit: median (IQR), mEq/L	1.5 (–0.9 to 3.15)	1.3 (–1.85 to 2.7)	1.0 (–2.95 to 1.7)
Hemoglobin: median (IQR), g/dL	14.2 (13.2–15.0)	14.0 (13.1–15.0)	14.6 (13.6–14.9)
INR (median, IQR)	1.1 (1.1–1.2)	1.1 (1.1–1.2)	1.1 (0.9–1.2)
Lactate: median (IQR), mmol/L	2.7 (1.7–4.175)	2.2 (1.6–3.65)	3.1 (1.95–5.95)
pH: median (IQR)	7.38 (7.34–7.4)	7.37 (7.35–7.4)	7.38 (7.36–7.39)
In-hospital mortality, %	0.0%	0.0%	0.0%

TABLE 5.

Comparison of Outcomes of Patients Without Physiologic Full Trauma Criteria to Patients With Physiologic Full Trauma Criteria

	All Isolated Proximal			Lower Proximal		Upper Proximal		
	No Additional Physiologic FTTA n = 395	Additional Physiologic FTTA n = 18	No Additional Physiologic FTTA n = 288	No Additional Physiologic FTTA n = 16	No Additional Physiologic FTTA n = 94	Additional Physiologic FTTA n = 2		
Systolic blood pressure: median (IQR), mmHg	142 (127–153)	89 (82–107)*	142 (127–152)	89 (83–105)*	142 (125–153)	106 (62–150)**		
Glasgow Coma Scale score: median (IQR)	15 (15–15)	15 (14.8–15)*	15 (15–15)	15 (15–15)*	15 (15–15)	14.5 (14–15)*		
ED disposition								
Discharged from ED	73.9%	16.7%*	76.1%	12.5%*	68.7%	0.0%		
Admissions (total)	26.1%	63.0%	23.9%	78.9%*	31.3%	100.0%**		
Operating room	5.3%	55.6%*	4.5%	50.0%*	8.6%	100.0%		
Surgical intensive care unit	0.3%	16.7% [†]	0.3%	18.8% [†]	0.0%	0.0%		
Nursing floor	13.9%	11.1%	12.5%	12.5%	15.1%	0.0%		
Observation unit	5.8%	0.0%*	5.9%	0.0%	6.5%	0.0%		
Left against medical advice	0.8%	0.0%	0.7%	0.0%	1.1%	0.0%		
Length of stay: median (IQR), d	0.2 (0.1–0.6)	3.6 (0.7–9.7)*	0.2 (0.1–0.4)	4.7 (0.7–9.9)*	0.2 (0.1–0.7)	1.1 (0.8–1.3)		
Blood products administered, units (median, IQR)	0 (0–0)	0 (0–4)*	0 (0–0)	1 (0–4)*	0 (0–0)	0 (0–0)		
Injuries requiring operation	15.7%	72.2%*	18.3%	75.0%*	13.5%	100.0%**		
Orthopedic intervention	13.8%	27.8%	15.2%	31.3%	9.7%	0.0%		
Vascular intervention	1.8%	61.1%*	1.0%	56.3%*	4.3%	100% [†]		

* $p < 0.0001$.** $p < 0.05$.[†] $p < 0.01$.