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A National Trauma Data Bank Study for Civilian Upper Extremity Vascular Injury

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Abstract

Objective: Traumatic Upper Extremity Vascular Injuries (UEVIs) pose unique challenges as they are relatively rare injuries. There are various potential treatment modalities to address these injuries which may be influenced by the location of the injury, mechanism of injury, concomitant injuries, and overall patient status. Limited studies are assessing the outcomes of these different treatment modalities and most of the recent literature is focused on combat trauma. Herein we present the largest study of civilian UEVIs with over 7,000 patients from a national databank.

Methods: The National Trauma Data Bank (NTDB) from 2017 was used to include subjects aged sixteen years and older presenting with UEVIs. These injuries were identified using ICD-10-CM codes with locations classified as subclavian, axillary, brachial or distal. Isolated superficial injuries were excluded. Vascular procedures were classified using the ICD-10-PCS and specific procedures of interest included surgical amputation, ligation, primary repair, and endovascular stent placement. Demographic data and injury descriptors such as Injury Severity Score (ISS) and mechanism of injury were compiled for all patients. Outcomes including surgical amputation and death were assessed for association with ISS using Chi-square analysis and *t*-tests. Associations between treatment modality and odds of surgical amputation were modeled using logistic regression.

Results: Seven thousand and fifty patients were included in the analysis. Penetrating injuries accounted for 63% of injuries while 35% were blunt. A total of 234 deaths (3.3%) occurred and 382 injuries involved traumatic amputation (5.4%) as seen in table 2. The commonly documented treatment modality was primary repair in 3,072 patients (43.6%) followed by surgical ligation in 1,152 patients (16.3%). Nine-hundred and forty-four patients (14.4%) underwent endovascular stent placement, and 445 patients (6.3%) underwent surgical bypass. Two hundred and seventy patients underwent surgical amputation (3.8%). Patients who underwent surgical amputation had significantly higher mean ISS when compared with patients who did not (11.6 *vs*. 9.7, P=0.007) but a lower prevalence of death (1.1% *vs*. 3.4%, P=0.036). Those undergoing ligation or primary repair had significantly decreased odds of surgical amputation (OR ligation = 0.45; OR primary repair = 0.68; both p<0.01) compared to those who underwent endovascular stent placement (OR=1.62, P=0.002).

Conclusion: Both penetrating and blunt civilian trauma may lead to significant UEVIs requiring surgical intervention. Surgical amputation was interestingly associated with lower mortality rates despite those patients having higher ISS. Open surgical interventions were associated with higher limb salvage rates compared to endovascular interventions.

Keywords: Upper extremity trauma; Civilian trauma; Vascular injuries; Traumatic vascular injuries

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Introduction

Traumatic Upper Extremity Vascular Injuries (UEVIs) in both the arterial and venous systems pose unique challenges for vascular and trauma surgeons. There are various potential options to treat UEVIs, which vary depending upon the location of the injury, Mechanism of Injury (MOI), concomitant injuries, and overall patient status. By evaluating and comparing these different options, useful knowledge can be found to help guide decisions made during these emergent and high-risk cases.

There are very few publications specifically examining traumatic UEVIs. Orcutt et al. reported a series of 143 patients sustaining 163 UEVIs in the civilian trauma setting [1]. Ninety-four percent of these injuries were due to penetrating trauma, with the most common treatment modality being primary repair followed by interposition vein graft, resulting in a zero percent amputation rate. Cikrit et al. also reported a similar series of 101 civilian UEVIs, also mainly due to penetrating mechanisms [2]. The majority of interventions in this series consisted of primary repair or vein patches. Their amputation rate was also extremely low at one percent.

Regarding combat trauma, there have been more recent publications. Clouse et al. reported a small series of 43 combat UEVIs from Iraq with an amputation rate of 9.3% [3]. In this series, the most common treatment modality was surgical repair with interposition graft. More recently, Vuoncino et al. published a series of 308 combat UEVIs from Afghanistan showing an amputation rate of 12.1%, with surgical ligation being the most commonly used treatment modality [4].

As can be seen, there is no clear standard for surgical management of these injuries. Given the multitude of factors that can impact treatment decisions in both civilian and combat trauma settings, this is not entirely surprising. Furthermore, the above-mentioned papers include relatively small numbers of patients. Much has also changed in the field of vascular surgery since Orcutt et al. and Cikrit et al. published their civilian UEVI series in 1986 and 1990 respectively, especially the tremendous growth of endovascular techniques. This is reflected in the most recent Vuoncino et al. paper where 4% of their UEVIs were treated with endovascular therapy. A more recent and extensive review of both injury patterns and management techniques for UEVI in the civilian setting is necessary to further our knowledge of this multifaceted problem.

Methods

This study utilized data from the 2017 National Trauma Data Bank (NTDB) Trauma Quality Programs Participant Use File (Version 1.0, released June 2019). The NTDB is the largest repository of trauma data in the United States and includes data submitted on pediatric and adult patients from participating Level I, II, III, IV, V, or undesignated trauma centers [1].

Included subjects were adult patients aged 16 years and older, presenting with an upper extremity vascular injury in NTDB during 2017. Upper extremity vascular injuries, both polytrauma and isolated, were identified using ICD-10-CM Codes [2], including S45.XXXX, S55.XXXX, S65.XXXX. Isolated superficial injuries were excluded. Anatomical regions were also designated using the ICD-10-CM, with locations classified as subclavian, axillary, brachial, or distal. Venous and/or arterial involvement was also classified using ICD-10-CM.

Vascular surgical procedures were identified using the ICD-10-PCS [3]. Major procedures of interest were surgical amputation, ligation, primary repair, bypass, and stent.

Descriptive statistics were compiled for all subjects, including age, sex, race, and ethnicity. Injury descriptors, such as anatomical region, Injury Severity Score (ISS), mechanism, trauma type, and intention, were also summarized. Frequencies of major procedures of interest were described.

Patient outcomes, including surgical amputation and death, were assessed for associations with injury severity using Chi-square analysis. Treatment modality and odds of surgical amputation were modeled using logistic regression. All analyses were carried out using SAS version 9.4 (Cary, NC).

Results

A total of 7,229 patients with upper extremity vascular injuries were identified for 2017, 179 of which had isolated superficial injuries. Exclusion of the superficial injuries resulted in a total of 7,050 patients for analysis.

The sample was 82.6% male, 60.4% White, 23.2% Black, and 17.8% Hispanic or Latino (Supplemental Table 1). Two-thirds of subjects were under age 45 with a mean age of 38.5 years (SD=15.9).

Injury severity scores averaged 9.8 with a range from 1 to 75 (Table 1). The injury severity score distribution was 61.9% minor (ISS 1-9), 21.8% moderate (ISS 10-15), 8.8% severe (ISS 16-24), and 7.5% very severe (ISS 25+). A total of 234 deaths occurred during

Table 1: Injury severity score.

	Upper Extremity Vascular Injuries n=7050	
	n	%
ISS Category		
Minor (ISS 1-9)	4357	61.9
Moderate (ISS 10-15)	1538	21.8
Severe (ISS 16-24)	620	8.8
Very Severe (ISS 25+)	530	7.5
	Mean (Range)	SD
ISS	9.8 (1-75)	9.2

Table 2: Death and traumatic amputation.

	Upper Extremity Vascular Injuries n=7050	
	n	%
Deaths	234	3.3
Traumatic Amputation	382	5.4

Table 3: Trauma type.

	Upper Extremity Vascular Injuries n=7013	
	n	%
Blunt	2450	34.8
Penetrating	4465	63.3
Burns	8	0.1
Other/Unspecified	90	1.3

Table 4: Association between surgical amputation and prevalence of death and distribution of injury categories.

	With Surgical Amputation	No Surgical Amputation	p
	n=270	n=6780	
Death	3 (1.1%)	231 (3.4%)	0.036
Mean ISS (SD)	11.6 (11.1)	9.7 (9.1)	0.0065
ISS Category			
Minor (ISS 1-9)	160 (59.3%)	4197 (62.0%)	p<0.0001
Moderate (ISS 10-15)	40 (14.8%)	1498 (22.1%)	
Severe (ISS 16-24)	35 (13.0%)	585 (8.6%)	
Very Severe (ISS 25+)	35 (13.0%)	495 (7.3%)	

Table 5: Odds of surgical amputation associated with treatment modality.

Treatment Modality	Odds Ratio	95% Confidence Interval for Odds Ratio	p
Bypass	1.15	0.73-1.81	0.5422
Stent	1.62	1.19-2.21	0.0021
Ligation	0.45	0.30-0.69	0.0002
Repair	0.68	0.52-0.88	0.0031

the documented hospitalization (3.3%), and 382 injuries involved traumatic amputation (5.4% of injuries) (Table 2). Penetrating injuries accounted for 63% of injuries, while 35% were blunt (Table 3). Sixty-four percent of injuries were unintentional. Mechanisms of injury are summarized in Supplemental Table 2.

Surgical amputation was documented for 270 patients (3.8%). The most documented treatment modality was primary repair in 3,072 patients (43.6%) followed by surgical ligation in 1,152 patients (16.3%) (Supplemental Table 3). Nine-hundred and forty-four patients (14.4%) underwent endovascular stent placement and 445 patients (6.3%) underwent surgical bypass. One-third of patients (n=2259) underwent none of the above-listed procedures and were grouped separately as "other." This group included both patients who did not undergo a surgical procedure at all, and also those who had other procedures such as dilation, drainage, etc.

Patients who underwent surgical amputation had a significantly higher mean injury severity score (mean ISS 11.6 among those with surgical amputation *vs.* 9.7 among those without surgical amputation, P=0.007) but a lower prevalence of death (1.1% *vs.* 3.4%, P=0.036; Table 4) when compared with patients without surgical amputation. Those undergoing ligation or primary repair of a vessel had significantly decreased odds of surgical amputation (OR ligation = 0.45; OR primary repair = 0.68; both p<0.01). In contrast, patients who underwent stent placement had significantly increased odds of surgical amputation (OR=1.62, P=0.002; Table 5).

Discussion

Significant UEVIs are relatively rare in the trauma setting. This paper presents the largest contemporary study of civilian UEVIs with over 7,000 patients taken from a large national databank.

When compared directly to recent data from combat injuries, significant differences exist. The recent study by Vuoncino et al. revealed a higher incidence of penetrating mechanism in military data (100% *vs.* 63%) and a higher average ISS (32.2 *vs.* 9.2) when compared with the NTDB civilian data [4]. The early amputation rate in the military study was 12.1%. In this civilian data, however, a much lower 3.8% overall amputation rate was noted. Mortality was also higher in the combat population, at 4.9% *vs.* 3.3% civilian.

There are some stark contrasts to the prior civilian studies as well. First, although penetrating trauma accounts for the majority of injuries in all studies, the proportion found in the 2017 NTDB is far less at 63.3% compared to over 90% in some earlier single-institution studies. Blunt trauma, therefore, was a more significant contributor to UEVIs requiring surgical intervention in this series than in those previously reported. Second, the surgical amputation rate was higher in this study at 3.8% compared to those rates published by Orcutt et al. and Cikrit et al. at 0% and 1%, respectively [1,2]. Third, it is also clear that over time there has been a significant increase in the use of endovascular techniques, with 14.4% of patients in this series undergoing stent placement. This is not surprising, given the tremendous growth of and access to endovascular techniques over the past several decades.

Supplemental Table 1: Patient demographics.

	Upper Extremity Vascular Injuries n=7050	
	n	%
Male	5820	82.6
Female	1229	17.4
White	4259	60.4
Black	1625	23.1
Asian	110	1.6
Pacific Islander	25	0.3
American Indian	98	1.4
Hispanic or Latino	1206	17.8
Not Hispanic or Latino	5565	82.2
Deaths	234	3.3
Age Category		
16-24	1486	21.1
25-34	1973	28
35-44	1309	18.6
45-54	1034	14.7
55-64	712	10.1
65-74	352	5
75-84	142	2
85-89	42	0.6
	Mean (Range)	SD
Age	38.5 (16-89)	15.9

This study offers some insight into the outcomes of different treatment modalities regarding limb salvage and mortality. Those undergoing ligation or primary repair of a vessel had significantly decreased odds of surgical amputation (OR ligation = 0.45; OR primary repair = 0.68; both p<0.01; Table 5) while undergoing surgical bypass showed no association with surgical amputation (OR bypass = 1.15; p=0.54). One may postulate that this represents injury to a lesser blood vessel in the case of ligation, or a less severe injury to the vessel involved in the case of primary repair, although it should be noted that these observational data do not show causation. Interestingly, patients who underwent stent placement had the highest odds of surgical amputation (OR=1.62; p=0.002).

There was a significantly lower prevalence of death in patients who underwent surgical amputation when compared to those who did not (1.1% *vs.* 3.4%, P=0.036; Table 4), even though those who underwent surgical amputation had higher average ISS scores (ISS 11.6 *vs.* 9.7, P=0.007). The exact cause of this correlation is not clear. Limb salvage attempts may raise mortality by increasing the number of procedures, surgical complexity, and time under anesthesia. This concern is what led to the creations of several scoring systems for lower extremity injuries to prevent futile and potentially harmful attempts at limb

Supplemental Table 2: Mechanisms of injury.

	Upper Extremity Vascular Injuries n=7050	
	n	%
Cut/pierce	3310	47.1
Firearm	1064	15.2
Fall	569	8.1
Machinery	525	7.5
MVT Occupant	494	7.0
Struck by, against	275	3.9
Other specified and classifiable	204	2.9
MVT Motorcyclist	163	2.3
Natural/environmental, bites and stings	91	1.3
MVT Other	84	1.2
Transport, other	73	1.0
MVT Pedestrian	57	0.8
Other specified, not elsewhere classifiable	39	0.6
Pedestrian, other	21	0.3
Natural/environmental, other	19	0.3
Pedal cyclist, other	18	0.3
Fire/flame	8	0.1
MVT Unspecified	4	0.06
Overexertion	3	0.04
Unspecified	1	0.01

Supplemental Table 3: Major procedure subtypes (not mutually exclusive).

ICD10 Procedure Group	Upper Extremity Vascular Injuries n=7050	
	n	%
Surgical Amputation	270	3.8
Bypass	445	6.3
Stent (Insertion)	944	14.4
Ligation (Occlusion)	1152	16.3
Primary Repair	3072	43.6

salvage, most notably the Mangled Extremity Severity Score (MESS) [8]. The MESS and other scoring systems, however, are designed for lower extremity trauma, have been shown to lack prognostic accuracy for upper extremity trauma [9]. In the absence of formal guidance, aggressive attempts at upper extremity limb salvage far outnumber cases of early primary amputation in the military literature, although civilian data has not been specifically reported [10]. The effects of these attempts on mortality warrant further investigation, especially given the above correlation.

There are several limitations to our study. As a retrospective database, the NTDB suffers from many limitations inherent in this type of data set. Specifically, many data points which may have been helpful in further investigation of UEVI simply do not exist within the database. We do not have data on outcomes beyond limb salvage and mortality such as functional impairment, need for further procedures, and others which are critical for the overall understanding of these complex injuries. Further, the effect of polytrauma and combination procedures on the dataset is unknown, as uncoupling these events is not possible. The data in NTDB is voluntarily submitted and therefore subject to errors including, but not limited to, selection bias and information bias.

Conclusion

Both penetrating and blunt civilian trauma may lead to significant UEVIs requiring surgical intervention. Open surgical interventions were associated with higher limb salvage rates compared to endovascular interventions in this study. Surgical amputation was associated with lower overall mortality. Further investigation of these correlations, including the effects of aggressive limb salvage attempts on mortality and quality of life, is warranted.

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