A Pulseless Limb Poorly Predicts an Arterial Injury in Combat Trauma

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Background: A pulseless limb is considered a hard sign of an arterial injury after penetrating trauma in the civilian population. However, the reliability of this finding has never been examined in combat trauma. The purpose of this study was to examine the reliability of the pulseless limb in the combat trauma population. Reasons for false positive physical examination findings were also identified.

Methods: The Joint Theater Trauma Registry identified all patients who presented to a military treatment facility (MTF) in Kandahar, Afghanistan, with a penetrating extremity injury over a 2-year period. Patients found to have a pulse deficit on initial physical examination were followed, and the results of the subsequent computed tomographic angiogram or arteriogram recorded. Patient demographics, injury patterns, and physiological data were examined. Standard statistical analysis was performed.

Results: From 2011 to 2012, 644 patients were treated at a single MTF for lower extremity penetrating injuries. The most common mechanisms of injury were explosions (62%) and gunshot wounds (20%). Of the 577 patients with complete medical records, 448 patients (78%) presented with palpable pulses, 115 patients (20%) presented with a pulseless limb, and 14 (2%) presented with hard signs of vascular injury. Of those with a pulseless limb and abnormal ankle-brachial index (ABI) or no ABI obtained who underwent further radiologic imaging, 38 patients (77%) had no arterial injury identified. Compared with those with a palpable pulse, patients with a pulseless limb without an arterial injury were more likely to have a higher Injury Severity Score (ISS), lower hematocrit, lower pH, greater base deficit, higher heart rate, more frequent use of tranexamic acid, and received greater volumes of packed red blood cells, plasma, and crystalloids.

Conclusions: Our results demonstrate that a pulseless limb is a poor predictor of arterial injury and should not be considered a hard sign of vascular injury in the combat population. Variables including a high ISS, anemia, acidosis, and need for resuscitation products, each a surrogate for injury severity, may contribute to the decreased accuracy of the physical examination in our troops. This may translate into unnecessary immediate exploration or other interventions in patients who present with more significant injuries from the battlefield. Future studies must continue to focus on improved algorithms for diagnostic accuracy of extremity vascular injuries in this population.

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INTRODUCTION

Extremity injuries continue to predominate in the current war in Afghanistan and recently completed war in Iraq. Compared with prior conflicts, troops wounded during the Global War on Terror (GWOT) sustained a significant number of injuries to the extremities, often with a higher Injury Severity Score (ISS) and more significant soft tissue, osseous, and neurologic damage.[1,2] The rate of vascular injury during Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) is 5 times that of previous conflicts.[3] The immediate threat to limb salvage is secondary to acute ischemia and warrants urgent evaluation and intervention. A pulseless limb has been considered a hard sign of vascular injury and historically warrants further imaging or even exploration in the operating room when advanced imaging modalities are not available. Computed tomographic angiography (CTA) and arteriography are considered the ''gold standard'' for diagnosing extremity arterial injuries. However, which patients are best served by invasive imaging remains controversial as most studies are based on data collected from civilian populations. One such study from Schwartz et al. concluded that a pulse deficit and an ankle-brachial index (ABI) <1 in an injured extremity were significant predictors of an arterial injury and warranted arteriography in a civilian trauma population.[4]

The military medical system consists of 5 levels of care which support the expeditious transport of troops from the battlefield to definitive care at stateside military medical treatment facilities (MTFs). Role III facilities, such as the MTF at Kandahar Air Field, are comparable to level I trauma centers and provide the highest level of medical care in combat theater. The role III facility has the ability to perform CTAs and arteriograms, allowing for identification and treatment of vascular injuries. In contrast, role I and II facilities have limited resources. Patients presenting to these facilities with a pulseless limb are frequently obligated to an operative exploration. Reliance on an inaccurate pulse examination may lead to a significant number of unnecessary operative procedures which would delay patient transfer to the next level of care. The purpose of this study was to examine the accuracy of the pulseless limb in evaluating arterial injuries in a combat trauma population at an MTF in Kandahar, Afghanistan. Furthermore, as the war in Afghanistan continues to de-escalate, we sought to examine the role of the physical examination in future MTFs with limited resources and imaging modalities.

MATERIAL AND METHODS

The Joint Theater Trauma Registry (JTTR) was queried to identify all patients who presented to an MTF in Kandahar, Afghanistan, with a penetrating lower extremity injury from January 2011 through December 2012. The JTTR is an administrative database located in the United States Army Institute of Surgical Research at Fort Sam Houston, Texas. Data extracted from the medical records in the JTTR included patient demographics, severity and types of injuries, admission vital signs, laboratory values, and resuscitation product administration over the initial 24 hr. Informed consent was not obtained. Mechanism of injury (MOI) was defined as either an explosion, gunshot wound (GSW), or other etiology. Other etiologies included injury from a blunt object or heavy machinery accidents, crush injuries, falls, helicopter or motor vehicle accidents, and knife injuries. Military service was classified as Air Force, Army, Marines, Navy, North Atlantic Treaty Organization (NATO), or non-NATO. Patients without a penetrating limb injury, those with only mangled extremities or primary traumatic amputations, detainees, and those aged younger than 18 years were excluded.

The Theater Medical Data Store (TMDS) was then queried to identify patients' affected and contralateral limb pulse examinations. The pulse examination was recorded from the admitting physician's note on initial presentation to the trauma bay. Those patients who proceeded to have a subsequent CTA or arteriogram were identified and the results recorded. The pulse examinations were recorded as ''0,'' not performed or not documented; ''1,'' lacking a pulse and an abnormal ABI, when documented; ''2,'' no palpable pulses but normal ABI; ''3,'' palpable pulses; and ''4,'' other hard signs of vascular injury. An abnormal ABI was defined as <0.9. Palpable pulses were documented as ''2+,'' ''1+,'' ''strong,'' or ''weak.'' Other hard signs of vascular injury included pulsatile bleeding, expanding hematoma, palpable thrill, or an audible bruit.

CTA and arteriography results were reviewed and documented. Indications for obtaining a CTA or arteriography were not explicitly stated on review of the each patient's medical record. These studies were then compared with the pulse examination. Patients with pulseless limbs and an abnormal radiologic study were compared with those with normal radiologic studies. Patients with palpable pulses were also compared with patients with pulseless limbs but no vascular injury. Factors which led to differences in the examination were reviewed.

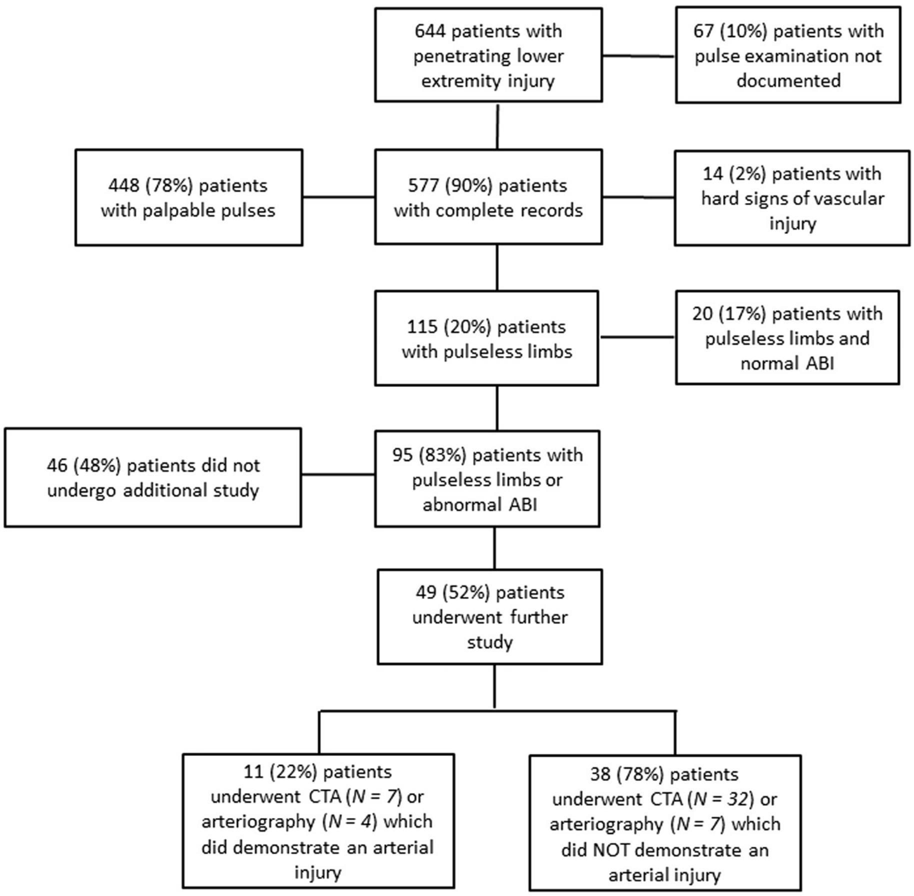

Fig. 1. Documented pulse examination findings in the 644 patients with a penetrating lower extremity injury who presented to the MTF in Kandahar, Afghanistan from 2011 to 2012.

SPSS v.22 (Armonk, NY; IBM Corp.) was used for all descriptive and inferential analyses.[5] A 99% level of significance was set for all inferential tests with differences considered significant if $P \leq 0.01$ because of the Bonferroni correction. Descriptive findings were reported as frequencies and percentages or central tendencies of the study variables. Descriptive variables were compared using Student's *t*-test for means. Categorical variables were compared as a proportion using chi-squared test or Fisher's exact test, as appropriate.

This study was authorized as a Performance Improvement Project entitled ''Improving Clinician Recognition, Assessment and Treatment for Potential Vascular Injuries'' and was approved by the Naval Medical Center San Diego Public Affairs Office.

RESULTS

Demographics

During the study period, 644 patients presented with a lower extremity penetrating injury to the NATO role III MTF in Kandahar, Afghanistan (Fig. 1). Sixty-seven patients (10%) had incomplete records. The remaining 577 patients (90%) had a pulse examination documented. Of these, 448 (78%) patients had palpable pulses in the affected limb on initial examination. Fourteen patients (2%) presented with hard signs of vascular injury.

The remaining 115 patients (20%) presented with a pulseless limb on the affected lower extremity and were the focus of this study.

The mean age of patients who presented with a pulseless limb ($n = 115$) was 26 ± 6 years; all patients were men. Eighty-six percent of the injuries occurred during battle. The most common cause of injury was an explosion (66%), followed by GSW (26%), or other etiology (8%). The mean ISS was 15.7 ± 13.5. The in-hospital mortality over the 2-year period was 7%. At the role III facility, the mean length of stay (LOS) was 2.5 ± 4.1 days and the mean intensive care unit (ICU) LOS was 1.3 ± 2.7 days. Of those who presented with a pulseless limb, 18 patients (16%) presented with a tourniquet for a mean time of

Table I. Study demographics

$n = 115$	Frequency	%
Age, years, mean ± SD	26 ± 6	
Gender		
Female	0	
Male	115	100
Service		
Non-NATO	29	25
NATO	86	75
Injury type		
Battle	99	86
Nonbattle	16	14
Mechanism of injury		
Explosive devices	76	66
Gunshot wound	30	26
Other	9	8
ISS, mean ± SD	15.7 ± 13.5	
Mortality	8	7
Length of stay, days, mean ± SD	2.5 ± 4.1	
ICU stay, days, mean ± SD	1.3 ± 2.7	
Tourniquet		
Yes	18	16
No	97	84
Tourniquet time, min, $n = 18$, mean ± SD	72 ± 33	

SD, standard deviation.

72 ± 33 min before arrival at the emergency department (Table I).

Vital Signs/Laboratory Values

Vital signs and laboratory values for those with pulseless limbs were recorded on arrival (Table II). The mean temperature was 36.8 ± 0.65°C, mean systolic blood pressure was 120 ± 28.1 mm Hg, and the mean heart rate (HR) was 101 ± 25. The mean Glasgow Coma Scale score was 12 ± 5, and 16% of patients arrived intubated. The mean hematocrit was 41.7 ± 5.4%, the mean pH was 7.37 ± 0.10, the mean base deficit was −1.75 ± 4.1, and the mean international normalized ratio (INR) was 1.23 ± 0.3.

Products of Resuscitation

The use of resuscitation products over the course of 24 hr after admission was also reviewed for those who presented with pulseless limbs (Table II). Tranexamic acid (TXA) was given to 16.5% of those injured. Packed red blood cells (pRBCs) were administered to 65 patients (56.5%) with a mean number of 7 ± 6 units per patient. Fresh frozen plasma (FFP) was administered to 54 patients (47%) with a mean number of 7 ± 6 units per patient. Platelets were administered to 24 patients (21%) with a mean number of 2 ± 2 units administered. Cryoprecipitate was given to 11 patients (10%) with a mean number of 13 ± 7 units administered. Crystalloid fluids were administered to 108 patients (94%) with a mean number of 3.75 ± 2.81 L administered. Finally, colloid fluids were administered to 13 patients with a mean of 634 ± 391 mL administered.

Table II. Indicators of injury severity and products of resuscitation

$n = 115$	Frequency	%
Temperature, °C, mean ± SD	36.8 ± 0.65	
Systolic blood pressure, mean ± SD	120 ± 28.1	
Heart rate, mean ± SD	101 ± 25	
Glasgow Coma Scale, mean ± SD	12 ± 5	
Arrived intubated		
Yes	18	16
No	97	84
Hematocrit, %, mean ± SD	41.7 ± 5.4	
pH, mean ± SD	7.37 ± 0.1	
Base deficit, mean ± SD	−1.75 ± 4.1	
INR, mean ± SD	1.23 ± 0.3	
Tranexamic acid		
Yes	19	16.5
No	96	83.5
pRBC, units, $n = 65$, mean ± SD[a]	7 ± 6	
Plasma, units, $n = 54$, mean ± SD[a]	7 ± 6	
Platelets, units, $n = 24$, mean ± SD[a]	2 ± 2	
Cryoprecipitates, units, $n = 11$, mean ± SD[a]	13 ± 7	
Crystalloids, mL, $n = 108$, mean ± SD[a]	3,745 ± 2,809	
Colloids, mL, $n = 13$, mean ± SD[a]	634 ± 391	

SD, standard deviation.
[a]Administered first 24 hr.

Vascular Injuries

Of the entire patient cohort ($n = 644$), 85 vascular injuries were identified in 54 patients of which 38 (57%) were arterial injuries, 11 (16%) venous injuries, and 18 (27%) with a combined arterial and venous injury. The incidence of a vascular injury in those presenting with a lower extremity injury was 8.4%. Of the 54 patients with a vascular injury, 14 (26%) patients had a palpable pulse or normal

Table III. Description of vascular injuries discovered during the entire study period and their associated pulse examination

$n = 644$	Frequency	%
Vascular injury, $n = 85$		
Artery	38	57
Vein	11	16
Combined artery/vein injury	18	27
Number of patients with vascular injuries	54	8.4
Pulse examination of those with a vascular injury		
Pulse examination not documented	7	13
Palpable pulses or normal ABI	14	26
Pulseless limb	21	39
Hard signs	12	22
Tourniquet		
Yes	117	18
No	527	82
Tourniquet time, min, $n = 49$, mean ± SD	56.6 ± 29.8	

Table IV. Number of ankle-brachial indices recorded from those patients who presented with a pulseless lower extremity

$n = 115$	Frequency	%
Pulseless limb	25	22
Normal ABI ($n = 20$)	20	17
Abnormal ABI ($n = 95$)	5	4
No further study ($n = 46$)	1	2
Further study with arterial injury identified ($n = 11$)	0	0
Further study without arterial injury identified ($n = 38$)	4	11

ABI, 21 (39%) had a pulseless limb, and 12 (22%) had a hard sign of vascular injury. Eighteen percent had documented prior use of a tourniquet with a mean tourniquet time of 57 ± 30 min (Table III).

The Pulseless Limb

Of the 115 patients who presented with a pulseless limb, only 25 (22%) ABIs were recorded in the patient's medical record. Twenty patients (17%) had a normal ABI, whereas 5 (4%) had an abnormal ABI (Table IV). This left 95 patients (83%) with a pulseless limb and abnormal ABI or no ABI obtained (Fig. 1). Forty-nine of these patients underwent additional imaging. Thirty-eight of these 49 patients (78%) had no arterial injury identified either on CTA ($n = 32$) or arteriography ($n = 7$), whereas only 11 patients (22%) had an arterial injury found on CTA ($n = 7$) or arteriography ($n = 4$). One patient underwent both a CTA and arteriogram, neither of which identified an arterial injury.

Of the 95 patients who presented with a pulseless limb and abnormal ABI or no ABI obtained, 46 (48%) did not undergo additional imaging. Thirty-seven (80%) of these patients were taken directly to the operating room for various injuries, 6 (13%) were directly admitted to the ward or ICU, 2 (4%) died in the trauma bay, and 1 (2%) patient had no further records. Of these 46 patients who did not undergo additional imaging, only 4 (9%) patients experienced an arterial injury.

The type of repair was also recorded of those arterial injuries identified in patients presenting with a pulseless limb. Of the 4 arterial injuries identified in those patients who presented with a pulseless limb with no additional study, 2 were repaired with a reverse saphenous vein graft, 1 was repaired primarily, whereas 1 arterial injury was ligated. Of the 11 arterial injuries identified in those patients who presented with a pulseless limb who underwent additional study, 4 were repaired with a reverse saphenous vein graft, 3 were repaired with a vein patch, and the rest repaired with a thrombectomy of a previously placed graft, internal iliac artery transposition, shunt placement, or ligation.

Of the 95 patients who presented with a pulseless limb and abnormal ABI or no ABI obtained, 63 (67%) had a palpable pulse or normal ABI, whereas 29 (31%) had a pulseless limb on the contralateral limb (Table V). Of those who presented with bilateral pulseless extremities ($n = 29$), 24 (83%) did not have an arterial injury in the affected limb, whereas 4 (14%) had a unilateral vascular injury and 1 (3%) had a bilateral lower extremity vascular injury. Of those who had a palpable contralateral limb pulse ($n = 63$), 52 (83%) did not have a vascular injury in the affected limb, whereas 11 (17%) had a unilateral vascular injury and no bilateral vascular injuries.

The 38 patients with a pulseless limb and no arterial injury on CTA/arteriogram were then compared with the 468 patients with normal pulses or ABI (Table VI). Patients with a pulseless limb were found to have a higher ISS (14.8 ± 9 vs. 10.5 ± 9.3,

Table V. Contralateral pulse examination and whether a vascular injury was identified in the affected limb in those presenting with a pulseless lower extremity

$n = 95$	Frequency	%
Contralateral limb pulse examination		
Missing	3	3
Pulseless limb	29	31
Palpable pulses or normal ABI	63	67
Bilateral pulseless limb ($n = 29$)		
Bilateral vascular injury	1	3
Unilateral vascular injury	4	14
No vascular injury	24	83
Palpable pulses or normal ABI contralateral limb ($n = 63$)		
Bilateral vascular injury	0	
Unilateral vascular injury	11	17
No vascular injury	52	83

Table VI. Comparison of patients with a pulseless limb who had no vascular injury identified on CTA or arteriogram and those with palpable pulses or normal ABI

Demographics	Palpable pulses or normal ABI	Study group
Mechanism of injury, *n* (%)		
N	468	38
Explosion	290 (62)	24 (63)
Gunshot	95 (20)	13 (34)
Other	83 (18)	1 (3)
Injury Severity Score*		
N	468	38
Mean ± SD	10.5 ± 9.3	14.8 ± 9
Hematocrit (%)*		
N	425	38
Mean ± SD	41.8 ± 5.4	38.9 ± 4.8
pH*		
N	396	35
Mean ± SD	7.38 ± 0.09	7.31 ± 0.14
Base deficit*		
N	394	35
Mean ± SD	−1.08 ± 3.75	−4.74 ± 4.75
Pulse*		
N	465	38
Mean ± SD	92 ± 22	108 ± 28
Tranexamic acid*, *n* (%)		
N	468	38
Yes	22 (5%)	7 (18%)
No	446 (95%)	31 (82%)
pRBC (units)*		
N	468	38
Mean ± SD	0.6 ± 2.7	5 ± 6.5
Plasma (units)*		
N	468	38
Mean ± SD	0.6 ± 2.5	4.4 ± 6.3
Crystalloids (mL)*		
N	461	38
Mean ± SD	2,001 ± 1,955	3,602 ± 2,729

SD, standard deviation.
Amount of pRBCs, plasma, and crystalloids given within 24 hr of admission.
*Significant with $P < 0.01$.

$P = 0.006$), lower hematocrit (38.9 ± 4.8 vs. 41.8 ± 5.4, $P = 0.002$), lower pH (7.31 ± 0.14 vs. 7.38 ± 0.09, $P = 0.008$), greater base deficit (−4.74 ± 4.75 vs. −1.08 ± 3.75, $P < 0.0005$), higher HR (108 ± 28 vs. 92 ± 22, $P = .0001$), more frequent use of TXA (18% vs. 5%, $P = 0.004$), greater pRBCs (5 ± 6.5 vs. 0.6 ± 2.7 units, $P < 0.0005$), FFP (4.4 ± 6.3 vs. 0.6 ± 2.5 units, $P = 0.001$), and crystalloid administration (3,602 ± 2,279 vs. 2,001 ± 1,955 mL, $P = 0.001$) than the group with a normal examination. There also appeared to be a difference in the MOI between those with normal pulses or ABI compared with those with a pulseless limb and no vascular injury identified on CTA/arteriogram ($P = 0.018$); however, this was not statistically significant. There were also no differences with respect to blood pressure, coagulopathy as measured by INR, or temperature.

Those pulseless limb patients who underwent additional imaging and no arterial injury identified were compared with those in whom an arterial injury was identified. The only difference between these 2 groups of patients was that patients who sustained an arterial injury had a significantly greater amount of crystalloid resuscitation (6.2 ± 2.8 L vs. 3.6 ± 2.7 L, $P = 0.007$). There were no other statistically significant differences with respect to patient vital signs, demographics, laboratory values, or MOI.

DISCUSSION

In civilian vascular literature, an absent distal pulse is reported as a hard sign of lower extremity arterial injury prompting immediate operative intervention without further diagnostic studies.[6] Similarly, the Third Revision of the combat manual Emergency War Surgery lists an absent pulse as a hard sign of an arterial injury along with pulsatile external bleeding, enlarging hematoma, a thrill/bruit, or an ischemic limb.[7] As the wars in Iraq and Afghanistan have progressed, it has become less clear whether a pulse deficit should be considered a hard sign of vascular injury in combat trauma. Notably, the most recent edition of the Emergency War Surgery manual defines hard signs of vascular injury as active hemorrhage, expanding hematoma, bruit or thrill, and ischemia. Ischemia is now defined as the absence of Doppler signals in the extremity on multiple attempts over time after adequate resuscitation.[8] Our finding that only 22% of patients who presented with a pulseless lower extremity on initial physical examination sustained an arterial injury supports this revised definition of hard signs of vascular injury.

Casualties presenting to MTFs in combat theater are different from patients presenting after civilian trauma. Application of civilian algorithms (including the use of an ABI and advanced imaging) to determine the presence or the absence of vascular injury in the combat injured has proven difficult and unreliable. In addition, this determination must be made in an expeditious manner and in certain combat environments, such as role II facilities, made without advanced imaging modalities. Only after continued resuscitation with correction of physiological derangements should a pulseless limb be considered a hard sign of vascular injury and mandate operative intervention. We believe the initial physical examination after combat trauma more likely reflects a patient in severe physiological distress than a patient with a true vascular injury. Patients with more significant injuries and physiological derangements may be at a greater risk of an unnecessary exploration because of a misleading pulse examination.

Of those presenting with a pulseless limb after a lower extremity injury in the acute combat setting who underwent further imaging, only a minority (22%) were found to have an arterial injury. The poor predictive value of a pulse deficit discovered on presentation to the combat trauma bay suggests that it is not reliable in diagnosing an arterial injury in patients presenting with penetrating lower extremity injuries. This may be due to the unique MOIs that troops endure during the GWOT. Injuries secondary to explosions and high-energy GSWs frequently result in extremity and torso wounds with significant soft tissue destruction.[9] Such severe injuries often lead to physiological derangements, including anemia, acidosis, and coagulopathy. To further analyze these injuries, we compared patients with a palpable pulse with those with a pulseless limb and no vascular injury. We found they had markedly different clinical and physiological markers. Patients with a pulse deficit but no vascular injury had a higher ISS, were more anemic, acidotic, and tachycardic and required greater amounts of pRBC, FFP, and crystalloid resuscitation.

The reliability of the physical examination compared with arteriography at a role V facility has been examined in patients with known or suspected vascular injuries sustained in either OIF or OEF.[10,11] At a median of 6 days from injury to evaluation, Johnson et al. found that the physical examination had a sensitivity of 38%, specificity of 90%, positive predictive value of 85%, and a negative predictive value of 51%. A normal physical examination did not accurately predict post-traumatic extremity arterial injuries sustained in combat, and the authors recommended liberal use of CTA and/or arteriography to assess for delayed or occult arterial injures.[10] We also found that the physical examination did not accurately predict an arterial injury in the combat population. In contrast, we found that an abnormal physical examination, specifically a pulseless limb, poorly predicted an arterial injury in the acute setting of combat trauma.

Similar to other published data from the GWOT, our cohort consisted largely of young healthy men. In a large cohort of 3,102 casualties from OIF and OEF through 2005, Owens et al.[12] described similar demographics and MOIs. They reported the highest proportion of injuries from explosions recorded during large-scale conflicts from the past 150 years. Casualties presenting to MTFs in combat theater are different from patients presenting secondary to civilian trauma. For example, the battlefield environment and weather conditions can impose delays in transit. Moreover, explosions, the cause of most casualties in this and other studies from the GWOT, impart an incredible amount of destruction to the body, especially the extremities.[13,14] These patients present with multiple concomitant injuries, frequently with extremity tourniquets in place, and often in extremis.

We acknowledge the limitations of this study. This was a retrospective review of an administrative database. The JTTR is subject to both coding and data entry errors. A significant number of patients presented with a pulse deficit did not undergo additional imaging. However, only 4 (9%) were ultimately found to have a lower extremity arterial injury. We were also disappointed by the surprisingly low number of ABIs that were completed and/or recorded in the patient charts. Starnes et al.[15] reported one of the challenges in obtaining a reliable ABI in the combat theater includes difficulty in performing the examination in the setting of helicopter and diesel generator noise. Similarly, it can be difficult to effectively perform an ABI on patients with multiple injuries who are being assessed by numerous teams and physicians. Nonetheless, the ABI remains an extremely important part of the physical examination, and its value cannot be overemphasized. Consideration may be given to installing an automated ABI machine, such as the Revo^R (Unetixs Vascular, Inc, North Kingstown, RI), at future MTFs with limited resources.

CONCLUSIONS

In contrast to civilian studies, we found that a pulseless limb does not reliably predict an arterial injury and should not be considered a hard sign of vascular injury in the combat trauma population. This study is the first to identify this outcome but is concordant with recent combat trauma guidelines. The best algorithm for troops presenting with a pulseless limb may include serial pulse examinations while physiological derangements persist, as obtaining an ABI in combat can be difficult. Patients presenting with more significant injuries as demonstrated by higher ISS, more significant acidosis and anemia, and greater resuscitation requirements remain at greatest risk of a misleading examination. Immediate operative exploration should be performed with caution at smaller MTFs with limited resources. Use of ABIs for evaluation of patients with a penetrating extremity trauma does remain important. Further studies will focus on which patients remain best served by immediate exploration or invasive imaging versus those patients who will benefit from timely safe observation after penetrating extremity trauma sustained in combat.

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