An 8-Year Review of Operation Enduring Freedom and Operation Iraqi Freedom Resuscitative Thoracotomies

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ABSTRACT Background: Appropriate indications for resuscitative thoracotomy (RT) in an austere environment continue to evolve; the aim of this study was to determine survival and to analyze demographics of survivors within U.S. military personnel undergoing RT. Methods: A retrospective review was performed of all U.S. soldiers who underwent thoracotomy in theater during Operation Iraqi Freedom and Operation Enduring Freedom. After individualized review, patients in extremis or who lost pulses and had their thoracotomy performed within 10 minutes of arrival to the emergency department were included. The primary outcome was survival at final hospital discharge, and secondary outcomes included demographics associated with survival. Results: Between January 2003 and May 2010, 81 U.S. military personnel met inclusion criteria for RT in theater. As low as 6.7% (3/45) of patients receiving prehospital cardiopulmonary resuscitation were alive at final hospital discharge. Survival from RT after explosive/blast injury, penetrating (gunshot wound), and blunt trauma were 16.3% (8/49), 0% (0/28), and 0% (0/4), respectively. Patients with primary explosive/blast extremity trauma undergoing RT had a survival of 27.3% (6/22). Higher initial oxygen saturations, larger volume of crystalloids and blood products infused, and higher extremity abbreviated injury score were all associated with survival. Conclusions: Combat casualties who present pulseless or in extremis who were injured as a result of an explosive/blast injury mechanism resulting in a primary extremity injury may have a survival benefit from undergoing a RT in an austere environment.

INTRODUCTION

Resuscitative thoracotomy (RT) is performed as a salvage procedure in severely injured trauma patients who arrive to the hospital in extremis with four main tenants: (1) control life-threatening thoracic exsanguination and pericardial tamponade; (2) improve perfusion to the heart and brain; (3) prevent infradiaphragmatic exsanguination; and (4) enable cardiac massage.[1] Survival RT rates associated with blunt force trauma compared to penetrating traumatic injury, are 1% to 2% versus 11% to 16% within the civilian literature.[2–3] In comparison, Morrison et al[4] and Edens et al[5] demonstrated survival rates of 21.5% and 12.5%, respectively, for penetrating trauma in Iraq and Afghanistan. Edens et al identified no survivors after blunt injury.[5]

The U.S. military's Joint Theater Trauma System clinical practice guideline for emergent RT published in June 2012 recommends that RT should be performed using clinical judgment in military personnel who present in extremis with a penetrating injury, or who lost vital signs immediately before arrival.[6] Current military traumatic injuries encountered are significantly different than the civilian experience with regard to the severity of wounding patterns caused by fragmentation injuries associated with improvised explosive devices (IEDs) and other military weaponry.[7] In addition, the military surgeon has to simultaneously balance limited medical personnel and resources, the tempo of operations, and complex transportation logistics when determining whether a combat casualty may benefit from RT.

The purpose of our study was to assess the utility of RT on American injury combat casualties over a period of 8 years of conflict in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) and to identify pre- and postprocedural demographic variables that favored survival at final hospital discharge.

METHODS

This retrospective study was conducted under a protocol approved by the San Antonio Military Medical Center institutional review board and included all combat casualties who had undergone RT at either a North American Treaty Organization (NATO) Role II or III facility in OEF and OIF between January 2003 and May 2010. NATO Role II facilities include basic primary care with limited surgical capabilities, two operating rooms (ORs), and a 20-person team including three general surgeons and one orthopedic surgeon.[8] NATO Role III facilities are the highest level of trauma care in theater with capabilities approaching a level one civilian trauma center including capacity for a 248-bed hospital and six ORs. A query was performed for all military

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casualties in the Joint Theatre Trauma Registry with an International Classification of Diseases, 9th Revision, Clinical Modification code of thoracotomy (34.02) performed on the same day as the wounded warrior's injury. We then reviewed available chart information using access to the Theater Medical Data Store to identify military personnel whose indication for thoracotomy was pulselessness or extremis and excluded all casualties who had the thoracotomy performed greater than 10 minutes of arrival to the emergency department (ED). This 10-minute criterion was established by the authors to capture those casualties most likely to benefit from RT, as the precise time of pulselessness or extremis was not documented from theater. Last, the location of the thoracotomy, ED or OR, was not part of the criterion for exclusion because the ORs were in close proximity to the EDs at NATO Role II and III facilities.

Demographic data collected included the following: age, gender, military branch, mechanism of injury, penetrating, blunt or explosive/blast injury, and location of injury for patients treated during the stated period. Explosive/blast injuries were reported as their own injury category, as this unique injury pattern is found largely within an austere environment, and usually combines both blunt and penetrating injury mechanisms simultaneously from the blast force combined with the fragmentation shrapnel injuries, respectively. Primary anatomical injury location was defined as the highest abbreviated injury score (AIS) among the following documented areas: head/neck/c-spine, face, chest (thorax), abdomen (L-spine), extremities (upper, lower, pelvis), and external (skin). Performance of cardiopulmonary resuscitation (CPR) in the prehospital or ED setting, demographic information (Glasgow coma scale and injury severity score [ISS]), admission laboratory results (hematocrit, international normalized ratio, and base deficit), physiologic data (heart rate, systolic blood pressure, and oxygen saturation) were evaluated. Furthermore, overall blood product utilization was also captured to include the total crystalloid, colloid, packed red blood cells (pRBCs), fresh frozen plasma, whole blood, cryoprecipitate, and platelets administered. Overall survival was reported as a patient's final discharged from U.S. military medical treatment facilities.

Statistical analysis was performed with SAS version 9.1 (SAS Institute, Cary, North Carolina), and Microsoft Excel 2007 (Microsoft, Redmond, Washington). Categorical data were analyzed using χ^2 tests. All continuous data were analyzed using Wilcoxon tests for nonparametric distributions and Student's t test for parametric distributions when appropriate. Statistical significance was set at $p < 0.05$. Values in the text are reported as median and inter-quartile ranges unless otherwise noted.

RESULTS

From January 1, 2003 to May 31, 2010, there were 20,162 combat casualty admissions in OEF and OIF, of whom 242 patients underwent thoracotomy, and 81 patients met inclusion criteria. Demographic information for the 81 patients who underwent RT is highlighted in Table I; survivors had a higher extremity AIS comparing survivors to nonsurvivors. Survivors from explosive/blast trauma, penetrating (gunshot wound), and blunt injuries were 16.3% (8/49), 0% (0/28), and 0% (0/4), respectively. Survival from primary extremity injury, 27.3% (6/22), was greater than primary chest injury, 0% (0/13) ($p = 0.06$), and primary abdominal injury, 0% (0/9) ($p = 0.01$). Physiologic and laboratory data are demonstrated in Table II; survivors were noted to have higher oxygen saturations on initial admission. Survivor's had a definitive airway secured in 75% (6/8) versus 36.7% (22/60)

TABLE I. Resuscitative Thoracotomies: Survivor Versus Nonsurvivor Patient Characteristics

Parameter	Survivors (n = 8) Median (IQR1,3)	Nonsurvivors (n = 73) Median (IQR1,3)	p Value
Age (Years)	21.5 (20, 23.25)	23 (21, 28)	<0.01
Gender (Male)	8 (100%)	71 (97.2%)	
Mechanism	Explosive: 8 (100%)	GSW: 28 (38.4%) Blunt: 4 (5.5%) Explosive: 41 (56.2%)	0.20
GCS (Total)	3 (3, 3)	3 (3, 3)	0.70
CPR (Prehospital)	3 (37.5%)	42 (57.5%)	0.28
ED CPR	7 (87.5%)	61 (83.6%)	0.77
Location of Thoracotomy	ED: 5 (62.5%) OR: 3 (37.5%)	ED: 66 (90.4%) OR: 5 (6.8%) Unknown: 2 (2.7%)	
ISS	34 (29.0, 38.3)	25 (17, 29)	0.08
AIS H/N	2 (1.0, 2.0)	0 (0, 2.3)	0.28
AIS Face	0 (0.0, 0.5)	0 (0, 0)	0.33
AIS Chest	2 (2.0, 3.0)	0 (0, 3)	0.09
AIS Body	2.5 (0.0, 3.3)	0 (0, 2.3)	0.21
AIS Extremity	4 (4.0, 4.3)	0 (0, 3)	<0.01
AIS External	1.5 (1.0, 2.0)	1 (0, 2)	0.22

AIS, abbreviated injury score; CPR, cardiopulmonary resuscitation; ED, emergency department; GCS, Glasgow coma scale; GSW, gunshot wound; H/N, head/neck; IQR, Inter-quartile range; ISS, injury severity score; OR, operating room.

TABLE II. Vital Signs and Laboratory Data of Survivor Versus Nonsurvivors After Resuscitative Thoracotomy

Parameter	Survivors Mean ± SD	Non survivors Mean ± SD	p Value Mean ± SD
Systolic Blood Pressure (mm Hg)	56.7 ± 69.5	37.4 ± 51.6	0.54
Heart Rate (beats/min)	46 ± 50.9	41.3 ± 55.4	0.84
Oxygen Saturation	93.8 ± 9.3	46.6 ± 24.4	<0.01
Respiratory Rate (breaths/min)	8.5 ± 12.0	2.2 ± 6.8	0.59
PaO_2 (mm Hg)	162.3 ± 173.5	64.0 ± 64.1	0.43
Hematocrit	31.0 ± 4.8	29.2 ± 9.2	0.51
INR	2.0 ± 0.7	2.2 ± 1.1	0.65
Base Deficit	−13.1 ± 5.6	−17.5 ± 8.3	0.11
PCO_2(mm Hg)	53.8 ± 17.2	69.0 ± 59.5	0.28

INR, International Normalized Ratio.

TABLE III. Total Blood Products and Volume Expander (Survivor Versus Nonsurvivor) for Resuscitative Thoracotomy. One Apheresis Unit = 6 Units Random Donor Platelets

Total Blood Product or Volume Expander	Survivors Mean (SD)	Nonsurvivors Mean (SD)	p Value
Crystalloid (L)	7.6 (2.6)	2.1 (3.1)	<0.01
Colloid (mL)	820 (798)	112 (305)	0.12
Whole Blood (U)	6.6 (9.5)	1.8 (4.2)	0.20
pRBC (U)	29.5 (12.3)	16.1 (16.5)	0.02
Platelets (U)	6.6 (5.2)	1.3 (2.0)	0.02
Cryoprecipitate (U)	11.9 (11.6)	3.5 (9.5)	0.09
FFP (U)	26.4 (6.7)	10.6 (13.8)	<0.01

FFP, fresh frozen plasma; U, unit of product.

of the nonsurvivors ($p = 0.06$). Table III demonstrates total blood product and volume expander requirements for survivors versus nonsurvivors; survivors had higher crystalloid, pRBC, platelets, and FFP than nonsurvivors.

DISCUSSION

During 8 years of conflict in OEF and OEF, survival rates for explosive/blast, penetrating (gunshot wound), and blunt injury were 16.3% (8/49), 0% (0/28), and 0% (0/4). Casualties who underwent prehospital CPR undergoing a RT had a 7% survival rate. More than 25% of casualties with a primary extremity injury survived RT.

The eight survivors from RT in OEF and OIF had higher preprocedural extremity AIS, initial oxygen saturations, and penetrating blast/explosive extremity injuries. The survivors had a nonstatistically significant increased ISS which is most likely attributable to their higher extremity AIS individual scores. Higher initial oxygenation in the survivor population may be related to the military medics securing a definitive surgical or mechanical airway in these patients during transport, although this study is not currently powered to identify a difference between definitive airway on transport ($p = 0.06$). Ultimately, the higher oxygenation in the survivors correlates to an initial higher cardiac output at their emergency room presentation portending a likely improved physiological and neurological outcome compared to the nonsurvivors. Finally, although preprocedural CPR was not identified to be statistically significant secondary to a lack of statistical powering, there was an obvious trend toward survivorship in patients who were not actively undergoing CPR on presentation to the emergency room. Effective and early recognition of when to implement CPR is still paramount to these critically wounded soldiers while in transport to a definitive military medical facility in an austere environment by military medics. However, prompt surgical intervention to control the underlying etiology of their cardiopulmonary deterioration and blood product resuscitation remain the foundation of surgical treatment on arrival to a medical treatment facility as opposed to active CPR.

Patients with a primary blast/explosive extremity injury demonstrated an improved survival after RT (27.3%). Edens et al[5] demonstrated that 10% of their patients survived with primary penetrating extremity hemorrhage after RT; they postulated that despite the liberal utilization of tourniquet in theater, most of these patients had sustained extensive hemorrhage leading to an impending circulatory collapse despite tourniquet utilization for primary extremity trauma. Morrison et al[4] demonstrated no statistical difference in survivors versus nonsurvivors comparing patients with an AIS extremity score of three or more. Furthermore, despite trends in civilian literature of higher survival with penetrating thoracic injuries with RT, our data demonstrated the main difference between survivors and nonsurvivors in a military population who suffer explosive/blast injury was AIS of the extremity. However, an austere environment provides unique weaponry (improvised explosive devices) and injury patterns unbeknown to most civilian trauma literature data. Soldiers on foot patrols are susceptible to dismounted complex blast injury that commonly result in junctional (e.g., pelvis, axilla, and neck), high extremity and truncal hemorrhage often with traumatic amputations. Specifically, 2001–2011 reviews from OIF and OEF demonstrated that junctional hemorrhage was responsible for 17.5% of all potentially survivable injuries, with 34.5% of all amputations performed in this group being transfemoral.[9–12] Traditional extremity tourniquets have demonstrated an improved survival benefit in combat casualties. Unfortunately, pelvic vascular injuries from explosive devices, especially in the setting of high traumatic, lower extremity amputation, are not effectively controlled by the traditional extremity tourniquet.[13] This appears to describe our study cohort where the median AIS for extremity is four, which describes an injury at the level of the hip or buttock. Aortic occlusion via RT, in these cases, may be helpful as an adjunct to resuscitation in patients presenting in extremis or who present pulseless with penetrating pelvic hemorrhage or complete lower extremity traumatic amputations where placement of an effective tourniquet is impossible.

The eight survivors from RT in OEF and OIF had higher postprocedural blood product and volume expander resuscitation. The increased blood product and volume expander administration was associated with survival and may be secondary to a survival bias; however, it demonstrates the importance of significant resuscitation in these patients likely presenting with hemorrhagic shock after the explosive/blast injury.

This study has several limitations. First, our study is retrospective in nature and has the inherent limitations of such a design. It was restricted to available data collected during the study period, and long-term neurological and functional outcomes of patients surviving RT are not included. Also, prehospital tourniquet utilization data and anatomical location of extremity injury were not documented for inclusion within this data analysis, the latter being inferred based on AIS. Second, the 10-minute criterion is an arbitrary time frame established by the authors to define a standard definition of RTs that occur at or near presentation to the ED, as the time when patient's lost their pulse was not readily identifiable within the study data; therefore, we may not have captured every true RT if it was performed beyond this time point. Third, our study's time frame overlaps with that of Edens et al's study,[5] thus the same subject may be included in both studies. Fourth, the duration of pulselessness and/or CPR in casualties presenting to the ED was not documented in the subject's medical record, where shorter times might portend better outcomes regardless of adjunct(s) used. Fifth, this study lacks statistical power secondary to the small number of patients undergoing RT to capture patients with a primary penetrating trauma to their abdomen or thorax that may also have directly benefited from an RT. Finally, our study does not have long-term follow-up neurologically to evaluate the results of those patients who survived to final hospital discharge.

CONCLUSION

Combat casualties presenting with a primary extremity blast/ explosive injury who were pulseless or in extremis at arrival to the ED and underwent a RT had a 27.3% survival; RT may improve overall outcomes in this specific injury mechanism.

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