Emergency Department Thoracotomy: Still Useful After Abdominal Exsanguination?

Mark J. Seamon, MD, Abhijit S. Pathak, MD, Kevin M. Bradley, MD, Carol A. Fisher, BA, John A. Gaughan, PhD, Heather Kulp, RN, MPH, Paola G. Pieri, MD, Thomas A. Santora, MD, and Amy J. Goldberg, MD

Background: Although literature regarding emergency department thoracotomy (EDT) outcome after abdominal exsanguination is limited, numerous reports have documented poor EDT survival in patients with anatomic injuries other than cardiac wounds. As a result, many trauma surgeons consider prelaparotomy EDT futile for patients dying from intra-abdominal hemorrhage. Our primary study objective was to prove that prelaparotomy EDT is beneficial to patients with exsanguinating abdominal hemorrhage.

Methods: A retrospective review of 237 consecutive EDTs for penetrating injury (2000–2006) revealed 50 patients who underwent EDT for abdominal exsanguination. Age, gender, injury mechanism and location, field and emergency department (ED) signs of life, prehospital time, initial ED cardiac rhythm, vital signs, Glasgow Coma Score, blood transfusion requirements, predicted mortality, primary abdominal injuries, and the need for temporary abdominal closure were analyzed. The primary study endpoint was neurologically intact hospital survival.

Results: The 50 patients who underwent prelaparotomy EDT for abdominal exsanguination were largely young (mean, 27.3 ± 8.2 years) males (94%) suffering firearm injuries (98%). Patients presented with field (84%) and ED signs of life (78%) after a mean prehospital time of 21.2 ± 9.8 minutes. Initial ED cardiac rhythms were variable and Glasgow Coma Score was depressed (mean, 4.2 ± 3.2). Eight (16%) patients survived hospitalization, neurologically intact. Of these eight, all were in hemorrhagic shock because of major abdominal vascular (75%) or severe liver injuries (25%) and all required massive blood transfusion (mean, 28.6 ± 17.3 units) and extended intensive care unit length of stay (mean, 36.3 ± 25.7 days).

Conclusions: Despite critical injuries, 16% survived hospitalization, neurologically intact, after EDT for abdominal exsanguination. Our results suggest that prelaparotomy EDT provides survival benefit to penetrating trauma victims dying from intra-abdominal hemorrhage.

Key Words: Prelaparotomy emergency department thoracotomy, Abdominal exsanguination.

J Trauma. 2008;64:1–8.

The American College of Surgeons Committee on Trauma reported in their Practice Management Guidelines for Emergency Department Thoracotomy (EDT) that "emergency department thoracotomy should be performed in patients sustaining exsanguinating abdominal vascular injuries, but these patients generally experience a low survival rate".[1] After numerous reports have documented poor EDT survival in patients with anatomic injuries other than cardiac wounds, many trauma surgeons consider this heroic procedure futile for patients dying from intra-abdominal hemorrhage.[2–12] Although literature regarding EDT survival for abdominal exsanguination is limited, recent investigations at our Level I urban trauma center suggest that EDT salvage rates from penetrating torso injuries are related to injury mechanism, hemodynamic profile, and Glasgow Coma Score (GCS) at the time of initial emergency department (ED) presentation, but not anatomic injury location.[13,14] We hypothesized that neurologically intact survival rates after EDT for abdominal exsanguination could be substantial in patients possessing these survival predictors. The primary objective of this study was to prove that prelaparotomy EDT is beneficial to patients with exsanguinating abdominal hemorrhage after penetrating injury.

Submitted for publication September 18, 2007.
Accepted for publication October 29, 2007.

From the Department of Surgery (M.J.S., A.S.P., K.M.B., C.A.F., H.K., P.G.P., T.A.S., A.J.G.) and Biostatistics Consulting Center (J.A.G.), Temple University School of Medicine, Philadelphia, Pennsylvania.
Presented at the 66th Annual Meeting of the American Association for the Surgery of Trauma, September 27–29, 2007, Las Vegas, Nevada.
Address for reprints: Mark J. Seamon, MD, Department of Surgery, Temple University Hospital, 3401 North Broad Street, Philadelphia, PA 19104; email: mark.seamon@tuhs.temple.edu.
DOI: 10.1097/TA.0b013e3181606125

METHODS

Temple University Hospital is an inner-city Level I trauma center in North Philadelphia, PA which draws the majority of its injured patients from within a 2 mile radius of the hospital. Our penetrating trauma population is comprised largely of young males suffering gunshot wounds. Approximately half of our patients are transported by Philadelphia Fire Rescue Emergency Medical Services, which is comprised of a combination of Advanced Life Support (ALS) and Basic Life Support (BLS) units, and the remainder are transported by police or private vehicle.[13] Resuscitation begins in the prehospital care phase in most ALS transported patients with endotracheal intubation, closed-chest cardiopulmonary resuscitation, placement of intravenous lines, and infusion of crystalloid solutions. Patients transported by BLS units, police, or private vehicle arrive to the ED after minimal or no prehospital resuscitative intervention with the exception of sporadic closed-chest cardiopulmonary resuscitation.

The decision to perform EDT upon patient arrival was made by the on call attending trauma surgeon or senior surgical resident. Judgment was based on the presence of field or ED signs of life (SOL), prehospital time, the presence of obtainable ED vital signs, and the nature of the initial ED cardiac rhythm. SOL were defined as the presence of any of the following clinical parameters: pupillary response, agonal respirations, carotid pulse, measurable blood pressure (BP), extremity movement, or cardiac electrical activity. Electrical activity was defined by the presence of any evident activity, including agonal or pulseless electrical activity (PEA), on either cardiac monitor or direct cardiac inspection after EDT. Organized cardiac rhythms were defined by PEA or sinus rhythms. The presence of measurable vital signs was defined by any of the following: palpable carotid pulse, measurable BP, or spontaneous respiratory activity. With the exception of isolated penetrating cranial injuries, EDT was performed for all injury locations.

All thoracotomies in this series were performed within 20 minutes of arrival to the ED by the trauma surgery team consisting of a supervising attending trauma surgeon, a senior surgery resident (postgraduate year [PGY] 4 or 5), a junior surgery resident (PGY 2 or 3), and an emergency medicine resident (PGY 1 or 3). Using well-described techniques, open chest cardiac massage was performed through a left anterolateral thoracotomy incision and the aorta was cross-clamped at the level of the distal descending thoracic aorta. Patients salvaged by EDT were emergently transported to the operating room (OR) for laparotomy. The abdominal cavity was expeditiously packed and retroperitoneal zones explored. When possible, the thoracic aortic cross clamp was rapidly replaced on the abdominal aorta before complete abdominal exploration. The location of the replaced aortic cross clamp was determined by suspected injury location. After several attempts, the attending trauma surgeon pronounced patients who could not tolerate unclamping the thoracic aorta as a result of hemodynamic collapse.

After institutional review board approval was obtained, a retrospective review of patients who underwent EDT between January 2000 and December 2006 revealed 237 patients with penetrating injuries. The final study group of 50 patients who underwent EDT for abdominal injury was included for analysis. A portion of data analyzed in this series was extracted from a dataset used in previous work from this institution.[13,14] Age, gender, injury mechanism, primary anatomic injury location, the presence of field SOL, prehospital time, the presence of ED SOL, initial cardiac rhythm, the presence of measurable vital signs, GCS, and blood transfusion requirements during the initial ED and OR resuscitation periods were studied in all patients. Initial ED BP and heart rate (HR), BP and HR immediately preceding EDT, predicted mortality using Trauma and Injury Severity Score (TRISS) methodology,[15] primary abdominal injuries, and the need for temporary abdominal closure were assessed in abdominal exsanguination survivors. Investigated outcomes included survival until the OR, survival to 48 hours, survival until hospital discharge, and intensive care unit (ICU) length of stay.

Patients with thoracic (cardiac and noncardiac thoracic) injuries are presented in tabular form for comparison, but are not the current study focus. Descriptive statistics were calculated for all continuous and categorical variables. Post hoc analysis included Pearson's χ^2, Fisher's exact test, and Student's t tests. Univariate and multivariate logistic regression analysis determined outcome predictors, and odds ratios with 95% confidence intervals were calculated for each measured variable. A p value less than or equal to 0.05 was considered statistically significant.

RESULTS

The 50 patients who underwent prelaparotomy EDT for abdominal exsanguination are summarized in Table 1. Patients were largely young (27.3 ± 8.2 years [mean ± SD]) males (94%) suffering firearm injuries (98%). Patients often presented with field (84%) and ED SOL (78%) after a mean

Table 1 Demographics and Clinical Characteristics

Characteristic	
Age (yr)	27.3 ± 8.2*
Male	47 (94.0%)
Mechanism	
Gunshot wound	19 (38.0%)
Multiple GSW	30 (60.0%)
Stab wound	0
Multiple SW	1 (2.0%)
Primary injury location	
Cardiac	0
Noncardiac thoracic	0
Abdominal	50 (100%)
Field SOL	42 (84.0%)
ED SOL	39 (78.0%)
Prehospital Time (min)	21.2 ± 9.8*
Initial cardiac rhythm	
Asystole	10 (20.0%)
PEA	22 (44.0%)
Agonal	3 (6.0%)
Sinus bradycardia	1 (2.0%)
Sinus tachycardia	7 (14.0%)
Normal sinus rhythm	7 (14.0%)
Obtainable vital signs	21 (42.0%)
Initial GCS	4.2 ± 3.2*
Survival to operating room	23 (46.0%)
Survival to 48 h	8 (16.0%)
Survival to hospital discharge	8 (16.0%)

Demographics, clinical characteristics, and outcomes were analyzed in abdominal exsanguination patients.

* Mean ± SD.

GSW, gunshot wound; SW, stab wound; SOL, signs of life; ED SOL, emergency department signs of life; PEA, pulseless electrical activity; GCS, Glasgow Coma Score.

prehospital time of 21.2 ± 9.8 minutes. Initial ED cardiac rhythms were highly variable (asystole, 20%; agonal, 6%; PEA, 44%; sinus bradycardia, 2%; sinus tachycardia, 14%; normal sinus rhythm, 14%) in this patient group, but none presented in ventricular tachycardia or ventricular fibrillation. Although 42% of the abdominal exsanguination patients presented with obtainable ED vital signs, mental status was severely depressed. Mean GCS was 4.2 ± 3.2. EDT for abdominal exsanguination successfully salvaged 23 of 50 (46%) patients until arrival in the OR. No patient expired in the ICU. All eight (16%) patients who survived 48 hours ultimately survived their entire hospitalization, neurologically intact (Fig. 1).

Patients were compared on the basis of primary anatomic injury location (Table 2). When cardiac and noncardiac thoracic injured patients were compared with abdominal exsanguination patients, no difference in injury mechanism (p = 0.085) or prehospital field time (p = 0.451) was noted. Cardiac and noncardiac thoracic injured patients presented less often with favorable physiologic survival predictors such as organized initial cardiac rhythms (cardiac/thoracic, 91 of 177 [51.4%] vs. abdominal 37 of 50 [74.0%], p = 0.006), obtainable vital signs (cardiac/thoracic, 39 of 177 [22.0%] vs. abdominal 21 of 50 [42.0%], p = 0.007), or the presence of SOL (cardiac/thoracic, 101 of 177 [57.1%] vs. abdominal 39 of 50 [78.0%], p = 0.008), than the abdominal injury cohort. Although GCS was determined to independently predict EDT outcome after torso injury,[14] no difference in either GCS (p = 0.866) or hospital survival (p = 0.313) was detected between cardiac and noncardiac thoracic injured patients and abdominal exsanguination patients. Univariate and multivariate analysis failed to reveal any outcome predictors in patients who underwent prelaparotomy EDT for abdominal exsanguination.

Although survivors presented with a variety of cardiac rhythms, all eight were in severe hemorrhagic shock (Table 3). Five of eight (62.5%) survivors arrived with a GCS of 3 (mean, 6.0 ± 4.8; range, 3–14) whereas four of eight (50%) had immeasurable BPs upon presentation. Immediately before EDT, six of eight (75%) had immeasurable BPs; the other two survivors were hypotensive with final recorded BPs of 75/39 mm Hg and 79/21 mm Hg (Fig. 2). Three of eight (37.5%) had a measurable HR on cardiac monitor before EDT. Predicted mortality based on TRISS methodology[15] using initial ED parameters was greater than 90% in five of eight (62.5%) survivors.

Survivors of EDT for abdominal exsanguination were critically ill with multiple intra-abdominal injuries (Table 4). Six of eight (75%) had major abdominal vascular injuries including five iliac vessel injuries and one combined superior mesenteric artery and vein injury. Two of eight (25%) survivors had severe liver injuries. Seven of eight (87.5%) survivors required temporary abdominal closure. All survivors required massive blood transfusion and prolonged stay in the ICU. The eight survivors were transfused a total of 28 units of blood in the ED and 199 units in the OR, totaling 227 units of red blood cell transfusion (mean, 28.6 ± 17.3 units; range,

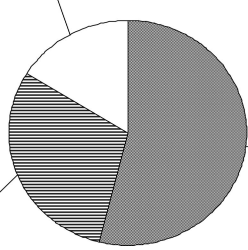

Fig. 1. *Fifty patients underwent EDT for abdominal exsanguination. Twenty-seven (54%) patients died in the ED and 15 (30%) died in the OR. All eight (16%) patients who survived the OR survived their entire hospitalization, neurologically intact. EDT, emergency department thoracotomy; ICU, intensive care unit; ED, emergency department; OR, operating room.*

Table 2 **A Comparison of Thoracic and Abdominal Injuries**

	Thoracic (n = 177)	Abdominal (n = 50)	p
Mechanism (GSW)	158/177 (89.3%)	49/50 (98.0%)	0.085*
Prehospital time (min)	20.1 ± 8.9	21.2 ± 9.8	0.451†
Organized cardiac rhythm	91/177 (51.4%)	37/50 (74.0%)	0.006*
ED vital signs	39/177 (22.0%)	21/50 (42.0%)	0.007*
ED signs of life	101/177 (57.1%)	39/50 (78.0%)	0.008*
GCS	4.2 ± 3.2‡	4.2 ± 3.2‡	0.866†
Survival until discharge	18/177 (10.2%)	8/50 (16.0%)	0.313§

No difference in penetrating injury mechanism or prehospital time was detected between the thoracic (cardiac and noncardiac thoracic) and abdominal injury groups. Thoracic injured patients less often presented with favorable physiologic survival predictors such as salvageable initial cardiac rhythms, obtainable vital signs, or the presence of signs of life than their abdominally injured counterparts. However, no difference in GCS or hospital survival was identified between groups. Organized rhythms were defined as PEA or sinus rhythms.

* Pearson's χ^2.

† Student's t test.

‡ Mean ± SD.

§ Fisher's exact test.

GSW, gunshot wounds; PEA, pulseless electrical activity; ED, emergency department; GCS, Glasgow Coma Score.

Table 3 Indicators of Injury Severity in Survivors

Survivor	Initial Cardiac Rhythm	Arrival GCS	BP Before EDT	HR Before EDT	Predicted Mortality (%)
1	Agonal	3	UO	0	90.8
2	Asystole	3	UO	0	95.8
3	Normal sinus	13	UO	86	6.3
4	Normal sinus	6	75/39	119	38.2
5	PEA	3	UO	0	97.4
6	PEA	3	UO	0	99.9
7	Sinus tachycardia	14	79/21	76	6.0
8	Normal sinus	3	UO	0	92.3

Survivors had severe physiologic derangement. Although initial cardiac rhythms were varied, most arrived with depressed mental status and all but 2 survivors had immeasurable blood pressures immediately preceding EDT. Predicted mortality was determined by TRISS methodology.[15]

GCS, Glasgow Coma Score; BP, blood pressure; EDT, emergency department thoracotomy; UO, unobtainable; HR, heart rate; PEA, pulseless electrical activity.

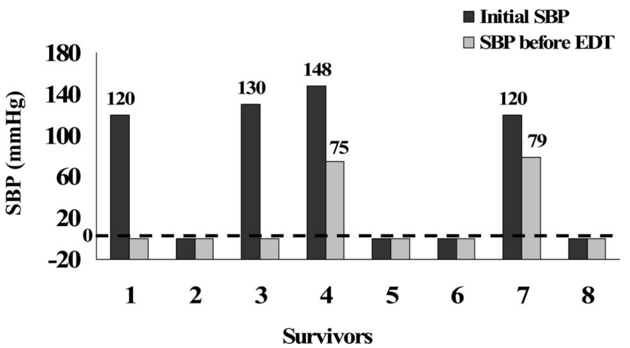

Fig. 2. *Four of eight (50%) survivors after EDT for abdominal exsanguination arrived without a measurable blood pressure. Immediately before EDT, only two survivors had measurable systolic blood pressure (75 and 79 mm Hg, respectively). EDT, emergency department thoracotomy; SBP, systolic blood pressure.*

14–68 units) during the initial ED and OR resuscitation. Extended length of stay in the surgical ICU (mean, 36.3 ± 25.7 days; range, 8–77 days) was necessary in each of the eight survivors.

DISCUSSION

The key finding of this study is that prelaparotomy EDT for abdominal exsanguination is not futile care in our patient population. Our results suggest that prelaparotomy EDT provides survival benefit to penetrating trauma victims dying from intra-abdominal hemorrhage and should remain in the trauma surgeon's armamentarium. Despite critical injuries, 16% survived hospitalization, neurologically intact, after EDT for abdominal exsanguination.

After a period of enthusiasm for prelaparotomy EDT for extrathoracic injury in the 1980s, interest in the heroic procedure has waned in recent years.[2] However, the use of EDT for penetrating abdominal injury may improve outcome by enabling both open cardiac massage and temporary aortic occlusion. These adjuncts are widely believed to provide more effective cardiopulmonary resuscitation whereas directing blood to the more essential cerebral and cardiac tissues as intra-abdominal hemorrhage is limited. Although the technique seems physiologically justified, its effects and outcomes in humans are essentially unproven and conclusions are largely based on controlled animal studies.

The left anterolateral thoracotomy incision allows rapid access to the pericardium and thoracic aorta for open cardiac massage and thoracic aortic occlusion. Numerous animal reports have described superior cardiac output, coronary and cerebral blood flow during open chest cardiac massage when compared with traditional closed chest cardiac massage.[16–20]

Table 4 Injuries and Outcome in Survivors

Survivor	Primary Injuries	Temporary Closure	RBC Transfusion (units)	ICU LOS (d)
1	Liver, bowel, diaphragm	Yes	16	31
2	Iliac artery and vein	Yes	23	77
3	Liver, spleen, bowel, diaphragm	No	22	8
4	Iliac artery, bowel, diaphragm	Yes	14	31
5	Iliac artery and vein	Yes	68	36
6	Iliac artery, lung, bowel, diaphragm	Yes	21	10
7	SMA and SMV, bowel	Yes	35	25
8	Iliac artery and vein	Yes	30	72

All survivors of prelaparotomy EDT had critical abdominal injuries. Six of 8 (75%) survivors had major abdominal vascular injuries while 2 survivors had severe solid organ injury. Seven of 8 (87.5%) required temporary abdominal closure and all required multiple packed RBC transfusions and extended stay in the intensive care unit. Noted RBC transfusion includes blood transfusion during both initial emergency department and intraoperative resuscitation.

RBC, packed red blood cell transfusion (units); ICU LOS, intensive care unit length of stay (d); SMA, superior mesenteric artery; SMV, superior mesenteric vein.

Similar hemodynamic benefits after thoracic aortic occlusion have also been well described in other animal models.[21–27] Each of our 50 patients who underwent EDT for abdominal exsanguination had open cardiac massage and aortic occlusion with the placement of a temporary descending thoracic aorta cross clamp. No complications related to aortic cross clamp placement including over-distension of the left ventricle, paraplegia, avulsion of intercostal arteries, or esophageal injury were noted during the study period. Although cardiac output, coronary perfusion pressures, or cerebral blood flow were not measured in the present report, neurologically intact survival, the ultimate assessment of treatment advantage, was substantial. Although we may only speculate that aortic occlusion improved cerebral and coronary perfusion in our patients, it may also be possible that aortic occlusion limited additional hemorrhage from abdominal arterial injuries and provided a relatively "bloodless" field to the operating surgeon. In fact, six of eight (75%) abdominal exsanguination survivors had major arterial injuries and are likely to have benefited most from aortic occlusion.

Human data regarding prelaparotomy EDT including open chest cardiac massage and thoracic aorta cross clamping for abdominal exsanguination is largely limited to EDT reports in which all injury locations including abdominal are described as a single cohort or in isolated abdominal vascular injury reports where a portion of patients required prelaparotomy EDT. In their landmark 1976 report, Ledgerwood et al.[23] brought 40 patients to the OR for exploratory laparotomy. The majority of these patients suffered penetrating injuries (95%) causing hemorrhagic shock (80%). Twenty-nine had prelaparotomy thoracotomy in the OR of which 11 ultimately survived. Eleven patients had thoracotomies after laparotomy, seven of which were caused by sudden cardiovascular collapse upon opening the peritoneum. The authors concluded that left thoracotomy with aortic cross-clamping before laparotomy is an alternative and beneficial approach to the exsanguinating patient with abdominal injury. Similarly, Wiencek and Wilson[28] retrospectively reviewed 154 patients with abdominal vascular injuries. Forty-two of these patients had persistent shock of which 26 underwent prelaparotomy thoracotomy in the OR and 5 (19.2%) survived. Only 1 of 17 (6%) patients with persistent shock who underwent laparotomy without thoracotomy survived.

With less severe physiologic derangement, outcome of patients undergoing "resuscitative" thoracotomy in the OR is believed to be more favorable than outcome after EDT. However, several series have reported significant survival rates in patients requiring EDT for abdominal exsanguination. In 1980, Baker et al.[29] reported that 5 of 33 (15%) EDT survivors suffered either blunt or penetrating abdominal injury. In the largest EDT review to date, Branney et al.[5] reported their 23-year experience involving 950 patients who underwent EDT. Seventy-three patients underwent EDT for penetrating abdominal injury. Of these 73 patients who underwent prelaparotomy EDT, 11% survived hospitalization. In another large EDT review from the same institution, 5 of 12 neurologically intact survivors suffered abdominal rather than thoracic injuries.[3] Velmahos et al.[12] reported 118 patients who underwent EDT for both blunt and penetrating abdominal injuries of which 6.8% survived. Others have reported survival rates in relation to specific abdominal vascular injuries. In a review of iliac vessel injuries, Asensio et al.[30] reported 15% survival in patients who underwent prelaparotomy EDT. In a large meta-analysis involving all EDT literature from 1978 to 1998 that reported primary injury location, Rhee et al.[10] described an overall survival rate of 4.5% in 640 patients who underwent EDT for abdominal exsanguination.

Although several reports have indicated that cardiac injuries offer the greatest survival potential for patients undergoing EDT, data from our institution have not supported these findings.[14] Although we have not realized a survival benefit for one primary anatomic injury location over another, we acknowledge that our finding is inconsistent with several previous reports.[3–12] Notably, Ivatury et al.[9] reported an EDT series with 134 penetrating injuries consisting of 49 (36.6%) stab wounds, 84 (62.7%) gunshot wounds, and 1 shotgun injury. Although 21% of patients with cardiac injuries survived, no patient with penetrating abdominal injury survived, leading to the concept of the "directed" EDT based on the probability of cardiac injury.[9] However, the specific type of penetrating injury was also important in this series, as 12 of 16 (75%) who ultimately survived hospitalization were stab wound injuries. Our series differed in that 98% of our abdominal exsanguination population suffered firearm injuries.

Branney et al.[5] reported survival rates similar to our present series. In their review, stab wounds to the chest and gunshot wounds to the abdomen realized the greatest survival. Seven of 56 (13%) patients with abdominal gunshot wounds survived EDT but only 1 of 17 (5%) with abdominal stab wounds survived. Reasons for improved EDT survival after abdominal gunshot wounds rather than abdominal stab wounds are unclear. The single patient in our series who suffered an abdominal stab wound survived an iliac artery injury.

Patients with abdominal exsanguination appeared to present with less physiologic derangement than their thoracic injured counterparts. Abdominal injured patients presented more often with organized cardiac rhythms such as PEA or sinus rhythm, evidence of ED SOL, and measurable ED vital signs. Despite the predominance of these factors, univariate and multivariate analysis failed to establish that any of these physiologic characteristics predicted outcome in abdominal exsanguination patients. Regardless, the survivors of prelaparotomy EDT had severe hemorrhagic shock and rapidly decompensated following presentation. Only two of eight survivors had a measurable BP immediately before EDT, and both were hypotensive with systolic blood pressure below 80 mm Hg.

Although five of eight abdominal exsanguination survivors had a predicted mortality of greater than 90%, three of eight had mortality predictions favoring survival. TRISS may grossly underestimate mortality predictions after single-body cavity, severe penetrating abdominal injury.[31] Cornwell III et al.[31] determined 36% of patients admitted with abdominal gunshot wounds, who subsequently died, to be "TRISS fallouts". This "fallout" population was similar to our own study population, in that it was comprised of young males with major vascular and multiple abdominal injuries caused by gunshot wounds confined to a single body cavity. Regardless of the predicted TRISS mortality, survivors had critical abdominal injuries necessitating prelaparotomy EDT, massive blood transfusion, temporary abdominal closure, and extended ICU length of stay.

Despite our findings that support the use of prelaparotomy EDT for abdominal exsanguination, we readily acknowledge several study limitations. This is a single center experience from an inner-city institution that has accrued considerable data and familiarity with penetrating injury. The majority of our penetrating trauma population were injured within a 2-mile radius of our trauma center and police or private vehicles rapidly transport approximately 50% of these patients without field intervention. Importantly, the prehospital times reported included only Emergency Medical Service transported patients, as data from the police or private vehicle transported patients were unavailable. The importance of rapid transport may be underscored by the fact that police or private vehicles transported seven of eight survivors in this series.[13] Several previous reports, both from this institution and other urban centers have demonstrated a survival advantage in patients rapidly transported after minimal field intervention ("scoop and run") and BLS rather than patients transported after extensive field prehospital care with ALS which often includes intravenous line placement, endotracheal intubation, and the delivery of cardioactive medications.[32–39] Unlike victims of cardiac arrest, these measures do not represent definitive care for the penetrating trauma victim in hemorrhagic shock requiring rapid transport to the hospital. This report supports these findings—seven of eight survivors had no field interventions.

Our study design faces similar limitations and biases as other retrospective studies that analyze uncommon injuries in a limited number of patients. Nonetheless, our conclusions are based on 8 survivors from a 50 patient study group that is currently one of the largest reported series of abdominal exsanguination patients. Additionally, our conclusions are corroborated by a previous 10-year (1989–1998) retrospective review of abdominal exsanguination from our institution. In this series, Bard et al.[40] reported a similar survival rate (11%) in 45 patients who underwent prelaparotomy EDT for isolated abdominal exsanguination.

In summary, our study findings suggest that prelaparotomy EDT is an effective technique for the management of patients with critical penetrating abdominal injuries who are dying from abdominal exsanguination. Based on our results, prelaparotomy EDT is not futile care for the critically injured and should remain in the trauma surgeon's armamentarium. Finally, it is our hope that other urban centers will analyze and report their own experience with EDT for abdominal exsanguination to support or refute our conclusions and refine future care for this challenging population as the ability to prospectively randomize these patients is precluded by the ethical concerns surrounding the randomization of patients in extremis to prelaparotomy EDT or laparotomy without EDT.

REFERENCES

1. Working group, Ad Hoc Subcommittee on Outcomes, American College of Surgeons' Committee on Trauma. Practice management guidelines for emergency department thoracotomy. *J Am Coll Surg.* 2001;193:303–309.
2. Miglietta MA, Robb TV, Eachempati SR, et al. Current opinion regarding indications for emergency department thoracotomy. *J Trauma.* 2001;51:670–676.
3. Baxter BT, Moore EE, Moore JB, et al. Emergency department thoracotomy following injury: critical determinants for patient salvage. *World J Surg.* 1988;12:671–675.
4. Boyd M, VanekVW, Bourguet CC. Emergency room resuscitative thoracotomy: when is it indicated? *J Trauma.* 1992;33:714–721.
5. Branney SW, Moore EE, Feidhaus KM, et al. Critical analysis of two decades of experience with postinjury emergency department thoracotomy in a regional trauma center. *J Trauma.* 1998;38:87–94.
6. Cogbill TH, Moore EE, Millikan JS, Cleveland HC. Rationale for selective application of emergency department thoracotomy in trauma. *J Trauma.* 1983;23:453–460.
7. Feliciano DV, Bitondo CG, Cruse PA, et al. Liberal use of emergency center thoracotomy. *Am J Surg.* 1986;152:654–659.
8. Feliciano DV, Burch JM, Spjut-Patrinely V, et al. Abdominal gunshot wounds: an urban trauma center's experience with 300 consecutive patients. *Ann Surg.* 1988;208:362–367.
9. Ivatury RR, Kazigo J, Rohman M, Gaudino J, Simon R, Stahl WM. "Directed" emergency room thoracotomy: a prognostic prerequisite for survival. *J Trauma.* 1991;31:1076–1082.
10. Rhee PM, Acosta J, Bridgeman A, et al. Survival after emergency department thoracotomy: review of published data from the past 25 years. *J Am Coll Surg.* 2000;190:288–298.
11. Schwab WC, Adcock OT, Max MH. Emergency department thoracotomy (EDT): a 26-month experience using an "agonal" protocol. *Am Surg.* 1986;52:20–29.
12. Velmahos GC, Degiannis E, Souter I. Outcome of a strict policy on emergency department thoracotomy. *Arch Surg.* 1995;130:774–777.
13. Seamon MJ, Fisher CA, Gaughan J, et al. Prehospital procedures before emergency department thoracotomy: "scoop and run" saves lives. *J Trauma.* 2007;63:113–120.
14. Seamon MJ, Fisher CA, Gaughan JA, et al. Emergency department thoracotomy: survival of the least expected. Presented at International Surgical Week, Montreal, Canada: August 28, 2007. *World J Surg.* In press.
15. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. *J Trauma.* 1987;27:370–378.
16. Boczar ME, Howard MA, Rivers EP, et al. A technique revisited: hemodynamic comparison of closed- and open-chest cardiac massage during human cardiopulmonary resuscitation. *Crit Care Med.* 1995; 23:498–503.
17. DeBehnke DJ, Angelos MG, Leasure JE. Comparison of standard external CPR, open-chest CPR, and cardiopulmonary bypass in a canine myocardial infarct model. *Ann Emerg Med.* 1991;20:754–760.
18. Luna GK, Pavlin EG, Kirkman T, et al. Hemodynamic effects of external cardiac massage in traumatic shock. *J Trauma.* 1989; 29:1430–1433.

19. Mattox KL, Feliciano DV. Role of external cardiac compression in truncal trauma. *J Trauma.* 1982;22:934–936.
20. Rubertsson S, Grenvik A, Wiklund L. Blood flow and perfusion pressure during open-chest versus closed-chest cardiopulmonary resuscitation in pigs. *Crit Care Med.* 1995;23:715–725.
21. Dunn EL, Moore EE, Moore JB. Hemodynamic effects of aortic occlusion during hemorrhagic shock. *Ann Emerg Med.* 1982; 11:238.
22. Kralovich KA, Morris DC, Dereczyk BE, et al. Hemodynamic effects of aortic occlusion during hemorrhagic shock and cardiac arrest. *J Trauma.* 1997;42:1023–1028.
23. Ledgerwood AM, Kazmers M, Lucas CE. The role of thoracic aortic occlusion for massive hemoperitoneum. *J Trauma.* 1976;16:610.
24. Millikan JS, Moore EE. Outcome of resuscitation thoracotomy and descending aortic occlusion performed in the operating room. *J Trauma.* 1984;24:387–392.
25. Sankaran S, Lucas C, Walt AJ. Thoracic aortic clamping for prophylaxis against sudden cardiac arrest during laparotomy for acute massive hemoperitoneum. *J Trauma.* 1975;15:290–297.
26. Spence PA, Lust RM, Chitwood WR Jr, et al. Transfemoral balloon aortic occlusion during open cardiopulmonary resuscitation improves myocardial and cerebral blood flow. *J Surg Res.* 1990;49:217.
27. Wesley RC Jr, Morgan DB. Effect of continuous intra-aortic balloon inflation in canine open chest cardiopulmonary resuscitation. *Crit Care Med.* 1990;18:630.
28. Wiencek RG, Wilson RF. Injuries to the abdominal vascular system: how much does aggressive resuscitation and prelaparotomy thoracotomy really help? *Surgery.* 1987;102:731–736.
29. Baker CC, Thomas AN, Trunkey DD. The role of emergency room thoracotomy in trauma. *J Trauma.* 1980;20:848–855.
30. Asensio JA, Petrone P, Roldan G, et al. Analysis of 185 iliac vessel injuries: risk factors and predictors of outcome. *Arch Surg.* 2003; 138:1187–1194.
31. Cornwell EE III, Velmahos GC, Berne TV, et al. Lethal abdominal gunshot wounds at a level I trauma center: analysis of TRISS (revised trauma score and injury severity score) fallouts. *J Am Coll Surg.* 1998;187:123–129.
32. Clevenger FW, Yarbrough DR, Reines HD. Resuscitative thoracotomy: the effect of field time on outcome. *J Trauma.* 1988; 28:441–445.
33. Durham LA III, Richardson RJ, Wall MJ Jr, et al. Emergency center thoracotomy: impact of prehospital resuscitation. *J Trauma.* 1992; 32:775–779.
34. Gervin AS, Fischer RP. The importance of prompt transport in salvage of patients with penetrating heart wounds. *J Trauma.* 1982; 22:443–448.
35. Ivatury RR, Nallathambi MN, Roberge RJ, et al. Penetrating thoracic injuries: in-field stabilization vs. prompt transport. *J Trauma.* 1987; 27:1066.
36. Smith JP, Bodai BI, Hill AS, et al. Prehospital stabilization of critically injured patients: a failed concept. *J Trauma.* 1985;25:65–68.
37. Sampalis JS, Lavoie A, Williams JI, et al. Impact of on-site care, prehospital time, and level of in-hospital care of survival in severely injured patients. *J Trauma.* 1993;34:252–260.
38. Sampalis JS, Tamin H, Denis R, et al. Ineffectiveness of on-site intravenous lines: is prehospital time the culprit? *J Trauma.* 1997; 43:608–617.
39. Liberman M, Mulder D, Lavoie A, et al. Multicenter Canadian study of prehospital trauma care. *Ann Surg.* 2003;237:153–160.
40. Bard M, Ballard R, Buckman RF, Badellino M, Kiehn M, Jaslow D. Emergency department thoracotomy in abdominal exsanguination is not futile even in the presence of circulatory arrest. *Ann Emerg Med.* 2000;36(suppl):S3.

DISCUSSION

Dr. Rao R. Ivatury (Richmond, Virginia): I would like to congratulate Dr. Seamon and my other friends from Temple for a very successful series and a very well presented paper.

He and his colleagues emphasize today that emergency department thoracotomy is not futile in the resuscitation of patients with abdominal injuries, contrary to several previously published studies. The authors achieved a salvage rate of 16% in patients with abdominal exsanguination.

One surprising finding in this series is the fact that survival with thoracic injuries was not any better than with abdominal gunshot wounds. The authors don't give an explanation for this in their manuscript and I wonder if they have any thoughts today about that.

I have no problem with their conclusions. Many of us in this room will continue to employ EDT when confronted with a patient in extremis but with vital signs after a gunshot wound to the abdomen.

As they point out themselves, this is remarkable because they got their patients from a two-mile radius and most of them were brought in by police or private vehicles, approximately 50% of these patients, without any field intervention. Seven of the eight survivors belonged to this group. In fact, this is a phenomenon that we reported on a long time ago from the Bronx. Are your findings applicable to other inner-city, less dense cities or semi-rural cities with longer transit times?

Second, you give us no details of the aortic cross clamp times and its physiologic aspects. Were they unduly long in the non-survivors? In fact, you really don't talk about your failures in your manuscript at all so I wonder what went wrong with the other 42 that died. How were they different than the survivors? With your enormous experience maybe you could give us some pointers and some lessons to be learned based on these failures.

Third, do you think that your success is due to large number of iliac artery injuries that directly benefited from thoracic aortic cross clamping?

I enjoyed this very stimulating paper. I congratulate the Temple team for their pioneering efforts in the management of penetrating trauma and they are uniquely qualified to do these very difficult penetrating trauma cases with very successful results.

Dr. Juan A. Asensio (Miami, Florida): We've long documented the fact that this is a valuable procedure, albeit with very limited and strict indications. My question relates to the cardiac rhythm, it looks to me like it is the cardiac rhythm upon arrival in the emergency department that you mention. Did you document the cardiac rhythm upon opening the chest? Work by Dr. Buckman and myself have shown that this is the best predictor of outcome.

I think the absence of abdominal aortic injuries and other major vessels such as vena cava and combined vascular injuries led to improved survival. Obviously signs of life were in favor of those that survived.

Rates for survival patients sustaining exsanguinating abdominal vascular injuries range anywhere from 5–12% in some of our studies.

I'd like to continue to encourage you in doing this kind of research and would like to thank you for quoting the work of the committee that generated the guidelines for Emergency Department Thoracotomy which include colleagues like Drs. Britt, Wall, Fabian, Demetriades, Tominaga and myself and would like to encourage you to continue to try to save these patients.

Dr. Peter Rhee (Los Angeles, California): Yes, I just would like a little clarification on the 78% with abdominal wounds that had vital signs in the emergency department.

Most of the time when we do emergency department thoracotomy the patients come in to us dead with no vital signs and that's why we're forced to perform the procedure.

So regarding the 78% of the 50 patients, were they alive in the emergency room with vital signs? And then was there a problem with getting them to the operating room? Is that why the emergency room thoracotomy was performed?

Dr. Erik Streib (Indianapolis, Indiana): I think it's a little confusing to compare people with abdominal gunshot wounds to patients with thoracic injuries as your comparison group.

It seems to me you should compare people with abdominal gunshot wounds that either underwent ED thoracotomy and those that did not because one could raise the concern that you're unnecessarily delaying control of the abdominal bleeding by performing this thoracotomy and the associated morbidity.

Dr. Arthur Cooper (New York, New York): Much of the literature on resuscitative thoracotomy, as we all know, was gathered during an era when damage control of bleeding abdominal injuries was not wide-spread as it is now. I wonder if the authors could comment on the methods of bleeding control following cross clamp.

Also, I noted that the authors emphasized the role of open chest cardiac massage during the resuscitation. As we all know, the American Heart Association has recently emphasized the role of maintaining myocardial perfusion through minimal interruption of CPR under those circumstances. I wonder if the authors could comment on those points.

Dr. Mark J. Seamon (Philadelphia, Pennsylvania): Dr. Ivatury asked why survival was better in our abdominal rather than cardiac injured patients. The difference in survival between our thoracic and abdominal injured patients we presume was due to the high incidence of gunshot wounds in our cardiac patients. In the present study, 98% of this population suffered gunshot wounds while other reports from our institution revealed 90% of our ED thoracotomy patients are due to gunshot wounds. Previous authors have commented that cardiac injuries have the best EDT survival, but for cardiac gunshot wounds survival is only about 3 to 5%. Cardiac stab wounds though enjoy much better survival. Additionally, the abdominal exsanguination patients did present with better physiology than their thoracic-injured counterparts. They more often presented with signs of life and more often presented with vital signs.

Are these findings applicable to other institutions? Yes, I believe they are. I think our findings are not necessarily applicable to rural or blunt trauma patients but, yes, I definitely think these results are applicable to other busy urban trauma centers.

Now a little bit about our failures and how we could improve our outcomes. We did not analyze our aortic cross clamp times. Cross clamps were removed in the operating room and replaced on the infradiaphramatic aorta as soon as patient hemodynamics permitted. The aortic cross clamp did seem to benefit patients with iliac artery injuries.

Additionally though, 7 of 8 survivors in this study were brought by either police or private vehicle with only one survivor brought by EMS. Transportation by police or private vehicle was determined to be a strong predictor of survival through multivariate analysis. In fact, police or private vehicle transported patients were 16 times as likely to survive than their EMS-transported counterparts. We think this is because EMS is placing IV lines, intubating patients, and placing cervical collars in the field. It's actually taking too much time in the field. In the future if we could limit this delay in definitive care, I think that would be a big step forward.

Dr. Asensio asked if the cardiac rhythm was documented upon opening the chest. This rhythm was documented some, but not all of the time. The remainder of the reported cardiac rhythms were those on monitor upon entering the emergency department.

Dr. Rhee asked why 78% of patients in our series had obtainable vital signs in the emergency department and if we were spending too much time in the ED. In fact, only 42% of patients had any evidence of vital signs in the ED and all ED thoracotomies were performed within minutes of hospital arrival. Operating rooms are available to us immediately 24 hours a day, 7 days a week and there was no delay in transport.

In terms of comparing patients that underwent ED thoracotomy to those that did not after abdominal gunshot wounds, that is a great idea. We have been wrestling with the thought of a prospective evaluation for some time, but in our opinion it would be ethically impossible to randomize patients to ED thoracotomy or no thoracotomy groups. In terms of a retrospective analysis, I think we would be biasing our study if we were trying to compare those two groups, assuming that the attending trauma surgeon was performing EDT for the correct indications.

Dr. Cooper asked about open chest cardiac massage. This was performed in all patients who did not have perfusing rhythm upon opening the chest and was continued until a perfusing rhythm was regained—often requiring the help of a junior resident to provide continuous compressions.

In terms of methods of bleeding control with the aortic crossclamp, we crossclamp with a Crawford clamp, immediately distal to the pulmonary hilum. The clamp was then replaced on the abdominal aorta in the operating room. Shunts were utilized at times to temporize bleeding. Thank you very much once again for the privilege of presenting and your interesting comments and questions.