Defining the Limits of Resuscitative Emergency Department Thoracotomy: A Contemporary Western Trauma Association Perspective

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Background: Since the promulgation of emergency department (ED) thoracotomy >40 years ago, there has been an ongoing search to define when this heroic resuscitative effort is futile. In this era of health care reform, generation of accurate data is imperative for developing patient care guidelines. The purpose of this prospective multicenter study was to identify injury patterns and physiologic profiles at ED arrival that are compatible with survival.

Methods: Eighteen institutions representing the Western Trauma Association commenced enrollment in January 2003; data were collected prospectively.

Results: During the ensuing 6 years, 56 patients survived to hospital discharge. Mean age was 31.3 years (15–64 years), and 93% were male. As expected, survival was predominant in those with thoracic injuries (77%), followed by abdomen (9%), extremity (7%), neck (4%), and head (4%). The most common injury was a ventricular stab wound (30%), followed by a gunshot wound to the lung (16%); 9% of survivors sustained blunt trauma, 34% underwent prehospital cardiopulmonary resuscitation (CPR), and the presenting base deficit was >25 mequiv/L in 18%. Relevant to futile care, there were survivors of blunt torso injuries with CPR up to 9 minutes and penetrating torso wounds up to 15 minutes. Asystole was documented at ED arrival in seven patients (12%); all these patients had pericardial tamponade and three (43%) had good functional neurologic recovery at hospital discharge.

Conclusion: Resuscitative thoracotomy in the ED can be considered futile care when (a) prehospital CPR exceeds 10 minutes after blunt trauma without a response, (b) prehospital CPR exceeds 15 minutes after penetrating trauma without a response, and (c) asystole is the presenting rhythm and there is no pericardial tamponade.

Key Words: Resuscitation, Thoracotomy, ED Thoracotomy, Asystole, Prehospital CPR.

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Emergency department (ED) thoracotomy for resuscitation of the moribund patient with penetrating cardiovascular injuries was promulgated by the Ben Taub General Hospital in 1967.[1] Within a decade, the Denver General Hospital[2] and the San Francisco General Hospital[3] challenged the unbridled enthusiasm for this heroic procedure and proposed guidelines to minimize futile care. In the ensuing 30 years, there have been a myriad of studies targeted to determine the indications for resuscitative thoracotomy,[4] culminating in a number of proposed guidelines for initiation of ED thoracotomy. However, these data are largely derived from retrospective analyses of trauma registries that have not been specifically designed to evaluate the critical factors predictive of survival after ED thoracotomy. The Denver General Hospital (now Denver Health) has maintained a prospective database to examine this question since 1977, but these data reflect a single institution's experience over 33 years.[5] Consequently, we designed this Western Trauma Association (WTA) multicenter trial to examine the outcome for resuscitative thoracotomy on the basis of a contemporary experience of multiple trauma centers. Because most ground emergency medical service (EMS) services do not monitor cardiac activity in the field, the decision-making analysis is based on patient characteristics at presentation to the ED. Specifically, the study purpose was to define the limits of resuscitative thoracotomy performed in the ED to enable the development of rational guidelines to withhold or terminate resuscitative efforts. The study hypothesis is that this contemporary, multicenter WTA experience will confirm the recently published long-term single institutional findings in Denver.

METHODS

Since 1988,[6] the WTA has conducted multicenter trials, targeted at analyzing relatively infrequent injuries or controversial issues that require large study cohorts for resolution. More

recently, the findings of these collaborative studies have been exploited to develop clinical management guidelines.[7] The WTA trials are designed to address specific questions on the basis of a systematic review of the existing literature. Data forms are then generated to capture critical information to answer these questions, and the data are collected prospectively to ensure accuracy. To enhance the quality of data collection nonessential information is not requested. For example, the total number of thoracotomies performed at each institution was not requested because this information was tangential to the study object.

Many survivors of ED thoracotomy do not have a detectable pulse in the field,[4,5] and most EMS systems do not monitor prehospital cardiac rhythm**.** Consequently, the decision to perform resuscitative thoracotomy is usually based on information obtained at the time of patient arrival to the ED. The decisive factors include injury patterns and physiologic status. For the latter, the key elements are duration of prehospital cardiopulmonary resuscitation (CPR) and presenting cardiac rhythm. The precise indications for ED thoracotomy, however, remain to be defined. Thus, existing institutional policies for ED thoractomy were allowed and, in fact, it was felt to be ethically inappropriate to mandate specific indications. All participating institutions used left anterior thoractomy with selective transsternal extension if further exposure was needed. This study was approved by each trauma centers' Institutional Review Board. The data form used for this study is given in the Appendix.

RESULTS

Eighteen WTA trauma centers (Denver Health/University of Colorado Denver; San Francisco General/University of California San Francisco, Los Angeles County/University of Southern California; Medical College of Virginia; Oregon Health and Health Sciences University; East Tennessee State University; University of California San Diego; Baptist Memorial Hospital; Wake Forest University; University of Medicine and Dentistry of New Jersey; and University Medical Center/Fresno; University of North Carolina; Rhode Island Hospital/Brown University; Parkland Memorial Hospital/University of Texas Southwestern; Jackson Memorial Hospital/University of Miami; East Texas Medical Center; Shock Trauma/University of Maryland; University Medical Center/Las Vegas; and Memorial Hermann/University of Texas Houston) commenced enrollment in January 2003. During the ensuing 6 years, 56 patients survived to hospital discharge. Mean age was 31.3; the youngest is a 15-year-old female and the oldest is a 64-year-old male; 93% were male. Injury mechanism was stab wound (SW) in 30 patients (Table 1), gunshot wound (GSW) in 21 patients (Table 2), and blunt trauma in 5 patients (Table 3).

Injury Patterns

The most common injury was a SW to a ventricle (n = 17), accounting for 30% of survivors, followed by a GSW to the lung (n = 9) in 16%. Considering the study objective, however, more relevant is the five survivors (9%) after blunt trauma (Table 4). Perhaps unexpectedly, two patients were revived with isolated head trauma. It is important to recognize that both these patients deteriorated from extensive hemorrhage, one from an open blunt skull fracture and the other from SWs to the scalp. Parenthetically, the blunt trauma patient was a 23-year-old victim assaulted outside a restaurant who, despite 5 minutes of prehospital CPR, left the hospital neurologically intact. Two patients also survived with isolated neck injuries: a SW to the vertebral artery and a GSW to the internal carotid artery.

Physiologic Status—Prehospital CPR

It is noteworthy that 34% of survivors underwent prehospital CPR. Corroborating the reported duration of CPR, the mean base deficit (BD) was 23.3 mequiv/L (range, 14–32 mequiv/L) in those undergoing CPR >5 minutes. In the SW group, the duration was 2 minutes to 10 minutes; the sole survivor after 10 minutes had ventricular wounds with pericardial tamponade. In the GSW group, prehospital CPR was from 1 minute to 15 minutes. The only patient surviving with 15 minutes of CPR also had a ventricular wound with pericardial tamponade but had a moderate neurologic deficit at discharge. Moreover, this patient arrived in ventricular fibrillation and had a BD = 14 mequiv/L, suggesting that the CPR may have been initiated prematurely. In the blunt group, CPR ranged from 3 minutes to 9 minutes; the survivor with 9 minutes of CPR had an atrial rupture with pericardial tamponade.

Physiologic Status—ED Asystole

Seven patients survived with asystole at ED arrival; of these, four had a BD >25 mequiv/L. Of significance, all patients had pericardial tamponade. At the time of hospital discharge, three of these patients (43%) had functional neurologic recovery.

Neurologic Outcome

At the time of hospital discharge, 10 (18%) of the 56 ED thoracotomy survivors had moderate to severe anoxic cerebral injury, requiring transfer to a rehabilitation center. Although prehospital CPR is clearly a risk for neurologic sequelae, there was no distinct injury pattern uniformly predictive of poor recovery. Of interest, none of the blunt trauma survivors were rendered neurologic invalids.

DISCUSSION

Resuscitative thoracotomy in the ED is a resource-intense procedure that warrants accurate evidence-based guidelines for its cost effective application. There is a general consensus in the United States that documented prehospital asystole in the injured patient should be acknowledged as death,[8,9] although there are data to challenge this policy.[10] Moreover, in Europe, field resuscitative thoracotomy for thoracic SWs has been reported successful in this scenario,[11,12] and there is a documented survivor from Houston.[13] In fact, some argue in the United States that declaration of futility should be extended to those with pulseless electrical activity at the scene,[14–16] but there are compelling data to refute this recommendation.[4,5] Therefore, the decision to perform resuscitative thoracotomy in the United States is usually based on injury mechanism and duration of prehospital CPR, ascertained at the time of patient arrival to the ED.

Injury mechanism is usually the first decision point for initiating resuscitation in the ED. Recent "guidelines" by the National Association of EMS Physicians Standards and Clinical Practice Committee and the American College of Surgeons Committee on Trauma (ACSCOT) state that "emergency thoracotomy does not appear to have a role in traumatic cardiopulmonary arrest as a result of blunt trauma".[9] Furthermore, the

TABLE 1. Stab Wound Survivors: WTA Study

Age (yr)/Sex	Injuries	Tamponade	Pre-Int	Prehospital CPR	ED EKG	ED BD	Neurologic Deficit
19/M	R Vent	+	+	5	Asystole	24	Mild
40/F	R Vent	+	+		40	23	—
36/M	R Vent	+	+	8	120	22	—
17/M	R Vent	+	+	3	Asystole	14	Severe
59/M	R Vent	+	+		126	14	—
19/M	R Vent				132	16	—
22/M	R Vent	+		8	Asystole	26	Moderate
54/M	R Vent	+			120	7	—
26/M	R Vent/LAD	+	+	6	35	28	—
20/M	R + L Vent	+	+		93	8	—
19/M	R + L Vent	+	+	10	Asystole	18	—
22/M	L Vent	+		3	Asystole	35	Moderate
23/M	L Vent	+	+		40	24	—
34/M	L Vent	+		8	Asystole	32	Moderate
32/F	L Vent	+		1	40	7	—
40/M	L Vent				34	17	—
20/M	L Vent/LAD				40	22	Moderate
64/M	L atrium	+			160	15	Moderate
52/M	L atrium	+			100	24	—
18/M	SVC				140	12	—
25/M	IMA				104	14	—
64/M	IMA	+			114	14	—
22/M	Lung				70	5	Mild
26/M	Lung		+		114	18	Mild
61/M	Brachial A		+		118	18	Mild
18/M	Brachial A/liver			5	40	21	—
21/M	Axillary A		+		106	28	Mild
20/M	Femoral A			2	52		—
45/M	Vertebral A		+	5	90	12	—
40/M	Scalp				106	9	—

Pre-Int, prehospital intubation; EKG, electrocardiogram; R, right; Vent, ventricle; L, left; LAD, left anterior decending; SVC, superior vena cava; IMA, interior mammary artery; A, artery.

most recent edition of the ACSCOT advanced trauma life support manual continues to declare "patients sustaining blunt injuries who arrive pulseless but with myocardial electrical activity are not candidates for resuscitative thoracotomy".[17] But these statements are not congruent with most of the recent literature.[4,5] Our WTA multicenter data substantiate that injury mechanism alone is not a discriminator of futility. Specifically, with the exception of an overtly devastating head injury, blunt trauma does not preclude meaningful survival after ED thoracotomy.

However, duration of prehospital CPR is a reliable means to establish futility, although the precise time limit remains to be established. Our WTA study has no documented survivors of resuscitative thoracotomy for patients sustaining blunt trauma and requiring >10 minutes of prehospital CPR, and for patients with penetrating injuries undergoing >15 minutes of CPR. These data are consistent with the recent Denver analysis of outcome after prehospital CPR from a prospective database over 33 years.[5] However, a recent Seattle retrospective review of prehospital CPR indicated three survivors of penetrating wounds with times of 16 minutes, 17 minutes, and 32 minutes.[10] Specifically, the first two patients had restoration of pulses in the field, and it is not clear whether the patient with a remarkable 32 minutes of CPR underwent resuscitative thoracotomy in the ED. There is also a report from Vienna indicating four survivors of blunt trauma with CPR >10 minutes (range, 11–15 minutes), but similarly, details are lacking to discern the role of ED thoracotomy.[18]

The final potential discriminator of futility is cardiac rhythm at ED presentation. Our WTA study documented survival of seven patients with asystole found at the time of thoracotomy. But all survivors had pericardial tamponade, six from ventricular SWs and one from a blunt atrial tear. These data are also consistent with the Denver prospective study published in 2004,[5] but subsequently, this group reported a survivor of asystole with a carotid GSW,[19] and the Temple group[20] reported a survivor without tamponade.

The limitations of this study include the inability to determine whether CPR was initiated at the appropriate time. The BD data from initial sampling in the ED, however, corroborate the need for CPR, with one exception as discussed. Unfortunately, this is the reality of decision-making in the ED, until there is more advanced physiologic monitoring in the field. In addition, this experience reflects academic Level I trauma centers that may not be appropriate to extrapolate to the community hospital that is not a dedicated trauma center.

Collectively, the WTA multicenter experience suggests that resuscitative thoracotomy in the ED is unlikely to yield productive survival when patients (1) sustain blunt trauma and

TABLE 2. Gunshot Wound Survivors: WTA Study

Age (yr)/Sex	Injuries	Tamponade	Pre-Int	Prehospital CPR	ED EKG	ED BD	Neurologic Deficit
40/M	L Vent	+	+	15	V fib	14	Moderate
30/M	L Vent	+	+		100	12	—
17/M	L + R Vent		+	10	129	18	Moderate
44/M	L Vent/lung	+	+		35	15	—
19/M	L Vent/spleen	+			117	26	—
27/M	R Vent				150	7	—
40/M	Lung				86		—
17/M	Lung		+		128		—
46/M	Lung		+		120	19	—
42/M	Lung				40	19	—
20/M	Lung				139	16	—
24/M	Lung				140	19	—
52/M	Lung				116	26	—
25/M	P Hilum				50	21	—
40/F	P Hilum		+		119	26	—
24/M	Subclavian A		+		140	16	—
20/M	Subclavian A		+	1	85	15	—
31/M	Internal		+	3	35	23	Mild
15/F	A Aorta/spleen				120	30	Moderate
27/M	Liver				130	14	—
32/M	Femoral A		+		130	12	Moderate

>Pre-Int, prehospital intubation; EKG, electrocardiogram; R, right; Vent, ventricle; L, left; V fib, ventricular fibrillation; P hilum, pulmonary hilum; A aorta, abdominal aorta; A, artery; CA, carotid artery.

TABLE 3. Blunt Trauma Survivors: WTA Study

Age (yr)/Sex	Injuries	Tamponade	Pre-Int	Prehospital CPR	ED EKG	ED BD	Neurologic Deficit
20/F	Right ventricle	+			144	30	Mild
27/M	Right atrium	+	+	9	Asystole	28	—
47/M	Liver/pelvis			3	110	14	—
42/M	Mesentery				130	21	—
23/M	Open head		+	5	56	17	—

Pre-Int, prehospital intubation; EKG, electrocardiogram.

TABLE 4. ED Thoracotomy Survival: WTA Study

	Tamponade	Prehospital Intubation	Prehospital CPR	ED Asystole	ED BD >25	Neurologic Disability
Stab wound (n = 30)	17 (57)	13 (43)	12 (40)	6 (20)	5 (17)	6 (11)
Gunshot wound (n = 21)	4 (19)	11 (52)	4 (20)	—	4 (19)	4 (19)
Blunt trauma (n = 5)	2 (40)	2 (40)	3 (40)	1 (20)	2 (40)	0

Border was extended for the first column. Values are presented as n (%).

require >10 minutes of prehospital CPR without response, (2) have penetrating wounds and undergo >15 minutes of prehospital CPR without response, or (3) manifest asystole without pericardial tamponade (Table 5). However, there will invariably be exceptions to these guidelines in the recorded literature. In fact, there are reports of survivors with functional neurologic recovery exceeding these thresholds.[10,18–20] On the other hand, these data provide further evidence that the National Association of EMS Physicians and ACSCOT guidelines are excessively restrictive. Our responsibility as members of the academic trauma community is to assimilate our contemporary experience along with a critical analysis of the current literature to generate what we believe are rationale guidelines for resuscitative thoracotomy in the ED in the appropriate setting.

TABLE 5. Limits of Resuscitative Thoracotomy in the ED: WTA Study

Prehospital CPR >10 min after blunt trauma without response
Prehospital CPR >15 min after penetrating injury without response
Asystole is the presenting rhythm, and there is no pericardial tamponade

APPENDIX

WTA MULTICENTER STUDY
EMERGENCY DEPARTMENT THORACOTOMY - ANALYSIS OF SURVIVORS
(PI: Gene Moore)

Institution_____ Admit Date:_____

Age:_____ Gender_____ Race_____

Injury Mechanism: GSW_____ SGW_____ SW_____
MVA_____ MCA_____ Aped_____ Fall_____
Other_____

Injuries: Head _____ AIS_____
Neck _____ AIS_____
Chest _____ AIS_____
Abdomen _____ AIS_____
Pelvis _____ AIS_____
Extremities _____ AIS_____
ISS_____

	Time	SBP	HR	RR	EKG	CPR	Pupil	GCS
Injury	0 min							
EMS Call	min							
EMS Arrival	min							
ED Arrival	min							
ED Thoracotomy	min							
Aortic X Clamp	min							
Response to X Clamp	min							
Aortic Declamp	min							
OR Arrival	min							

Prehospital Rx

Airway: (Yes/No)	Fluids (Amount)	Drugs(List):	CPR Duration:

ED Rx

Airway: (Yes/No)	Fluids (Amount by Type)	Drugs(List):	CPR Duration:

Base Deficit on initial ABG ____ Lowest base deficit:_____ Time to correct BD:_____
Findings at ED Thoracotomy: Cardiac Rhythm_____
Pericardial Tamponade (Yes/No)_____

Operative Procedure:_____
_____
_____

Outcome: ICU LOS_____ Hospital LOS_____
Full Recovery (Yes/No)_____ Disposition_____
Surgeon:_____

Neurological Status on Discharge

GOS: (discharge)
1 death
2 persistent vegetative state
3 severe disability
4 moderate disability
5 good recovery

FIM (discharge)			
	expression	feeding	locomotion
unknown			
Total dependence			
Partial dependence			
Device dependence			
None			

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