

# An evidence-based approach to patient selection for emergency department thoracotomy: A practice management guideline from the Eastern Association for the Surgery of Trauma

Mark J. Seamon, MD, Elliott R. Haut, MD, PhD, Kyle Van Arendonk, MD, Ronald R. Barbosa, MD, William C. Chiu, MD, Christopher J. Dente, MD, Nicole Fox, MD, Randeep S. Jawa, MD, Kosar Khwaja, MD, J. Kayle Lee, MD, Louis J. Magnotti, MD, Julie A. Mayglothling, MD, Amy A. McDonald, MD, Susan Rowell, MD, MCR, Kathleen B. To, MD, Yngve Falck-Ytter, MD, and Peter Rhee, MD, MPH, Philadelphia, Pennsylvania

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<b>BACKGROUND:</b>	Within the GRADE (Grading of Recommendations Assessment, Development and Evaluation) framework, we performed a systematic review and developed evidence-based recommendations to answer the following PICO (Population, Intervention, Comparator, Outcomes) question: should patients who present pulseless after critical injuries (with and without signs of life after penetrating thoracic, extrathoracic, or blunt injuries) undergo emergency department thoracotomy (EDT) (vs. resuscitation without EDT) to improve survival and neurologically intact survival?
<b>METHODS:</b>	All patients who underwent EDT were included while those involving either prehospital resuscitative thoracotomy or operating room thoracotomy were excluded. Quantitative synthesis via meta-analysis was not possible because no comparison or control group (i.e., survival or neurologically intact survival data for similar patients who did not undergo EDT) was available for the PICO questions of interest.
<b>RESULTS:</b>	The 72 included studies provided 10,238 patients who underwent EDT. Patients presenting pulseless after penetrating thoracic injury had the most favorable EDT outcomes both with (survival, 182 [21.3%] of 853; neurologically intact survival, 53 [11.7%] of 454) and without (survival, 76 [8.3%] of 920; neurologically intact survival, 25 [3.9%] of 641) signs of life. In patients presenting pulseless after penetrating extrathoracic injury, EDT outcomes were more favorable with signs of life (survival, 25 [15.6%] of 160; neurologically intact survival, 14 [16.5%] of 85) than without (survival, 4 [2.9%] of 139; neurologically intact survival, 3 [5.0%] of 60). Outcomes after EDT in pulseless blunt injury patients were limited with signs of life (survival, 21 [4.6%] of 454; neurologically intact survival, 7 [2.4%] of 298) and dismal without signs of life (survival, 7 [0.7%] of 995; neurologically intact survival, 1 [0.1%] of 825).
<b>CONCLUSION:</b>	We strongly recommend that patients who present pulseless with signs of life after penetrating thoracic injury undergo EDT. We conditionally recommend EDT for patients who present pulseless and have absent signs of life after penetrating thoracic injury, present or absent signs of life after penetrating extrathoracic injury, or present signs of life after blunt injury. Lastly, we conditionally recommend against EDT for pulseless patients without signs of life after blunt injury. ( <i>J Trauma Acute Care Surg.</i> 2015;79: 159–173. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)
<b>LEVEL OF EVIDENCE:</b>	Systematic review/guideline, level III.
<b>KEY WORDS:</b>	Emergency department thoracotomy; resuscitative thoracotomy; practice management guideline; evidence-based medicine.

## BACKGROUND

Since its first formal description nearly 50 years ago,<sup>1</sup> emergency department thoracotomy (EDT) has remained among the most polarizing and controversial procedures that physicians perform. When treating moribund trauma victims presenting in extremis, clinicians are forced to make immediate life-or-death decisions for their patients—decisions that attempt to balance the last chance of survival<sup>2–72</sup> with the risk of salvaging patients with severe anoxic encephalopathy<sup>4,5,7,8,10,12,13,16,18,20,21,23–32,34,36,37,39–46,48,49,51–55,57,59,60,64,65,68–71,73</sup> or exposing health care providers to blood-borne pathogens.<sup>74–82</sup> Limited salvage rates<sup>2–72</sup> in conjunction with considerable potential risks<sup>4,5,7,8,10,12,13,16,18,20,21,23–32,34,36,37,39–46,48,49,51–55,57,59,60,64,65,68–71,73–82</sup> associated with EDT have been central to the controversy. These reported outcomes have led to a more discriminating focus on patients most likely to benefit from the heroic procedure while limiting unnecessary

risk. A selective approach to the performance of EDT based on the presence or absence of several predictors of survival has thus emerged.

EDT survival predictors have been well described. Often reported survival predictors include injury mechanism,<sup>2–37,39–46,48–67,70,72</sup> anatomic injury location,<sup>2,4,6,7,11,12,14,15,17–22,24–30,32,33,37,41,43,44,46,48,49,51–55,57–59,61,63,65–67</sup> and degree of physiologic derangement as indicated by the performance of prehospital closed-chest cardiopulmonary resuscitation (CPR),<sup>9,12,15,28,32,51,55,66,67</sup> presenting signs of life,<sup>2–14,18,20–22,24–26,29,31,36,37,39,40,44,49,51,53,55,57,58,63,65–67,72</sup> cardiac rhythm,<sup>10,13,15,20,28,35,53,72</sup> or vital signs.<sup>2–15,20–22,24–26,29,30,37,39,41–44,49,51–53,58,61,66</sup> Although, in reality, patients present with either the presence or the absence of each one of these survival predictors, most prior reports have focused on a single survival predictor at a time, making interpretation of the data and extrapolation to clinical practice difficult. To this end, our subcommittee of the Practice Management Guideline

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From the Division of Traumatology (M.J.S.), Surgical Critical Care and Emergency Surgery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; Division of Acute Care Surgery (E.R.H.), Department of Surgery (K.V.A.), the Johns Hopkins Hospital, Baltimore, Maryland; Trauma Services (R.R.B.), Legacy Emanuel and Randall Children's Hospitals, Portland, Oregon; R Adams Cowley Shock Trauma Center (W.C.C.), University of Maryland School of Medicine, Baltimore, Maryland; Department of Surgery (C.J.D.), Emory University and Grady Memorial Hospital, Atlanta, Georgia; Division of Trauma (N.F.), Department of Surgery, Cooper University Hospital, Camden, New Jersey; Division of Trauma, Emergency Surgery, and Surgical Critical Care (R.S.J.), Stony Brook Medicine, Stony Brook, New York; Division of Trauma and Acute Care Surgery (K.K.), McGill University Health Centre, Montreal, Quebec, Canada; Division of Trauma Surgery and Surgical Critical Care (J.K.L.), Department of Surgery, Advocate Christ Medical Center, Oak Lawn, Illinois; Department of Surgery (L.J.M.), University of Tennessee Health Science Center, Memphis, Tennessee; Departments of Emergency Medicine and Surgery (J.A.M.), Division of Trauma/Critical Care, Virginia Commonwealth University, Richmond, Virginia; Division of Trauma, Critical Care, Burns, and Acute Care Surgery (A.A.M.), Department of Surgery, Metrohealth Medical Center, Cleveland, Ohio; Division of Trauma, Critical Care and Acute Care Surgery (S.R.), Departments of Surgery and Emergency Medicine, Oregon Health and Science University, Portland, Oregon; Division of Acute Care Surgery (K.B.T.), Department of Surgery, University of Michigan Hospital, Ann Arbor, Michigan; Division of Gastroenterology (Y.F.-Y.), Case and VA Medical Center, Case Western Reserve University, Cleveland, Ohio; and Division of Trauma, Critical Care, Burn, and Emergency Surgery (P.R.), Department of Surgery, University of Arizona, Tucson, Arizona.

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Address for reprints: Mark J. Seamon, MD, Division of Traumatology, Surgical Critical Care and Emergency Surgery Department of Surgery, Hospital of the University of Pennsylvania, 51 North, 39th St, Medical Office Bldg, 1st Floor, Suite 120, Philadelphia, PA 19104; email: [mark.seamon@uphs.upenn.edu](mailto:mark.seamon@uphs.upenn.edu).

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Committee of the Eastern Association for the Surgery of Trauma (EAST) has compiled measured outcomes and evidence for the performance of EDT in patients presenting with or without multiple combinations of common survival predictors together. By analyzing patients with the presence or absence of multiple EDT survival predictors together, we hope to present a more realistic and accessible guideline to the clinician.

The primary objective of this article is to provide clear evidence-based recommendations for the physician facing the most common presenting clinical scenarios after critical injury. These recommendations are meant to provide an evidence-based framework from which clinicians can make rapid decisions regarding further resuscitation with EDT or futility. This guideline has been endorsed by EAST and uses Grading of Recommendations, Assessment, Development and Evaluations (GRADE) methodology<sup>83</sup>—a framework recently adopted by EAST.

## OBJECTIVES

The objective of this guideline was to evaluate whether EDT (vs. resuscitation without EDT) improves outcomes in patients who present to the hospital pulseless after critical injuries. Our PICO (Population, Intervention, Comparator, and Outcome) questions were as follows:

Population:

1. Patients presenting pulseless to the emergency department with signs of life after penetrating thoracic injury
2. Patients presenting pulseless to the emergency department without signs of life after penetrating thoracic injury
3. Patients presenting pulseless to the emergency department with signs of life after penetrating extrathoracic injury
4. Patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury
5. Patients presenting pulseless to the emergency department with signs of life after blunt injury
6. Patients presenting pulseless to the emergency department without signs of life after blunt injury

Intervention: EDT

Comparator: Resuscitation without EDT

Outcomes:

1. Hospital survival
2. Neurologically intact hospital survival

## INCLUSION CRITERIA FOR THIS REVIEW

### Study Types

For the purposes of making recommendations, studies included prospective observational or retrospective studies without controls and case series.

### Participant Types

All patients who underwent EDT regardless of age, sex, ethnicity, or comorbidities were included. Only studies that involved resuscitative EDT were included, whereas those involving either prehospital resuscitative thoracotomy or operating room thoracotomy were excluded from the analysis.

Meta-analyses, reviews without original data, case reports, and letters were excluded.

### Intervention Type

We included studies in which EDT was performed in the above populations with the above measured outcomes. No direct comparator population exists in the literature; therefore, baseline risk of hospital survival for patients presenting pulseless to the emergency department with each of the above conditions was estimated by the subcommittee as presented in the Evidence Profiles.

### Outcome Measure Types

Relevant outcomes including hospital survival, neurologically intact hospital survival, health care personnel exposure to blood-borne pathogens, and costs were independently rated by each individual member of the subcommittee. Only hospital survival and neurologically intact hospital survival were deemed “critical” outcomes necessary to decision making, whereas blood-borne pathogen exposure was “moderately” important and costs were of minimal importance to the group. However, we recognize that exposure is an important consideration for many clinicians when deciding whether or not to perform an EDT and a review of the topic is included in the present article for reference.

## REVIEW METHODS

### Electronic Search

A systematic search using the PubMed and Embase databases was performed using the following combination of the Medical Subject Headings (MESH) terms and related key words: thoracotomy, emergency medical services, emergency treatment, emergencies, emergency room, emergency department, emergency service, and emergency ward. We included only articles available in English. Bibliographies of included studies were also reviewed to find potential additional articles for study inclusion.

### Study Selection

Titles and abstracts from the electronic search were screened for relevance to each PICO question. Studies initially deemed relevant for inclusion then underwent full text review by the subcommittee to determine final appropriateness for inclusion.

### Data Extraction and Management

Data were extracted using a standardized Microsoft Excel spreadsheet and consisted of the study authors, location, publication year, journal, methodology, and the relevant outcome measures with respect to EDT survival predictors. All entered data were checked in triplicate to ensure accuracy.

### Assessment of Methodological Quality

The articles were evaluated using the GRADE system<sup>83</sup> and documented in each Evidence Profile figure. The quality of evidence was evaluated for each of the following domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. The strength of recommendations was based on the quality of

evidence, risk-versus-benefit ratio, and patient values/preferences and was classified as “strong” (prefaced by “strongly recommend”) or “weak” (prefaced by “conditionally recommend”).

## Measures of Treatment Effect

Data on hospital survival and neurologically intact survival after EDT were collected from the included studies. The 95% confidence intervals for these event rates were calculated using the exact mid-P method. As described, no comparison or control group (i.e., no survival or neurologically intact survival data for similar groups of patients who did not undergo EDT) was available for the PICO questions of interest and prompted thorough consultation with GRADE methodology experts. Relative effects and risk differences were then estimated by comparing the event rates with EDT with the expected probability of survival without EDT as estimated by the subcommittee. To this end, individual subcommittee members were polled to predict patient survival without EDT but with standard resuscitation including large bore access, blood product and crystalloid infusion, thoracostomy tube placement, and emergent transport to the operative suite as necessary for each PICO. One high and low outlier response was excluded for each PICO and the remaining responses used to calculate the mean estimated probability of survival without EDT. These estimates were then presented as the comparison group for each PICO. Without a control group in each constituent study, meta-analyses, assessments of heterogeneity, and confidence intervals for relative treatment effects were not calculable as a result.

## Study Definition: Signs of Life

Signs of life, often used interchangeably with vital signs, were defined for the present study as defined by American College of Surgeons Committee on Trauma in 2001.<sup>84</sup> Signs of life were considered present with any of the following: pupillary response, spontaneous ventilation, presence of carotid pulse, measureable or palpable blood pressure, extremity movement, or cardiac electrical activity.

## RESULTS

A Pubmed/Embase literature search yielded 2,152 studies of which 2,031 were removed after title and abstract review (Supplemental Digital Content 1, <http://links.lww.com/TA/A593>). The subcommittee reviewed 121 full articles of which 48 were excluded (24 operating room thoracotomy studies, 8 prehospital resuscitative thoracotomy studies, 16 studies did not address PICO questions or chosen outcomes). Ultimately, 72 studies were used in this guideline for recommendations.<sup>2-73</sup> Of the 72 included studies, 64 were retrospective,<sup>2-9,11-23,25,27-46,49-59,61-70,72</sup> 3 had both retrospective and prospective observational components,<sup>10,24,71</sup> and 5 were prospective observational in design.<sup>26,47,48,60,73</sup> Studies primarily originated from major American trauma centers (54 Level I,<sup>2,4-20,22-29,31-36,39,41-44,46-48,50,52-54,56-58,61,62,64,65,68,71,73</sup> 2 Level II<sup>3,70</sup>), but 16 studies<sup>21,30,37,38,40,45,49,51,55,59,60,63,66,67,69,72</sup> were from a variety of other countries on several continents.

The 72 included studies provided 10,238 patients who underwent EDT. Before evaluating the combinations of survival predictors for each PICO question, an analysis of each

individual EDT survival predictor alone was undertaken across all 72 studies and presented in Table 1 for reference.

## RESULTS OBTAINED FOR PICO QUESTION 1

In patients presenting pulseless to the emergency department with signs of life after penetrating thoracic injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

## Qualitative Synthesis

The combination of three EDT survival predictors—injury mechanism, anatomic injury location, and the presence of signs of life on presentation—was evaluated with respect to hospital survival and neurologic outcome. Overall, 853 patients in 32 studies<sup>2-4,6,11,14,15,18,21,22,24-26,29,31,35,38-40,42-44,49,51,52,57-59,63,65-67</sup> met these criteria, and 182 (21.3% [18.7–24.2%]) survived their hospitalization after EDT (Supplemental Digital Content 2, <http://links.lww.com/TA/A594>; Fig. 1). As the subcommittee

TABLE 1. Single Survival Predictor Analysis

	No. Studies	Hospital Survival	% (95% CI)
<b>Injury mechanism</b>			
Penetrating injury	64	674/6,390	10.6 (9.8–11.3)
% Penetrating EDT survivors neuro intact	35	282/312	90.4 (86.7–93.3)
Gun shot wounds	44	213/2,966	7.2 (6.3–8.2)
Stab wounds	44	302/1,907	15.8 (14.3–17.5)
Blunt injury	42	50/2,172	2.3 (1.7–3.0)
% Blunt EDT survivors neuro intact	8	19/32	59.4 (41.9–75.2)
<b>Primary injury location</b>			
Cardiac	24	250/1,449	17.3 (15.4–19.3)
Thoracic	27	222/2,117	10.5 (9.2–11.9)
Abdominal	22	60/856	7.0 (5.4–8.9)
Neck/extremity	8	9/128	7.0 (3.5–12.5)
<b>Physiologic predictors</b>			
<b>Prehospital CPR</b>			
Yes	9	22/425	5.2 (3.4–7.6)
No	8	41/301	13.6 (10.1–17.9)
<b>ED signs of life</b>			
Yes	35	290/1,523	19.0 (17.1–21.1)
No	33	62/2,166	2.9 (2.2–3.6)
<b>ED cardiac rhythm</b>			
Asystole	8	10/382	2.6 (1.4–4.6)
Pulseless electrical activity	3	17/152	11.2 (6.9–17.0)
Sinus	3	21/63	33.3 (22.6–45.6)
Other	5	4/83	4.8 (1.6–11.2)
<b>ED vital signs</b>			
Yes	25	241/1,382	17.4 (15.5–19.5)
No	35	135/3,516	3.8 (3.2–4.5)
<b>Overall</b>			
EDT hospital survival	71	871/10,238	8.5 (8.0–9.1)
EDT neuro intact hospital survival	47	408/6,746	6.1 (5.5–6.6)
% EDT survivors neuro intact	45	466/544	85.7 (82.5–88.4)

All described predictors of EDT were each individually analyzed across all studies.



QUESTION 1: Should Patients Who Present Pulseless to the Emergency Department: with SIGNS OF LIFE <sup>1</sup> after PENETRATING THORACIC INJURY Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
853 (32 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	2.8% <sup>2</sup>	182/853 (21.3% pooled, 95% CI: 18.7%, 24.2%)	RR 7.6 <sup>3</sup>	28 survivors per 1000 <sup>2</sup>	185 more survivors per 1000 (from 156 to 215 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
454 (16 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	2.5% <sup>4</sup>	53/454 (11.7% pooled, 95% CI: 9.0%, 15.0%)	RR 4.7 <sup>3</sup>	25 survivors per 1000 <sup>4</sup>	92 more survivors per 1000 (from 61 to 123 more)

**Figure 1.** EDT for patients who present pulseless with signs of life after penetrating thoracic injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Baseline risk of hospital survival for patients presenting pulseless with ED signs of life after penetrating thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 2.8% (range, 2–5%). <sup>3</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>4</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless with ED signs of life after penetrating thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 2.8% x 90% (90% of penetrating EDT survivors are neurologically intact) = 2.5%.

estimated hospital survival without EDT in this population to be 2.8% (range, 2–5%), patients presenting pulseless to the emergency department with signs of life after penetrating thoracic injury were nearly eight times (relative risk [RR], 7.6) more likely to survive their hospitalization after EDT than without EDT by group estimates. Neurologic outcome after EDT in this population was reported in 16 studies<sup>4,18,21,24–26,31,39,40,43,44,49,52,57,59,65</sup> involving 454 patients. Of these, 53 patients (11.7% [9.0–15.0%]) survived EDT neurologically intact, whereas the subcommittee estimated hospital survival without EDT in this population to be 2.5% (2.8% x 90% [90% of penetrating EDT survivors are neurologically intact]). When compared with the estimated neurologically intact survival of patients resuscitated without EDT, patients who underwent EDT were nearly five times (RR, 4.7) more likely to survive neurologically intact.

## DISCUSSION

An analysis of all available evidence revealed that EDT improves both survival and neurologically intact survival in patients presenting pulseless to the emergency department with signs of life after penetrating thoracic injury.

Injury mechanism is a well-recognized predictor of survival after EDT. Although those who sustain penetrating injuries clearly have more favorable outcomes than those who sustain blunt injuries (Table 1),<sup>2–37,39–46,48–67,70,72</sup> the specific type of penetrating injuries also impacts EDT survival.<sup>2–7,10–14,17–27,29,31,32,35–37,39,41,42,44,46,48,49,51–55,57,63,65–67,72</sup> Branney et al.<sup>41</sup> reported their 23-year experience with EDT in 1998, revealing

that 14.6% survived EDT after cardiac stab wounds whereas only 1.8% survived after cardiac gunshot wounds. In a contemporary series evaluating 283 patients sustaining penetrating cardiac or great vessel injuries,<sup>57</sup> this author determined that 24% survived EDT after stab wounds as compared with 3% surviving gunshot wounds. Although few would argue that single cardiac stab wounds are the injury associated with the best EDT survival, other physiologic survival predictors such as the presence or absence of signs of life are also essential to predict EDT outcomes.

## RECOMMENDATION

Despite moderate overall quality of evidence (Fig. 1) for both critical outcomes, subcommittee panelists believed that patients would strongly favor undergoing EDT in this clinical scenario because of the substantial improvements in both survival and neurologically intact survival over patients resuscitated without EDT. For these reasons, a strong recommendation was made, implying that most patients would want the recommended course of action and only a small proportion would not.

### Recommendation

In patients presenting pulseless to the emergency department with signs of life after penetrating thoracic injury, we strongly recommend that patients undergo EDT. This recommendation is based on moderate quality of evidence and places emphasis on patient preference for improved survival and neurologically intact survival after EDT.

## RESULTS OBTAINED FOR PICO QUESTION 2

In patients presenting pulseless to the emergency department without signs of life after penetrating thoracic injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

### Qualitative Synthesis

Hospital survival and neurologic outcome were evaluated with respect to injury mechanism and anatomic injury location in patients without signs of life on presentation. Of 920 patients in 32 studies,<sup>2-4,7,11,14,15,18-22,24-26,29,31,35,38,39,42-44,49,51,52,57-59,65-67</sup> 76 (8.3% [6.6-10.2%]) survived their hospitalization (Supplemental Digital Content 3, <http://links.lww.com/TA/A595>; Fig. 2). As the subcommittee estimated hospital survival without EDT in this population to be 0.2% (range, 0-2%), patients presenting pulseless to the emergency department without signs of life after penetrating thoracic injury were 41 times (RR, 41.3) more likely to survive their hospitalization after EDT than without EDT. Neurologic outcome after EDT in this population was reported in 16 studies involving 641 patients.<sup>4,7,18,21,24-26,31,39,43,44,49,52,57,59,65</sup> Of these, 25 patients (3.9% [2.6-5.6%]) survived EDT neurologically intact, whereas the subcommittee estimated hospital survival without EDT in this population to be 0.18% (0.2% × 90% [90% of penetrating EDT survivors are neurologically intact]). When compared with the estimated neurologically intact survival of these patients resuscitated without EDT,

patients who underwent EDT were nearly 20 times (RR, 19.5) more likely to survive neurologically intact.

### DISCUSSION

Complete review of available data revealed that EDT improves both survival and neurologically intact survival in patients presenting pulseless to the emergency department with absent signs of life after penetrating thoracic injury. In the three largest series during the past 20 years,<sup>39,52,57</sup> 0 of 80, 3 of 79, and 5 of 107 (3 of 107 neurologically intact) survived their hospitalization after EDT when presenting without signs of life after a penetrating thoracic wound.

Not only is the presence or absence of signs of life important, but the duration without signs of life is also vital to the decision-making process. Once again, accurate nomenclature is essential because this phenomenon has been labeled arrest time, CPR time, duration of absent vital signs, and duration of absent signs of life. Adding to the interpretation difficulties, these reported elapsed times are often reliant on Emergency Medical Services (EMS) documentation—documentation that occurs retrospectively based on EMS estimates after the termination of a resuscitation. In the 2012 joint position statement of the NAEMSP-ACSCOT (National Association EMS Physicians—American College of Surgeons Committee on Trauma), “Withholding and Termination of Resuscitation of Adult Cardiopulmonary Arrest Secondary to Trauma,” Millin et al.<sup>85</sup> states that “protocols should require a specific interval

QUESTION 2: Should Patients Who Present Pulseless to the Emergency Department: <u>without</u> SIGNS OF LIFE <sup>1</sup> after PENETRATING THORACIC INJURY Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
920 (32 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	0.2% <sup>2</sup>	76/920 (8.3% pooled, 95% CI: 6.6%, 10.2%)	RR 41.3 <sup>3</sup>	2 survivors per 1000 <sup>2</sup>	81 more survivors per 1000 (from 63 to 99 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
641 (16 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	0.18% <sup>4</sup>	25/641 (3.9% pooled, 95% CI: 2.6%, 5.6%)	RR 19.5 <sup>3</sup>	2 survivors per 1000 <sup>4</sup>	37 more survivors per 1000 (from 24 to 54 more)

**Figure 2.** EDT for patients who present pulseless without signs of life after penetrating thoracic injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Baseline risk of hospital survival for patients presenting pulseless without ED signs of life after penetrating thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 0.2% (range, 0-2%). <sup>3</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>4</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless without ED signs of life after penetrating thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 0.2% × 90% (90% of penetrating EDT survivors are neurologically intact) = 0.18%.

of CPR that accompanies other resuscitative interventions. Past guidance has indicated that up to 15 minutes of CPR should be provided before resuscitative efforts are terminated, but the science in this regard remains unclear.” For these reasons, exact durations of traumatic cardiopulmonary arrest have been removed from the recent position statement.<sup>85,86</sup>

Although we recognize the importance of the duration without a perfusing rhythm in patients who have sustained a traumatic cardiopulmonary arrest, the above current evidence limitations prevent its incorporation into our evidence-based guidelines. Clearly, patients who require prehospital CPR before EDT survive less often than those who do not (Table 1).<sup>9,12,15,28,32,51,55,66,67</sup> After careful analysis of all available pertinent data and its shortcomings though, we are unable to offer any alteration to the commonly held dictum: EDT is likely futile after 15 minutes of arrest time after penetrating injury. Furthermore, both survival and neurologically intact survival are rare after more than 15 minutes of CPR regardless of injury mechanism or anatomic location.<sup>85,86</sup>

## RECOMMENDATION

Despite moderate overall quality of evidence for both critical outcomes (Fig. 2), subcommittee panelists believed that a majority of patients would favor undergoing EDT in this clinical scenario because of the improvements in both survival and neurologically intact survival over patients resuscitated without EDT. We recognize that the duration of time without signs of life is a vital component to the decision-making process, but an evidentiary basis for exact length of arrest times is extremely limited. For these reasons, a conditional recommendation is made, implying that, although most patients would want the recommended course of action, others would not.

### Recommendation

In patients presenting pulseless to the emergency department without signs of life after penetrating thoracic injury, we conditionally recommend that patients undergo EDT. This recommendation is based on moderate quality of evidence and places emphasis on patient preference for improved survival and neurologically intact survival after EDT but also acknowledges that elapsed time without signs of life is an important component.

## RESULTS OBTAINED FOR PICO QUESTION 3

In patients presenting pulseless to the emergency department with signs of life after penetrating extrathoracic injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

### Qualitative Synthesis

The combination of three EDT survival predictors—injury mechanism, anatomic injury location, and the presence of signs of life on presentation—was evaluated with respect to hospital survival and neurologic outcome. Overall, 160 patients in 11 studies<sup>2–4,6,15,24,26,29,43,49,54</sup> met these criteria, and 25 (15.6% [10.6–21.9%]) survived their hospitalization after EDT in this group (Supplemental Digital Content 4, <http://links.lww.com/TA/A596>; Fig. 3). As the subcommittee

estimated hospital survival without EDT in this population to be 1.7% (range, 1–5%), patients presenting pulseless to the emergency department with signs of life after penetrating extrathoracic injury were nine times (RR, 9.2) more likely to survive their hospitalization after EDT than without EDT. Neurologic outcome after EDT in this population was reported in six studies involving 85 patients.<sup>4,24,26,43,49,54</sup> Of these, 14 patients (16.5% [9.7–25.5%]) survived EDT neurologically intact, whereas the subcommittee estimated hospital survival without EDT to be 1.5% (1.7% × 90% [90% of penetrating EDT survivors are neurologically intact]) in this population. When compared with the estimated neurologically intact survival of these patients resuscitated without EDT, patients who underwent EDT were 11 times (RR, 11.0) more likely to survive neurologically intact.

## DISCUSSION

Analysis reveals that EDT improves both hospital survival and neurologically intact hospital survival in patients presenting pulseless to the emergency department with signs of life after penetrating extrathoracic injury. The present study did not include patients with isolated cranial injuries nor did it consider organ preservation for transplantation as a measured outcome. Our penetrating extrathoracic data included neck, abdominal, and extremity injuries and were grouped together both to provide adequate sample size and to simplify the clinician’s decision-making algorithm. Importantly though, all extrathoracic injury sites likely do not have equivalent salvage rates after EDT. Recent data do suggest a role for EDT after penetrating abdominal, neck, or extremity injury however. This author reviewed 50 consecutive patients who underwent EDT for abdominal exsanguination.<sup>54</sup> Of 39 patients who presented with signs of life after penetrating abdominal injury, 7 survived their hospitalization, all neurologically intact. Sheppard et al.<sup>48</sup> reported outcomes after EDT for penetrating nontorso injuries. Of 27 patients, 3 survived (2 neck, 1 extremity) of which 1 had a poor neurologic outcome. These data suggest that EDT is another potentially useful maneuver in the physician’s armamentarium when confronted with an exsanguinating extrathoracic wound.

## RECOMMENDATION

Despite moderate overall quality of evidence for both critical outcomes (Fig. 3), subcommittee panelists believed that a majority of patients would favor undergoing EDT in this clinical scenario because of the improvements in both survival and neurologically intact survival over patients resuscitated without EDT. We recognize that all extrathoracic injury locations such as the neck, abdomen, and extremities may not have equivalent salvage rates after EDT. For these reasons, a conditional recommendation is made.

### Recommendation

In patients presenting pulseless to the emergency department with signs of life after penetrating extrathoracic injury, we conditionally recommend that patients undergo EDT. This recommendation does not pertain to patients with isolated cranial injuries. This recommendation is based on moderate quality of evidence and places emphasis on patient preference

QUESTION 3: Should Patients Who Present Pulseless to the Emergency Department: with SIGNS OF LIFE <sup>1</sup> after PENETRATING EXTRA-THORACIC INJURY <sup>2</sup> Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
160 (11 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	1.7% <sup>3</sup>	25/160 (15.6% pooled, 95% CI: 10.6%, 21.9%)	RR 9.2 <sup>4</sup>	17 survivors per 1000 <sup>3</sup>	139 more survivors per 1000 (from 82 to 196 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
85 (6 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊕ MODERATE due to large effect	1.5% <sup>5</sup>	14/85 (16.5% pooled, 95% CI: 9.7%, 25.5%)	RR 11.0 <sup>4</sup>	15 survivors per 1000 <sup>5</sup>	150 more survivors per 1000 (from 71 to 229 more)

**Figure 3.** EDT for patients who present pulseless with signs of life after penetrating extrathoracic injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Patients with isolated cranial injuries were excluded from analysis. <sup>3</sup>Baseline risk of hospital survival for patients presenting pulseless with ED signs of life after penetrating extra-thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 1.7% (range, 1–5%). <sup>4</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>5</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless with ED signs of life after penetrating extra-thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 1.7% x 90% (90% of penetrating EDT survivors are neurologically intact) = 1.5%.

for improved survival and neurologically intact survival after EDT but also acknowledges that penetrating injuries to all extrathoracic anatomic areas will not have equivalent salvage rates after EDT.

### RESULTS OBTAINED FOR PICO QUESTION 4

In patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

#### Qualitative Synthesis

The combination of three EDT survival predictors—injury mechanism, anatomic injury location, and the absence of signs of life upon presentation—was evaluated with respect to hospital survival and neurologic outcome. Overall, 139 patients in eight studies<sup>2,4,15,19,24,26,29,54</sup> met these criteria, and four (2.9% [0.9–6.8%]) survived their hospitalization after EDT in this group (Supplemental Digital Content 5, <http://links.lww.com/TA/A597>; Fig. 4). Compared with an estimated hospital survival of 0.1% (range, 0–1%) without EDT in this population, patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury were nearly 29 times (RR, 28.8) more likely to survive their hospitalization after EDT than without EDT.

Neurologic outcome after EDT in this population was reported in four studies<sup>4,24,26,54</sup> involving 60 patients. Of these,

three patients (5.0% [1.3–13.0%]) survived EDT neurologically intact. As the baseline neurologically intact survival for patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury is unreported in prior literature, the subcommittee estimated hospital survival without EDT in this population to be 0.09% (0.1% x 90% [90% of penetrating EDT survivors are neurologically intact]). When compared with the estimated neurologically intact survival of these patients resuscitated without EDT, patients who underwent EDT were nearly 56 times (RR, 55.7) more likely to survive neurologically intact.

#### DISCUSSION

Data suggest a role for EDT in patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury. We recognize that evidence is limited regarding this clinical scenario. Eight cohort studies without controls or case series contributed data—each with less than 40 patients contributed and either 0 or 1 survivor per study.<sup>2,4,15,19,24,26,29,54</sup> These sample size limitations then in turn create less reliable RR survival calculations.

Importantly, the limitations reflect not only a difference in outcomes when compared with thoracic injuries but also hesitation of the practitioner to perform the procedure under these circumstances. Of the several functions of EDT (relieve pericardial tamponade, temporize thoracic bleeding, open-chest cardiac massage, maximize cerebral and coronary blood flow while limiting infradiaphragmatic exsanguination, prevention of



QUESTION 4: Should Patients Who Present Pulseless to the Emergency Department: <b>without SIGNS OF LIFE<sup>1</sup></b> after <b>PENETRATING EXTRA-THORACIC INJURY<sup>2</sup></b> Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
139 (8 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	serious risk of imprecision	undetected	⊕⊕⊕⊖ LOW	0.1% <sup>3</sup>	4/139 (2.9% pooled, 95% CI: 0.9%, 6.8%)	RR 28.8 <sup>4</sup>	1 survivor per 1000 <sup>3</sup>	28 more survivors per 1000 (from 0 to 56 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
60 (4 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	serious risk of imprecision	undetected	⊕⊕⊕⊖ LOW	0.09% <sup>5</sup>	3/60 (5.0% pooled, 95% CI: 1.3%, 13.0%)	RR 55.7 <sup>4</sup>	1 survivor per 1000 <sup>5</sup>	49 more survivors per 1000 (from 0 to 104 more)

**Figure 4.** EDT for patients who present pulseless without signs of life after penetrating extrathoracic injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Patients with isolated cranial injuries were excluded from analysis. <sup>3</sup>Baseline risk of hospital survival for patients presenting pulseless without ED signs of life after penetrating extra-thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 0.1% (range, 0–1%). <sup>4</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>5</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless without ED signs of life after penetrating extra-thoracic injury was unavailable. The guideline group estimated hospital survival without EDT at 0.1% x 90% (90% of penetrating EDT survivors are neurologically intact) = 0.09%.

air embolism), open-chest cardiac massage, and placement of a descending thoracic aortic cross clamp may offer an improved, albeit small, chance of survival for these critically injured patients.

### RECOMMENDATION

Although all voting members of the subcommittee sought a conditional recommendation, 11 members voted in favor of EDT and 4 voted against the procedure based on the PICO No. 4 Evidence Profile. Group disagreement and low quality of evidence for both critical outcomes (Fig. 4) led to a conditional recommendation.

#### Recommendation

In patients presenting pulseless to the emergency department without signs of life after penetrating extrathoracic injury, we conditionally recommend that patients undergo EDT. This recommendation does not pertain to patients with isolated cranial injuries and is based on low quality of evidence. The majority of subcommittee members believed that most patients would prefer undergoing EDT in hopes of improved survival and neurologically intact survival.

### RESULTS OBTAINED FOR PICO QUESTION 5

In patients presenting pulseless to the emergency department with signs of life after blunt injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

### Qualitative Synthesis

The combination of two EDT survival predictors—*injury mechanism and the presence of signs of life on presentation*—was evaluated with respect to hospital survival and neurologic outcome. Overall, 454 patients in 22 studies<sup>2,4,6,8–10,24,26,29,31–33,35,36,41,43,51,58,63,65–67</sup> met these criteria, and 21 (4.6% [3.0–6.9%]) survived their hospitalization after EDT (Supplemental Digital Content 6, <http://links.lww.com/TA/A598>; Fig. 5). When compared with a subcommittee estimated hospital survival of 0.5% (range, 0–3%) without EDT in this population, patients presenting pulseless to the emergency department with signs of life after blunt injury were nine times (RR, 9.3) more likely to survive their hospitalization after EDT than without EDT. Neurologic outcome after EDT in this population was reported in 10 studies<sup>4,10,24,26,31,32,36,41,43,65</sup> involving 298 patients. Of these, seven patients (2.4% [1.0–4.6%]) survived EDT neurologically intact. As the subcommittee estimated hospital survival without EDT in this population to be 0.3% (0.5% x 60% [60% of blunt EDT survivors are neurologically intact]) when compared with the estimated neurologically intact survival of these patients resuscitated without EDT, patients who underwent EDT were nearly eight times (RR, 7.8) more likely to survive neurologically intact.

### DISCUSSION

In patients presenting pulseless to the emergency department with signs of life after blunt injury, EDT improves both hospital survival and neurologically intact hospital. Pointing

QUESTION 5: Should Patients Who Present Pulseless to the Emergency Department: with SIGNS OF LIFE <sup>1</sup> after BLUNT INJURY Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
454 (22 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊖ MODERATE due to large effect	0.5% <sup>2</sup>	21/454 (4.6% pooled, 95% CI: 3.0%, 6.9%)	RR 9.3 <sup>3</sup>	5 survivors per 1000 <sup>2</sup>	41 more survivors per 1000 (from 22 to 61 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
298 (10 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	no serious imprecision	undetected	⊕⊕⊕⊖ MODERATE due to large effect	0.3% <sup>4</sup>	7/298 (2.4% pooled, 95% CI: 1.0%, 4.6%)	RR 7.8 <sup>3</sup>	3 survivors per 1000 <sup>4</sup>	21 more survivors per 1000 (from 3 to 38 more)

**Figure 5.** EDT for patients who present pulseless with signs of life after blunt injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Baseline risk of hospital survival for patients presenting pulseless with ED signs of life after blunt injury was unavailable. The guideline group estimated hospital survival without EDT at 0.5% (range, 0–3%). <sup>3</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>4</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless with ED signs of life after blunt injury was unavailable. The guideline group estimated hospital survival without EDT at 0.5% × 60% (60% of blunt EDT survivors are neurologically intact) = 0.3%.

to the importance of EDT survival predictors, EDT salvage rates after blunt injury have been unfavorable. Rhee et al.<sup>87</sup> compiled 25 years of EDT literature in a 2000 meta-analysis, revealing that 1.4% of blunt injury patients survived EDT. As in our evidence table (Table 6; see Supplemental Digital Content 6, <http://links.lww.com/TA/A598>), many series contributed no survivors despite the presence of signs of life on presentation. Importantly, both hospital survival rates and neurologic outcome are poor after EDT for blunt injury. Although 90% of EDT survivors after penetrating injury survive neurologically intact,<sup>4,7,10,12,13,16,18,21,23–28,30–32,34,36,39–41,43,44,46,48,49,52–54,57,59,60,64,65</sup> only 59% of blunt EDT survivors are neurologically intact (Table 1).<sup>10,23,24,26,28,41,45,60</sup> This association may reflect the absence of wounds to rapidly temporize in blunt trauma victims or concomitant traumatic brain injury in multi-injured blunt trauma patients. Thus, not only are patients less likely to survive after EDT for blunt injury but also, when they do survive, blunt injury patients are more likely to be neurologically impaired.

## RECOMMENDATION

With a moderate overall quality of evidence for both critical outcomes (Fig. 5), subcommittee panelists believed that most patients would favor undergoing EDT in this clinical scenario because of the improvements in both survival and neurologically intact survival over patients resuscitated without EDT. However, the subcommittee recognizes that many patients would not want to undergo EDT after blunt injury

because of the possibility of concomitant severe traumatic brain injury and poor neurologic outcome in survivors.

## Recommendation

In patients presenting pulseless to the emergency department with signs of life after blunt injury, we conditionally recommend that patients undergo EDT. This recommendation is based on moderate quality of evidence and places emphasis on patient preference for improved survival and neurologically intact survival after EDT.

## RESULTS OBTAINED FOR PICO QUESTION 6

In patients presenting pulseless to the emergency department without signs of life after blunt injury (P), does EDT versus resuscitation without EDT (C) improve hospital survival and neurologically intact hospital survival (O)?

## Qualitative Synthesis

The combination of two EDT survival predictors—*injury mechanism and the presence of signs of life on presentation*—was evaluated with respect to hospital survival and neurologic outcome. Overall, 995 patients in 24 studies<sup>2–4,8–10,19,20,24–26,29,31–33,35,36,41,43,51,63,65–67</sup> met these criteria, and seven (0.7% [0.3–1.4%]) survived their hospitalization after EDT in this group (Supplemental Digital Content 7, <http://links.lww.com/TA/A599>; Fig. 6). As the subcommittee estimated hospital survival without EDT in this population to be 0.001% (range, 0–0.01%), despite limited survival after EDT, patients presenting pulseless to the emergency

QUESTION 6: Should Patients Who Present Pulseless to the Emergency Department: <u>without</u> SIGNS OF LIFE <sup>1</sup> after BLUNT INJURY Undergo Emergency Department Thoracotomy versus No Emergency Department Thoracotomy?											
Quality Assessment							Summary of Findings				
Participants (studies)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Quality of Evidence	Study Event Rates (%)			Anticipated Absolute Effects	
							Without EDT	With EDT	Relative Effect	Risk without EDT	Risk Difference with EDT (95% CI)
<b>Hospital Survival (CRITICAL OUTCOME)</b>											
995 (24 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	serious risk of imprecision	undetected	⊕⊕⊕⊖ LOW	0.001% <sup>2</sup>	7/995 (0.7% pooled, 95% CI: 0.3%, 1.4%)	RR 704 <sup>3</sup>	0 survivors per 1000 <sup>2</sup>	7 more survivors per 1000 (from 2 to 12 more)
<b>Neurologically Intact Hospital Survival (CRITICAL OUTCOME)</b>											
825 (11 cohort studies without controls)	serious risk of bias	no serious inconsistency	no serious indirectness	serious risk of imprecision	undetected	⊕⊕⊕⊖ LOW	0.0006% <sup>4</sup>	1/825 (0.1% pooled, 95% CI: <0.01%, 0.6%)	RR 202 <sup>3</sup>	0 survivors per 1000 <sup>4</sup>	1 more survivors per 1000 (from 0 to 4 more)

**Figure 6.** EDT for patients who present pulseless without signs of life after blunt injury, evidence profile. <sup>1</sup>Signs of life were defined as the presence of any of the following: spontaneous respirations, palpable pulse, measureable blood pressure, spontaneous movement, cardiac electrical activity, or pupillary reactivity. <sup>2</sup>Baseline risk of hospital survival for patients presenting pulseless without ED signs of life after blunt injury was unavailable. The guideline group estimated hospital survival without EDT at 0.001% (range, 0–0.01%). <sup>3</sup>Relative risk of estimates based on comparison of observed intervention effect compared to estimated baseline risk. <sup>4</sup>Baseline risk of neurologically intact hospital survival for patients presenting pulseless without ED signs of life after blunt injury was unavailable. The guideline group estimated hospital survival without EDT at 0.001% x 60% (60% of blunt EDT survivors are neurologically intact) = 0.0006%.

department without signs of life after blunt injury were more likely (RR, 704) to survive their hospitalization after EDT than without EDT.

Neurologic outcome after EDT in this population was reported in 11 studies<sup>4,10,24–26,31,32,36,41,43,65</sup> involving 825 patients. Of these, only one patient (0.1% [ $<0.01$ –0.6%]) survived EDT neurologically intact. When compared with the estimated neurologically intact survival of 0.0006% (0.001% x 60% [60% of blunt EDT survivors are neurologically intact]) without EDT, patients who underwent EDT were more likely (RR, 202) to survive neurologically intact.

## DISCUSSION

In patients presenting pulseless to the emergency department without signs of life after blunt injury, EDT did not improve either hospital survival or neurologically intact hospital survival. Although survival was universally poor in this group, outcomes were yet more dismal when neurologic outcomes were considered. Of seven hospital survivors, only one survived neurologically intact. Overall, a single patient of 825 who underwent EDT for blunt injury without signs of life survived without neurologic impairment.<sup>4,10,24–26,31,32,36,41,43,65</sup> For these reasons, this subcommittee recommends against the performance of EDT in this clinical situation. Highlighting the importance of both injury mechanism and the physiologic signs of life, clinicians should be equipped to make rapid evidence-based life-or-death decisions using this framework.

## RECOMMENDATION

Although subcommittee members unanimously voted against the performance of EDT based on the PICO No. 6 Evidence Profile, 10 members voted for a “strong” recommendation and 5 voted for a “conditional” recommendation. Group disagreement regarding the recommendation strength and low quality of evidence for both critical outcomes (Fig. 6) led to a conditional recommendation. Subcommittee panelists believed that a majority of patients would not favor undergoing EDT in this clinical scenario because of the dismal survival and likelihood of poor neurologic outcome.

### Recommendation

In patients presenting pulseless to the emergency department without signs of life after blunt injury, we conditionally recommend against the performance of EDT. This recommendation is based on low quality of evidence and reflects subcommittee group disagreement regarding the strength of the unanimous recommendation against EDT.

### ANOTHER IMPORTANT OUTCOME: BLOOD-BORNE PATHOGEN EXPOSURE

Although GRADE recommendations are formulated from the perspective of the patient,<sup>83</sup> another important consideration for many when deciding to perform EDT is the possibility of exposure to blood-borne pathogens. Both the human immunodeficiency virus (HIV) and hepatitis prevalence

rates of patients who undergo EDT and the occupational exposure rates of health care personnel during EDT are unknown at present. The prevalence of HIV and hepatitis in other trauma populations, including penetrating trauma victims, has been well documented. Since 1990, eight reports<sup>74–77,79–82</sup> have assessed the prevalence of blood-borne pathogens in trauma victims (Supplemental Digital Content 8, <http://links.lww.com/TA/A600>), of which four studies<sup>74,77,80,82</sup> have prospectively tested for all serum markers (anti-HIV, HBsAg, anti-hepatitis C virus [anti-HCV]). Contrary to assumptions, HIV and hepatitis prevalence rates are greater in blunt (HIV, 3.7% [2.6–5.2%]; hepatitis B virus [HBV], NA; HCV, 12.3% [10.4–14.5%]) than penetrating (HIV, 1.9% [1.1–3.3%]; HBV, 0.6% [0.2–2.1%]; HCV, 9.9% [8–12.2%]) trauma victims.<sup>74–77,79–82</sup> Regardless, when needlestick or cut exposure transmission rates (HIV, 0.3%; HBV, 6–30%; HCV, 1.8% [0–7%]) from known seropositive blood are considered, it is imperative that universal precautions are maintained for all resuscitations.<sup>78</sup>

### Future Investigation

Several prior and ongoing studies show promise for the resuscitation of critically injured future trauma victims. The use of cardiac ultrasound in the pulseless trauma patient has been described,<sup>88,89</sup> but its role in the EDT decision-making algorithm awaits further study. Several small case series from European countries have reported outcomes after prehospital thoracotomy.<sup>90</sup> Although survival is appreciable in these series, importantly, their prehospital care differs from that of the United States in that physicians are part of the prehospital care team.

The REBOA (resuscitative endovascular balloon occlusion of the aorta) is a technique described several decades ago that now, with improved technology and greater emphasis on endovascular therapies, has shown potential as an adjunct for the critically injured patient with hemorrhagic shock.<sup>91,92</sup> The

technique offers some EDT benefits (maximizing cerebral and coronary perfusion while limiting infradiaphragmatic hemorrhage) without the invasiveness of a thoracotomy. A comparison of EDT and REBOA outcomes is warranted, and the exact indications for balloon occlusion await elucidation.

Lastly, a multi-institutional, prospective, nonrandomized, parallel assignment trial (ClinicalTrials.gov identifier NCT01042015) entitled “Emergency Preservation and Resuscitation for Cardiac Arrest From Trauma (EPR-CAT)” is currently recruiting participants.<sup>93</sup> This study compares pulseless penetrating trauma victims with scene signs of life who undergo standard resuscitative efforts including EDT with similar patients who undergo EDT along with insertion of an arterial catheter into the descending thoracic aorta to rapidly induce hypothermia followed by resuscitative surgery and cardiopulmonary bypass. The goal of the investigators is to improve both hospital survival and neurologically intact survival in these patients.

### USING THESE GUIDELINES IN CLINICAL PRACTICE

These guidelines represent a very detailed summary of the literature regarding EDT after six common clinical presentation scenarios. The vast majority of studies used within these guidelines are from major urban Trauma Centers—as such, their data and the resulting recommendations may not be applicable to community or rural centers. The guidelines are intended to inform the decision-making process rather than replace clinical judgment.

### CONCLUSIONS

In summary, we have provided six evidence-based recommendations using GRADE methodology (Fig. 7) and several

Question	Recommendation
PICO #1	In patients who present pulseless to the Emergency Department <u>with signs of life</u> after <u>penetrating thoracic injury</u> , we <b>strongly recommend</b> resuscitative Emergency Department thoracotomy. <b>Strong Recommendation</b>
PICO #2	In patients who present pulseless to the Emergency Department <u>without signs of life</u> after <u>penetrating thoracic injury</u> , we <b>conditionally recommend</b> resuscitative Emergency Department thoracotomy. <b>Conditional Recommendation</b>
PICO #3	In patients who present pulseless to the Emergency Department <u>with signs of life</u> after <u>penetrating extra-thoracic injury</u> , we <b>conditionally recommend</b> resuscitative Emergency Department thoracotomy. <b>Conditional Recommendation</b>
PICO #4	In patients who present pulseless to the Emergency Department <u>without signs of life</u> after <u>penetrating extra-thoracic injury</u> , we <b>conditionally recommend</b> resuscitative Emergency Department thoracotomy. <sup>1</sup> <b>Conditional Recommendation</b>
PICO #5	In patients who present pulseless to the Emergency Department <u>with signs of life</u> after <u>blunt injury</u> , we <b>conditionally recommend</b> resuscitative Emergency Department thoracotomy. <b>Conditional Recommendation</b>
PICO #6	In patients who present pulseless to the Emergency Department <u>without signs of life</u> after <u>blunt injury</u> , we <b>conditionally recommend against</b> resuscitative Emergency Department thoracotomy. <sup>2</sup> <b>Conditional Recommendation</b>

**Figure 7.** Final recommendations. <sup>1</sup>Group voting for a recommendation was mixed. While all voted for a “conditional” recommendation, 11 members voted in favor of Emergency Department Thoracotomy and 4 voted against the procedure based on the PICO #4 Evidence Profile. <sup>2</sup>Group voting for a recommendation was mixed. While all voted against the performance of Emergency Department Thoracotomy based on the PICO #6 Evidence Profile, 10 members voted for a “strong” recommendation and 5 voted for a “conditional” recommendation.



well-described EDT survival predictors. First, we strongly recommend that patients who present pulseless but with signs of life after penetrating thoracic injury undergo EDT. Second, we conditionally recommend EDT for patients who present pulseless and absent signs of life after penetrating thoracic injury. Third, we conditionally recommend EDT for patients who present pulseless but with signs of life after penetrating extrathoracic injury. Fourth, we conditionally recommend EDT for patients who present pulseless and absent signs of life after penetrating extrathoracic injury. Fifth, we conditionally recommend EDT for patients who present pulseless but with signs of life after blunt injury. Lastly, we conditionally recommend against the performance of EDT for patients who present pulseless with absent signs of life after blunt injury.

#### AUTHORSHIP

M.J.S. contributed to the study design, literature review, data acquisition, analysis and interpretation of data, and manuscript drafting. E.R.H., R.R.B., W.C.C., C.J.D., N.F., R.S.J., K.K., J.K.L., L.J.M., J.A.M., A.A.M., S.R., and K.B.T. contributed to the study design, literature review, data acquisition, analysis and interpretation of data, and manuscript critique. K.V.A. contributed to the analysis and interpretation of data and manuscript critique. Y.F.-Y. and P.R. contributed to the study design, analysis and interpretation of data, and manuscript critique.

#### DISCLOSURE

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