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Original Contributions

RIGHT PLACE AT THE RIGHT TIME: THORACOTOMIES AT LEVEL I TRAUMA CENTERS HAVE ASSOCIATED IMPROVED SURVIVAL

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☐ **Abstract—Background: Early thoracotomy (ET) is a procedure performed on patients in extremis. Identifying factors associated with ET survival may allow for optimization of guidelines and improved patient selection. Objectives: The objective of this study was to assess whether ETs performed at Level I trauma centers (TC) are associated with improved survival. Methods: This was a retrospective study utilizing the National Trauma Databank 2014–2015. We included all thoracotomies performed within 1 h of hospital arrival. Patients were stratified according to TC designation level. Patient demographics, outcomes, and center characteristics were compared. We conducted multivariable regression with survival as the outcome. Results: There were 3183 ETs included in this study; 2131 (66.9%) were performed at Level I TCs. Patients treated at Level I and non-Level I TCs had similar median injury severity scores, as well as signs of life and systolic blood pressures on admission. Patients treated at Level I TCs had significantly higher survival rates (21.6% vs. 16.3%, $p < 0.001$), with 40% greater odds of survival after controlling for injury-specific factors and emergency medical services transportation time (adjusted odds ratio 1.40, 95% confidence interval 1.04–1.89, $p = 0.03$). Penetrating injuries had 23.1% survival after ET vs. 12.9% for blunt injuries (adjusted odds ratio 1.86, 95% confidence interval 1.37–2.53, $p < 0.001$). Conclusions: ETs performed at Level I TCs were associated with 40% greater odds of survival compared with ETs at non-Level I TCs. This demonstrates that factors extrinsic to the patient may play a role in survival of severely injured patients.**

☐ **Keywords—trauma; early thoracotomy; emergency department thoracotomy; level I trauma center**

INTRODUCTION

Early thoracotomy is a potentially life-saving procedure performed on patients presenting to the emergency department (ED) in extremis. Early thoracotomy (ET), defined as a thoracotomy performed within 1 h of hospital arrival, allows surgeons to rapidly evacuate pericardial tamponade, cross clamp the descending aorta, control bleeding from the heart, lungs, or associated vessels, and perform an internal cardiac massage (1,2). However, its use has been subject to controversy due to poor outcomes and potential risks that accompany the procedure (3,4). Indiscriminate ET also results in considerable financial and resource burdens with dismal salvage rates, making appropriate use of this intervention an area of interest (5,6). As such, studies have analyzed various factors that predict ET survival to optimize guidelines and improve patient selection.

Identifying elements that affect ET outcomes is essential in improving patient selection guidelines for the appropriate application of this life-saving intervention.

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Many ET survival predictors that are patient based have already been identified. In a systematic review performed by Seamon et al. (7), evidence-based recommendations were made based on injury mechanism and anatomic location, as well as vitals and signs of life on admission. As is traditionally reported, penetrating mechanisms and thoracic injuries had improved outcomes vs. blunt and extrathoracic injuries (7–9). Rhee et al. (9) found similar results in a review of published data over a span of 25 years reporting that mechanism of injury, location of major injury, and signs of life influenced ET outcomes. A prospective study performed by Moore et al. (10) that sought to define limits for resuscitation by ET found similar results, which also included increased futility for patients with prolonged cardiopulmonary resuscitation prior to arrival and asystole without pericardial tamponade. Age was found not to influence ET mortality in patients presenting in extremis (11).

Most previous emergency thoracotomy research, including the aforementioned studies, have only analyzed thoracotomies performed in the ED. However, a significant proportion of emergent thoracotomies are performed in the operating room (OR). As some hospitals now have OR equipment set up in the ED for emergency surgeries such as ET, this distinction between ED and OR thoracotomy has become increasingly blurred (12,13). In this study, all thoracotomies performed within 1 h of hospital admission were analyzed, whether they were performed in the ED or operating room.

The objective of this study was to analyze the National Trauma Databank to assess the impact of Level I trauma centers (TCs) on ET survival. It has been previously shown that care provided in Level I TCs significantly lowers risks of death in patients between the ages of 18 and 84 years with moderate-to-severe injury when compared with hospitals without a TC (14). Further, improved outcomes were reported in American College of Surgeons (ACS) Level I TC designation compared with Level II in severely injured patients (15). Considering the documented impact of Level I TCs on survival, we hypothesized that ETs performed in Level I TCs would be associated with improved survival rates.

METHODS

Data Sources and Designs

Data for this study were obtained from the National Trauma Databank (NTDB) from the years 2014 and 2015. The NTDB is the largest U.S. trauma registry and contains over 800,000 annual cases with valid trauma diagnoses, making it ideal for studying rare procedures like ET. The database contains information related to demographics, injury mechanism, emergency medical services (EMS) transportation, admission physiologic data, diagnoses, injury severity, procedures, and outcomes. The NTDB is a de-identified registry. The New York University School of Medicine Institutional Review Board determined that this study was exempt from review.

We queried the NTDB for all patients who received an exploratory thoracotomy utilizing the International Classification of Diseases, Ninth Revision procedure code 34.02. Thoracotomies were considered to be ETs if they occurred within the first hour of admission. This 1-h cutoff has been used in previous research investigating early thoracotomies utilizing the NTDB, and was selected because a substantial number (50%) of NTDB thoracotomy procedure times were rounded up to the nearest hour (1). This cutoff maximized this study's sample size while still including only the most emergent thoracotomies. We excluded thoracotomy cases missing data on the time of procedure or discharge disposition.

We stratified hospitals by TC designation. TC designation is a process determined at the state level and is based on hospital resources available as well as the number of patients admitted annually. TC designation is not to be confused with ACS TC verification level. "Requirements for state designation are typically based on the ACS guidelines, however, some requirements—including frequency and structure of site visits—may differ by state" (16). Although ACS verification criterion are standardized nationally, hospital verification is a voluntary and potentially resource-intensive process (16). As a result, many hospitals have TC designation, but not ACS verification. In our sample of early thoracotomies, 3008 cases (94.3%) occurred at state-designated TCs, but only 1855 (58.2%) were at ACS-verified hospitals. Recent national research has demonstrated that ACS-verified and state-designed Level I TCs have similar rates of overall survival (16,17). Due to this and the large proportion of missing data, we used TC designation instead of ACS verification level to stratify hospitals, despite the potential for regional differences in classification criterion.

We additionally stratified hospitals by teaching status and hospital volume. Teaching status was a variable available in the NTDB, and hospital volume was calculated based on annual thoracotomies performed. Hospitals were considered to be high-volume centers if they performed four or more thoracotomies per year (the mean annual thoracotomy rate of hospitals in our study), whereas hospitals that performed fewer than four thoracotomies annually were considered to be low-volume centers.

Analyses

We performed descriptive analysis of patients undergoing early thoracotomies, stratified by TC designation. *t*-Tests

and chi-squared analyses were used to assess for significant differences. We used Mann-Whitney-Wilcoxon tests to compare injury severity scores because these were not normally distributed. Survival rates were calculated based on patient demographics, injury mechanism, injury severity, admission physiologic data, and hospital characteristics. We performed univariable and multivariable regression to determine factors significantly associated with survival. A p value < 0.05 was used as the threshold for statistical significance. All analyses were conducted using R version 3.0.

RESULTS

From 2014 to 2015, 3183 ETs were performed in the NTDB and included in this study. The median age of patients undergoing ET was 30 years (interquartile range [IQR] 23–44), and the majority were male (2710, 85.2%; Table 1). There were 1351 (44.4%) black non-Hispanic, 998 (32.8%) white non-Hispanic, and 563 (18.5%) Hispanic patients. There were 2131 (66.9%) thoracotomies performed at Level I TCs. Patients undergoing ET were most frequently injured by firearms (1693, 53.2%), followed by stab wounds (494, 15.5%) and motor vehicle crashes (418, 13.1%, Table 2). The median injury severity score (ISS) was 25 (IQR 16–38). On admission, 2086 (66.5%) patients had signs of life (defined as having one or more of the following: organized electrocardiogram activity, pupillary responses, spontaneous respiratory attempts or movement, or unassisted blood pressure) and 1503 (52.7%) had a measurable (nonzero) systolic blood pressure (SBP). Average EMS time from dispatch to hospital arrival was 28 min (IQR = 22–37).

Demographic and injury characteristics were compared between patients who received their thoracotomies at Level I and lower-tier TCs (Table 1). On average, patients at Level I TCs were more likely to be black non-Hispanic (47.1% vs. 38.8%, $p < 0.001$) males (86.1% vs. 83.3%, $p = 0.04$), and were less likely to have a Glasgow Coma Scale score (GCS) ≤ 8 on admission (75.3% vs. 80.6%, $p < 0.001$). Patients at Level I TCs had significantly longer EMS transport times in minutes (median 29, IQR 22–42), compared with those at non-Level I TCs (median 28, IQR 22–37, $p < 0.001$). Patients at Level I and non-Level I TCs did not differ significantly in terms of ISS, chest Abbreviated Injury Scale score, signs of life on admission, or SBP on admission.

Overall ET survival was 19.8% (95% confidence interval [CI] 18.5–21.3%), with ETs performed at Level I TCs having significantly higher survival rates (21.6%, 95% CI 19.9–23.4%) than thoracotomies at non-Level I TCs (16.3%, 95% CI 14.1–18.6%, $p < 0.001$). Survival comparisons by mechanism of injury revealed that stab wounds had the highest ET survival (43.7%, 95% CI 39.3–48.2%), followed by gunshot wounds (17.0%, 95% CI 15.2–18.8%). Overall survival after blunt injuries was 12.9% (95% CI 10.8–15.1%), but varied considerably by specific mechanism of injury due to small sample sizes (Table 2). The majority of survivors were discharged home (53.2%), followed by discharge to inpatient rehab facilities (14.6%), home with health aid assistance (7.5%), and skilled nursing facilities (5.0%). Discharge dispositions for survivors were not significantly different between Level I and non-Level I TCs ($p = 0.13$).

In multivariable regression controlling for age, race and ethnicity, ISS, injury mechanism, signs of life, SBP, GCS, teaching hospital status, hospital thoracotomy volume, and EMS transport time, ETs performed at Level I TCs were associated with significantly improved survival (adjusted odds ratio [AOR] 1.40, 95% CI 1.04–1.89,

Table 1. Patients Characteristics at Level I and Non-level I Trauma Centers

Variable	Level I Trauma Center n = 2131 (66.9%)	Non-level I Trauma Center n = 1052 (33.1%)	p-Value
Age (y): median, IQR	30, 23–44	30, 23–45	0.15
Male (%)	86.1%	83.3%	0.04*
ISS: median, IQR	25, 16–38	25, 16–36	0.11
AIS chest ≥ 3 (%)	77.0%	74.0%	0.79
Signs of life on admission (%)	66.5%	63.6%	0.11
SBP on admission = 0 (%)	46.0%	49.9%	0.052
GCS ≤ 8 on admission (%)	75.3%	80.6%	0.001*
EMS dispatch to hospital arrival (minutes): median, IQR	29, 22–42	28, 22–37	< 0.001*
Race			< 0.001*
Black non-Hispanic	47.1%	38.8%	
White non-Hispanic	31.2%	36.1%	
Hispanic	17.9%	19.7%	
Other non-Hispanic	3.9%	5.4%	

y = years; IQR = interquartile range; ISS = injury severity score; AIS = Abbreviated Injury Scale score; SBP = systolic blood pressure; GCS = Glasgow Coma Scale score; EMS = emergency medical services.
* Indicates a statistically significant difference.

Table 2. Survival by Mechanism of Injury

	Proportion of Injuries		Survival		
Mechanism of Injury	Number	Percentage	Number	Percentage	95% CI
All thoracotomies	3183	100%	631	19.8%	18.5–21.3%
Penetrating	2165	68.0%	500	23.1%	21.3–24.9%
Gunshot wound	1693	53.2%	287	17.0%	15.2–18.8%
Stab wound	494	15.5%	216	43.7%	39.3–48.2%
Blunt	996	31.3%	128	12.9%	10.8–15.1%
Motor vehicle crash	418	13.1%	46	11.0%	8.2–14.4%
Pedestrian	194	6.1%	17	8.8%	5.2–13.7%
Motorcycle	158	5.0%	10	6.3%	3.1–11.3%
Fall	81	2.5%	15	18.5%	10.8–28.7%
Cyclist	35	1.1%	6	17.1%	6.6–33.6%
Other blunt	132	4.2%	37	28.0%	20.6–36.5%

CI = confidence interval.

$p = 0.03$; Table 3) Other factors associated with increased survival included white non-Hispanic race (AOR 1.36, 95% CI 1.01–1.84, $p = 0.04$), penetrating injuries (AOR 1.86, 95% CI 1.37–2.53, $p < 0.001$), stab injuries (AOR 3.82, 95% CI 2.84–5.17, $p < 0.001$), and signs of life on hospital arrival (AOR 3.51, 95% CI 2.13–6.01, $p < 0.001$). Factors associated with worse outcomes were higher ISS (ISS > 15, AOR 0.60, 95% CI 0.46–0.78, $p < 0.001$), no SBP on admission (AOR 0.13, 95% CI 0.08–0.21 $p < 0.001$), and low GCS (GCS < 9, AOR 0.21, 95% CI 0.17–0.27, $p < 0.001$). Hospital teaching status, hospital volume, and EMS transport time were not significantly associated with thoracotomy survival.

DISCUSSION

ET is a potentially lifesaving procedure, but its use remains controversial. Our results demonstrate that ETs performed at Level I TCs are associated with improved survival. The increased survival associated with Level I TCs is not surprising. Several previous studies have demonstrated that Level I TCs are associated with improved survival for patients with severe injuries (14,15). These benefits may be the result of Level I TCs having greater access to resources and health care providers more familiar with managing severe injuries.

To the best of our knowledge, this is the first study to report that intrinsic TC characteristics are associated with improved ET survival. We were able to find one previous study that investigated the impact of TC designation on ET survival in the NTDB but did not find a statistically significant survival benefit (1). However, the results of this study were trending toward a Level I TC survival benefit and narrowly missed the threshold for statistical significance (OR 0.4, 95% CI 0.1–1.0, $p = 0.051$). It is possible that if that study had used a larger sample size (similar to this present study), the authors would have found a significant difference.

The survival benefit of Level I TCs has meaningful implications for EMS and other services making patient transport decisions. In this study we found that patients who received their thoracotomies at Level I TCs had 40% greater odds of survival after controlling for injury-specific factors and EMS transport time. Future research is warranted to determine if taking extra time to travel to Level I TCs could still result in improved survival. If this were demonstrated, EMS protocols for patients in extremis could be revised to further prioritize transport to Level I TCs.

Table 3. Factors Associated With Survival on Multivariable Logistic Regression

Variable	Adjusted OR (95% CI)	*p*-Value
Level I trauma center	1.40 (1.04–1.89)	0.03*
Age ≥ 30	0.83 (0.66–1.05)	0.12
Race (ref: black non-Hispanic)		
White non-Hispanic	1.36 (1.01–1.84)	0.04*
Hispanic	1.06 (0.75–1.47)	0.76
ISS ≥ 15	0.60 (0.46–0.78)	< 0.001*
Penetrating injury	1.86 (1.37–2.53)	< 0.001*
Stab wound	3.82 (2.84–5.17)	< 0.001*
Signs of life on admission	3.51 (2.13–6.01)	< 0.001*
SBP on admission = 0	0.13 (0.08–0.21)	< 0.001*
GCS < 9	0.21 (0.17–0.27)	< 0.001*
Teaching hospital	0.86 (0.66–1.13)	0.29
High ET volume center	1.22 (0.92–1.62)	0.16
EMS Time from dispatch to hospital arrival (ref: 1–10 min)		
11–20 min	0.57 (0.16–2.30)	0.40
21–30 min	0.48 (0.14–1.92)	0.27
31–40 min	0.53 (0.15–2.16)	0.35
41–50 min	0.80 (0.22–3.35)	0.75
51–60 min	0.77 (0.20–3.29)	0.71

OR = odds ratio; CI = confidence interval; ET = early thoracotomy; ISS = injury severity score; SBP = systolic blood pressure GCS = Glasgow Coma Scale score; ET = early thoracotomy; EMS = emergency medical services.
Multivariable odds ratios adjusted for trauma center designation, age, race, ISS, injury mechanism, signs of life on admission, measurable SBP on admission, GCS, teaching hospital status, hospital volume, and EMS time from dispatch to hospital arrival.
* Indicates a statistically significant association.

Our overall ET survival rate of 19.8% is substantially higher than what is reported in most emergency thoracotomy studies. This is, in part, because this study included thoracotomies performed in both the ED and the operating room, whereas most previous ET research has included only patients who received thoracotomies in the ED.

Limitations

This study is subject to a number of limitations. Thoracotomies were identified in the NTDB using the International Classification of Diseases, Ninth Revision procedure code 34.02. Although we believe this captured the majority of early thoracotomies in the NTDB, it is possible that exploratory thoracotomies could be coded using alternate procedure codes and that our survival results would have been altered if these thoracotomies had been included. Detailed information regarding the NTDB's methods of national data collection and coding can be found in ACS NTDB National Trauma Data Standard (18).

There are also some limitations inherent to conducting a study with the NTDB. The NTDB is a dataset collected from voluntary reporting from TCs, and the vast majority of these data is collected from Level I TCs. This may mean our study does not accurately estimate survival at non-Level I TCs. In particular, voluntary datasets such as the NTDB are subject to a reporting bias and may over-represent centers that allocate more resources to aggregating and reporting data.

Although we were able to control for EMS transport time in this study, we recognize that EMS transport decisions may be an unmeasured confounding factor that could influence outcomes. For example, EMS may elect to rapidly transport a severely injured patient with cardiovascular collapse to the nearest hospital, rather than taking additional time to travel to a Level I TC. If more severely injured patients were less likely to make it to Level I TCs, this bias in transport decision-making could potentially influence hospital survival rates. However, because our multivariable survival analysis controlled for multiple metrics of injury severity and cardiorespiratory status, we believe that such biases, if they in fact do exist, would be unlikely to be responsible for the observed difference in survival.

Unfortunately, the NTDB does not have data on indications for ET. In this study we assumed that exploratory thoracotomies performed within 1 h of admission were performed for patients in extremis, but it is possible there were other indications as well. Although the large proportion of patients having no systolic blood pressure on admission does indicate that many of our patients were in extremis, it would have been helpful to control for specific indications as well as injury patterns and locations in our analyses.

Previous research has found that patients at non-Level I TCs are, on average, older and more likely to have injuries from blunt mechanisms, both of which could conceivably contribute to a survival disparity (19,20). However, this study's multivariable regression analyses accounted for age and injury mechanism along with several other injury-related factors, so it is unlikely that our results are due to any confounding variable.

Lastly, we recognize that the data used in this study, being a few years old, may not accurately reflect current practice patterns. With increasing utilization of resuscitative endovascular balloon occlusion of the aorta, it is possible that ET practice patterns have changed to some extent, now that there is a less invasive resuscitative technique available. The ACS takes multiple years to prepare and code national trauma data for release in the NTDB, and when this study was first conceived, 2014–2015 were the latest years available for request. Nonetheless, we believe our data accurately identify factors associated with survival in contemporary ET.

CONCLUSIONS

Our study demonstrates that ETs performed at Level I TCs are associated with 40% greater odds of survival. This demonstrates that factors extrinsic to the patient may play a role in the survival of severely injured patients.

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ARTICLE SUMMARY

1. Why is this topic important?

Early thoracotomy (ET) is a potentially life-saving procedure for patients presenting in extremis, but indiscriminate ET results in considerable financial and resource burdens with dismal salvage rates. Identifying elements that affect ET outcomes is essential in improving patient selection guidelines.

2. What does this study attempt to show?

The objective of this study was to determine factors associated with improved ET survival, and, in particular, if ET performed at Level I trauma centers (TCs) is associated with improved survival.

3. What are the key findings?

This study demonstrates early thoracotomies performed at Level I TCs are associated with 40% greater odds of survival. This demonstrates that factors extrinsic to the patient may play a role in survival of severely injured patients.

4. How is patient care impacted?

The survival benefit of Level I TCs has meaningful implications for EMS and other services making patient transport decisions. Future research is warranted to determine if taking extra time to travel to Level I TCs could still result in improved survival.