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Mortality after emergency department thoracotomy for pediatric blunt trauma: Analysis of the National Trauma Data Bank 2007–2012☆,☆☆,★

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ABSTRACT

Purpose: The purpose of this study was to determine the proportion of children who survived after emergency department thoracotomy (EDT) for blunt trauma using a national database.
Methods: A review of the National Trauma Data Bank was performed for years 2007–2012 to identify children <18 years of age who underwent EDT for blunt trauma.
Results: Eighty-four children <18 years of age underwent EDT after blunt trauma. Every child died during their hospitalization. The median age was 15 (IQR 6–17) years. Mean injury severity score (ISS) was 34.2 (SD 20.8), and 56% had an ISS of 26–75. Data for "signs of life" were available for 21 children. Fifteen (71%) had signs of life upon ED arrival. Sixty percent of children died in the ED. Of those who survived to the operating room (OR), 66% died in the OR. Four children (5%) survived more than 24 hours in the intensive care unit, three of whom had a maximum head abbreviated injury score of 5.
Conclusion: There were no survivors after EDT for blunt trauma in the pediatric population in this national dataset. Usual indicators for EDT after blunt trauma in adults may not apply in children, and use should be discouraged without compelling evidence of a reversible cause of *extremis*.

Emergency department thoracotomy (EDT) is a potentially lifesaving procedure, particularly for patients with penetrating cardiac injury and signs of life on presentation to the emergency department (ED) [1,2]. Survival after EDT in adults is 8.8–11.2% for penetrating injury and between 1.4 and 1.6% for blunt injury [2,3]. The indications for and predictors of survival after EDT following blunt trauma in children have not been well defined. However, given the survival benefit of EDT in the adult population, the American College of Surgeons Committee on Trauma has recommended application of adult EDT guidelines to children despite a paucity of evidence on outcomes [2].

The literature on pediatric EDT for blunt trauma consists of small single-institution series with an average sample size of 16 (range 7–47) [4–10]. Only two reports documented survival after EDT for blunt trauma in the pediatric population, both prior to 1990 [8,11]. Recent studies have used the National Trauma Data Bank (NTDB) to evaluate early thoracotomy among pediatric populations [12,13]. While adding to the literature on overall management of the pediatric patient *in extremis* after blunt trauma, the subanalyses completed for thoracotomy intervention were not stratified by location of procedure, limiting their contribution to the data on thoracotomy in the ED setting. This distinction is important as studies of adults have shown that early thoracotomy in the operating room (OR) for patients in extremis had substantially higher survival compared to those that occurred in the ED, highlighting the differences in the physiologic status between the two patient populations [14–16].

This study aimed to evaluate survival in children undergoing EDT for blunt trauma using a multiinstitutional dataset to inform practice guidelines. By doing so, the results might influence clinical decision-making around the utility and timing of pediatric EDT after blunt injury.

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★ Level of Evidence: IV (Case Series).

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1. Methods

1.1. Study design and study population

A retrospective review of the National Trauma Data Bank (NTDB) Research Dataset (RDS) from 2007 to 2012 was completed. All patients who sustained blunt trauma aged younger than 18 years who underwent *exploratory thoracotomy*, defined by International Classification of Disease-9th revision Clinical Modification (ICD-9-CM) procedure code 34.02, were identified. Blunt trauma was defined by ICD-9-CM primary external cause of injury codes (E-codes) as outlined by the Centers for Disease Control and Prevention [17]. For primary E-codes "Other/Unspecified," ascertainment of blunt trauma as the primary mechanism of injury was captured by three-author (KF, BS, FR) review of the patient's ICD-9-CM diagnosis and procedure codes in their entirety. Emergency department thoracotomy (EDT) was defined as an exploratory thoracotomy with a start time that preceded ED discharge time (including death).

1.2. Outcome and predictors of survival

The primary outcome was inhospital mortality. Secondary outcomes included survival to OR, survival to intensive care unit (ICU), and length of stay in the ICU. Variables extracted included demographic characteristics (e.g. sex, age, race, ethnicity, insurance status), injury characteristics (e.g. Injury Severity Score (ISS), maximum Abbreviated Injury Scale (AIS) scores), and physiologic data from the scene of injury and upon arrival to the ED (e.g. vital signs, Glasgow Coma Scale (GSC) score, signs of life (SOL)). "Signs of life" were defined by the NTDB as organized EKG activity, pupillary responses, spontaneous respiratory attempts or movement, or unassisted blood pressure [18]. Age-adjusted tachycardia was defined in accordance with the American College of Surgeons Advanced Trauma Life Support manual [19]. Age-adjusted hypotension was defined as a systolic blood pressure ≤70 mmHg + (2 × age in years) based on Pediatric Advanced Life Support protocol. [20]

1.3. Statistical analysis

Descriptive statistics and frequency distributions were performed for all variables of interest. Missing data were presented owing to concern for missing not at random. Means and standard deviations (SD) were presented for variables normally distributed. Medians and interquartile ranges (IQR) were presented for variables not normally distributed. Bivariate and multivariable logistic regression were planned *a priori* to determine predictors of survival to hospital discharge. Post-hoc regression analyses were completed to identify predictors for survival to the OR and to the ICU. Analyses were completed with Stata v12 (College Station, TX). The study was declared nonhuman subject research by the University of Washington Institutional Review Board.

2. Results

Exploratory thoracotomy for blunt trauma was performed for 307 children between 2007 and 2012. Of those, 84 (27%) occurred in the ED and 173 (56%) in the OR. Fifty (16%) children were missing data on procedure timing; thus, we were unable to determine location of thoracotomy. Only children with documented EDT were included in analyses.

EDT was performed at 57 facilities with no more than two performed at any one institution per year and no overall trend over time. Demographic and injury characteristics of children who underwent EDT are presented in Table 1. The median time from emergency medical services (EMS) dispatch to scene of injury and to ED arrival was 8.5 (IQR 5–15) and 37 (IQR 24.5–57) minutes, respectively. Median time in the ED (i.e., from arrival to discharge or death) was 36.5 minutes (IQR 20–67).

Table 1
Demographic and injury characteristics of children who underwent emergency department thoracotomy after blunt trauma from the National Trauma Data Bank, 2007–2012 (n = 84).[a]

Demographic characteristics	n	%
Sex		
Male	55	65.5
Female	27	32.1
Missing	2	2.4
Age, median years (IQR)	15	6–17
Race/ethnicity		
White	47	56.0
Black	10	11.9
Hispanic	19	22.6
Other	4	4.8
Missing	4	4.8
Insurance		
Commercial/private	23	27.4
Medicaid/Medicare/governmental	15	17.9
Self-pay	20	23.8
Other	10	11.9
Not applicable/not billed	3	3.6
Missing	13	15.5
Injury characteristics		
Injury Severity Score (ISS)		
ISS 1–15	15	17.9
ISS 16–25	12	14.3
ISS 26–75	47	56.0
Missing	10	11.9
ISS, mean (SD)[b]	34.2	20.8
Maximum head Abbreviated Injury Scale (AIS) score		
≤3	7	8.3
4	10	11.9
≥5	16	19.0
Missing	51	60.7
Maximum head AIS, mean (SD)	4.1	1.3
Maximum thoracic AIS Score		
≤3	44	52.3
4	7	8.3
≥5	8	9.5
Missing	25	29.8
Maximum thoracic AIS, mean (SD)	3.5	1.1
Maximum abdominal AIS score		
≤3	15	17.9
4	11	13.1
≥5	5	6.0
Missing	53	63.1
Maximum abdominal AIS, mean (SD)	3.2	1.3

[a] Row sample size and column proportions presented unless otherwise noted.
[b] SD, standard deviation.

Injury scene and ED arrival physiologic data are presented in Tables 2 and 3, respectively. Available scene data indicated 18 (21%) of patients were pulseless, 23 (27%) had no ascertainable blood pressure, and 22 (26%) were apneic. In aggregate, 68 (81%) had at least one documented vital sign and/or a GCS greater than 3 in the field. Upon arrival to the ED, 37 (44%) patients were pulseless, 38 (45%) had no blood pressure, and 49 (58%) were apneic. Median GCS as recorded upon ED arrival was 3 (IQR 3–3). Fifty-two patients (62%) had GCS qualifier information available (i.e. sedated, paralyzed, intubated, eye obstruction); 42 (81%) where intubated, sedated, and/or paralyzed. Among the 10 remaining patients, eight had an unparalyzed and nonsedated motor GCS of 1 upon arrival to the ED, and two did not have a motor component score recorded. Overall, 48 (57%) had at least one documented vital sign and/or GCS greater than 3 upon ED arrival.

Signs of life as an independent variable were recorded in the NTDB only for 2011 and 2012 admissions (n = 21 children). Of these, 6 children (27%) did not have SOL upon arrival, all of whom expired in the ED. Among the 15 children who presented with signs of life, 9 (60%) expired in the ED, 3 (20%) in the OR, and 3 (20%) in the ICU. For 63 children, the NTDB-provided "signs of life" variable was missing (n = 1)

Table 2
Scene physiologic status at emergency medical services arrival of children who underwent emergency department thoracotomy after blunt trauma.[a,b]

	n	%
Pulse		
Pulseless (pulse = 0)	18	21.4
Age-adjusted tachycardia (n = 45)[c,d]	25	55.6
Mean (SD) if pulse >0 (n = 45)[c]	107.0	38.5
Missing	21	25.0
Systolic blood pressure (SBP)		
No blood pressure (SBP = 0)	23	27.4
Age-adjusted hypotension (n = 27)[c,e]	12	44.4
Mean (SD) if SBP >0 (n = 27)[c]	105.9	36.7
Missing	34	40.5
Respiratory rate (RR)		
Apneic (RR = 0)	22	26.2
Mean (SD) if RR >0 (n = 39)[c]	16.6	10.3
Missing	23	27.4
Glasgow Coma Scale (GCS)		
GCS 3	43	51.2
GCS 4–8	10	11.9
GCS 9–12	5	6.0
GCS 13–15	8	9.5
Missing	18	21.4
Median (IQR) (n = 66)[c]	3	3–6
Median (IQR) motor GCS score (n = 65)[c]	1	1–2

[a] National Trauma Data Bank, 2007–2012.
[b] Row sample size and column proportions presented unless otherwise noted.
[c] Calculated for nonmissing values.
[d] Age-adjusted tachycardia defined by the American College of Surgeons Advanced Trauma Life Support, 7th edition, appropriate age-specific vital signs in patients with an ascertainable pulse.
[e] Age-adjusted hypotension defined by systolic blood pressure ≤70 + (2 × age in years) in patients with an ascertainable blood pressure.

Table 3
Initial emergency department physiologic status of children who underwent emergency department thoracotomy after blunt trauma.[a,b]

	n	%
Pulse		
Pulseless (pulse = 0)	37	44.1
Age-adjusted tachycardia (n = 41)[c,d]	23	56.1
Mean (SD) if pulse >0 (n = 41)[c]	107.8	39.7
Missing	6	7
Systolic blood pressure (SBP)		
No blood pressure (SBP = 0)	38	45.2
Age-adjusted hypotension (n = 40)[c,e]	20	50.0
Mean (SD) if SBP >0 (n = 40)[c]	102.8	34.8
Missing	6	7.1
Respiratory status		
Apneic (RR = 0)	49	58.3
Mean (SD) if RR >0 (n = 25)[c]	23.9	14.0
Missing	10	11.9
Signs of life (years 2011 and 2012 only; n = 22)		
Yes	15	68.2
No	6	27.3
Unknown	1	4.6
Glasgow Coma Scale (GCS)		
GCS 3, valid	8	6.5
GCS 3, paralyzed/sedated/intubated	40	47.6
GCS 3, qualifier missing	24	28.6
GCS 4–8	4	4.8
GCS 9–12	0	0.0
GCS 13–15	5	6.0
Missing	3	3.6
Median (IQR) (n = 81)[c]	3	3–3
Median (IQR) motor GCS score (n = 80)[c]	1	1–1

[a] National Trauma Data Bank, 2007–2012.
[b] Row sample size and column proportions presented unless otherwise noted.
[c] Calculated for nonmissing values.
[d] Based on the American College of Surgeons Advanced Trauma Life Support, 7th edition, appropriate age-specific vital signs.
[e] Age-adjusted hypotension defined by systolic blood pressure ≤70 + (2 × age in years) in patients with ascertainable blood pressure.

or unavailable because the child presented prior to 2011 (n = 62). Among these children, 35 (56%) expired in the ED, 18 (21%) in the OR, and 10 (12%) in the ICU. In multivariable regression, evaluating age, ISS, head AIS, and ED pulse, SBP, RR, and motor GCS, there were no independent predictors of survival to the OR or to the ICU.

Of the 84 children who underwent EDT, 100% died before hospital discharge (Table 4). Fifty children (60%) died in the ED, 21 (25%) died in the OR, and 13 (15%) died in the ICU. Four patients survived more than 24 hours in the ICU before expiring. Three of these four children had a maximum head AIS of 5, and the remaining child had a maximum head AIS of 4. Among survivors to the ICU, the median time to death was 1 day (IQR 1–2).

3. Discussion

This study aimed to evaluate survival in children undergoing EDT for blunt trauma using the National Trauma Data Bank between 2007 and 2012. In this large national dataset, there were no survivors. These data compromise the largest and only multiinstitutional report on pediatric EDT after blunt trauma, thus improving upon the existing published literature in both quantity and quality.

3.1. Survivability and comparison to other EDT studies

These findings are consistent with the majority of literature on pediatric EDT in which no survivors were reported after blunt injury (Table 5) [4–7,9]. Among all published reviews, only two pediatric survivors after EDT for blunt trauma have been described [8,11]. One child survived at Denver General Hospital between 1977 and 1988, and was reported to have been discharged with "intact neurological function" [8]. Another survived at Hospital for Sick Children in Toronto in 1989, however the child underwent EDT two hours after ED arrival and after transfer from another facility [8,11]. Other small yet recent reviews of pediatric EDT for blunt trauma have not documented survival [4,5,10]. Most recent was a single-institution review including individuals 18 years and younger, by Allen et al; all 7 patients with blunt trauma in their series died. In their systematic review of pediatric EDT, 124 were after blunt trauma. There were 2 documented survivors (including the child in Denver and one child described by Powell et al who underwent OR thoracotomy), both of whom had SOL on arrival to the ED [6,8].

3.2. Comparison to other NTDB studies

In light of the limitations of small single institution studies, there have been efforts to evaluate predictors of survival after thoracotomy for pediatric blunt trauma by analyzing nationwide datasets such as the NTDB [12,13,21]. The NTDB public-use dataset provides "time to procedure" only to the closest hour, making it difficult to ascertain the location of emergent procedures such as a thoracotomy [22]. Reported survival after thoracotomy performed in the OR compared to the ED was markedly different, making the discrimination of thoracotomy location important [14–16]. Wyrick et al reported 70 children who underwent "emergency thoracotomy" within one hour of ED arrival

Table 4
Mortality and duration of survival in children who underwent emergency department thoracotomy after blunt trauma from the National Trauma Data Bank, 2007–2012.

Mortality	n	%	Cumulative %
Died in the ED	50	59.5	59.5
Died in the OR	21	25.0	84.5
Died ≤24 hours in the ICU	9	10.7	95.2
Died >24 hours in the ICU	4	4.8	100

Table 5
Comparison of all studies previously published evaluating emergency department thoracotomy in children.

Author, year of publication	Years reviewed	Institution(s)	Patient population	Procedure of interest	No. patients	No. patients with blunt trauma	Survival after blunt trauma, n (%)
Allen, 2014	January 1991–December 2012	University of Miami/Jackson Memorial Hospital	All children, ≤18 years of age	Thoracotomy in ED	61	7	0 (0%)
Easter,[a] 2012	January 1, 1995–December 31, 2009	Denver Health Medical Center	All children, ≤18 years of age[b]	Thoracotomy in ED	29	13	0 (0%)
Hofbauer, 2010	January 1992–December 2008	Medical University in Vienna	Children, age range undefined	Thoracotomy in ED	11	10	0 (0%)
Sheikh, 1993	July 1986–July 1991	University of California at Davis	All children, ≤18 years of age	Thoracotomy in ED	23	15	0 (0%)
Rothenberg, 1989	September 1977–September 1988	Denver General Hospital	All children, <18 years of age	Thoracotomy in ED	83	47	1 (2.1%)
Langer, 1989	1989	Hospital for Sick Children	Case study, 14 year old boy	Thoracotomy in ED after transfer	1	1	1 (100%)
Powell, 1988	January 1981–July 1986	University of South Alabama Medical Center	Children 4–18 years of age	Thoracotomy in OR or ED	19	8[c]	0 (0%)
Beaver, 1987	July 1980–August 1985	Maryland Regional Pediatric Trauma Center	Children 15 mo to 4 years of age	Thoracotomy in ED	17	15	0 (0%)
Total					244	116	2 (0.9%)

OR, operating room; ED, emergency department; OSH, outside hospital.
[a] Boatwright et al reported 8 children with EDT after blunt trauma at Denver Health Center or Children's Hospital of Colorado from 1993 to 2010, and from 2004 to 2010 [24]. Because of overlapping years at the same institution, and risk for "double counting," falsely inflating the denominator, these data were excluded.
[b] Inclusion criteria included "no detectable pulse on arrival of EMS or loss of pulse in transit".
[c] One survivor of blunt trauma in this study had thoracotomy in the OR, hence not included here.

after blunt trauma using the NTDB RDS from 2007 to 2010 [21]. Thirteen children (18.6%) survived. The survival disparity between the results reported in the current study and those reported by Wyrick highlights the importance of discriminating between EDT and "emergency resuscitative thoracotomy," or ERT. ERT performed in the OR captures patients with physiologic reserve to tolerate transfer. Based on the definition of emergency thoracotomy by Wyrick, more than half of thoracotomies performed within an hour of arrival in this dataset would have occurred in the OR (53%, n = 35/66). In a 2006 review, Cothren and Moore described EDT as a thoracotomy performed in the emergency department for patients arriving *in extremis*, and explained: "this should not be used interchangeably with, or confused with, a thoracotomy that is performed in the OR or ICU within hours after injury for delayed physiologic deterioration" [23]. This distinction is critical because the patient population, procedure indications, and outcomes are different between EDT and ERT [14–16].

Prior authors have also evaluated ERT in patients with predefined physiologic parameters in the field or upon ED arrival to further delineate the population of interest. Duron et al examined patients aged 18 and younger without SOL in the field after blunt trauma in the NTDB from 2002 to 2010 [12]. "Without SOL" was defined as a systolic blood pressure, pulse, and respiratory rate recorded as zero, in addition to a GCS of three. The subanalysis of thoracotomy described those performed in the first 24 hours. Of the 499 children who presented without SOL in the field and received a thoracotomy in the first 24 hours, seven survived (1.4%), three of whom also had no SOL upon arrival to the ED. However, in this study the location of thoracotomy was not known; thus it is possible these survivors underwent intervention in the OR rather than the ED. When applying the Duron et al definition of SOL to our patient population, there was minimal effect on the relative proportions for location of death, and no effect on the primary outcome; all patients expired before hospital discharge.

3.3. Informing clinical decision-making

Including this study, which is nearly twice the size of any previously published study, with all other studies documenting nonoverlapping years and institutions, only 180 children have undergone EDT for blunt trauma. Two children (1%) survived—both were described before 1990 and one after many hours of evaluation and transfer from another institution, thus making direct comparison with the other cases difficult. The 95% confidence interval for a binomial proportion (2/180, 1%) is 0–4%. Hence, this indicates the "true" survival may be as low as 0% and as high as 4.0%. Without the addition of this study, the confidence interval width increases by 50% and the upward bound of the confidence interval becomes an even more inconceivable 6%. It is important to recognize the contribution of these data as the largest and the only multiinstitutional report of EDT for pediatric blunt trauma described, improving the precision, power, and accuracy of data from which we as clinicians make inference. It is also important to acknowledge, however, that data are only one component of a complex relationship between knowledge, bedside clinical decisions, ethics, and the art of medicine.

3.4. Limitations

Although this is the largest and only nationwide description of pediatric EDT for blunt trauma published, it has several limitations. The NTDB RDS is a convenience sample and does not capture all trauma patients in the United States. However, it does capture all American College of Surgeons Level I trauma centers where survival from EDT in the pediatric population would be expected to occur. The database is retrospective and lacks data such as duration of cardiopulmonary arrest and precise time to procedures. The NTDB also has high proportions of missing values for key variables, such as EMS vital signs and GCS at the scene of injury. Finally, while this study describes the largest cohort of pediatric patients undergoing EDT after blunt trauma, findings from a study with a sample size of 84 may not negate one's inferences from larger adult studies of EDT for blunt trauma. Nevertheless, these data do allow reasonable conclusions to be drawn regarding universal mortality after EDT for blunt trauma in the pediatric population as *no single* pediatric survivor after EDT for blunt trauma has been described in the past 25 years.

4. Conclusion

This study significantly strengthens the available evidence regarding use of EDT after blunt trauma in children by adding quantity and generalizability to the existing literature limited by small sample sizes from single-institutions. From 2007 to 2012, the NTDB did not report survival in any pediatric patient after EDT for blunt trauma. Further, usual

indicators for EDT in adults may not apply in children, such as SOL upon ED arrival. The use of EDT for pediatric blunt trauma should be discouraged without compelling evidence of a reversible cause of extremis. Rather, further studies should focus on alternative therapies to resuscitate these children and to influence their outcomes.

Appendix A. Discussions

Presented by Katherine Flynn-O'Brien, Seattle, WA

PETER EHRLICH (Ann Arbor, MI) One of the things I think we all face when looking after injured children is that we are brought a lot of children who have actually died in the field. There are two reasons for that: one, people don't want to pronounce a child dead in the field and, two, they don't feel comfortable following the guidelines that do exist in adults. One of the things that we found, and you brought that up as a limitation, when we looked at, from a different standpoint was when we looked at the criteria for calling death is that we have had no survivors since 2002 of any child who had more than 15 minutes of CPR in the field. We have started to apply that to do that, so I think your study goes a long with that too.

KATHERINE FLYNN-O'BRIEN I agree wholeheartedly. I think that there needs to be more education of our prehospital providers and confidence building in terms of when to call it and when not to call it.

MICHAEL KLEIN (Detroit, MI) Did you find – is there any way to get a hint of why people decided to do this? Was it because they were treated at adult trauma centers?

KATHERINE FLYNN-O'BRIEN That is a good question. You know, when looking at the centers that treated, there was no tendency – two thoracotomies were not completed at any one center, more than two, and there was no trend over time, so really finding a theme was difficult.

STEVEN STYLIANOS (New York, NY) I think if you polled the audience honestly you will learn that many chests have been opened simply to write the final chapter in a child's life, whether it be done for the physician to think they did all they could or to show the team that everything was done or perhaps to be able to tell the parents that everything was done. Otherwise, this is a message that we all know and it was very good that you brought it back home because perhaps we have evolved as a specialty to the point where that should be removed from our armamentarium. At the same time, I am enthused about the endovascular way to achieve the same goal as long as you are just trying to do a resuscitative thoracotomy. If you are trying to see if there is intrathoracic injury, perhaps ultrasound will allow us to do that. There will be chances where we will open the chest to see if the heart is okay, but otherwise as a resuscitative maneuver, we should probably seek other modes. Congratulations.

KATHERINE FLYNN-O'BRIEN I agree completely. Thank you, sir.

UNIDENTIFIED SPEAKER I just have one brief comment from a parent's perspective. On the very first day that I was a pediatric surgery fellow, I had a patient just like this come in. I had no idea, anything about the hospital, so I opened the kid's chest because there was nothing else to do. It turned out that the child's mother was a nurse in that hospital and as upset as she was about her son, she was more upset with me for opening his chest, and I will never – I have never forgotten that for the rest of my career.

KATHERINE FLYNN-O'BRIEN Thank you for sharing that.

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