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Emergency Resuscitative Thoracotomy: A Nationwide Analysis of Outcomes and Predictors of Futility

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ABSTRACT

Background: Most studies on emergency resuscitative thoracotomy (ERT) suffer from either small sample size or unclear inclusion criteria. We sought to assess ERT outcomes and predictors of futility using a nationwide database.

Methods: Using a novel and comprehensive algorithm of combinations of specific *International Classification of Diseases, Ninth Revision* and *International Classification of Diseases, Tenth Revision* procedure codes denoting the multiple steps of an ERT (e.g., thoracotomy, pericardiotomy, cardiac massage) performed within the first 60 min of patient arrival, we identified ERT patients in the 2010-2016 Trauma Quality Improvement Program database. We defined the primary outcome as survival to discharge and the secondary outcomes as hospital length of stay (LOS), intensive care unit LOS, number of complications, and discharge destination. Univariate then backward stepwise multivariable logistic regression analyses were performed to assess independent predictors of mortality. Multiple imputations by chained equations were performed when appropriate, as additional sensitivity analyses.

Results: Of 1,403,470 patients, 2012 patients were included. The median age was 32, 84.0% were males, 66.7% had penetrating trauma, the median Injury Severity Score was 26, and 87.5% presented with signs of life (SOL). Of the 1343 patients with penetrating injury, 72.9% had gunshot wounds and 27.1% had stab wounds. The overall survival rate was 19.9%: 26.0% in penetrating trauma (stab wound 45.6% *versus* gunshot wound 18.7%; $P < 0.001$) and 7.6% in blunt trauma. Independent predictors of mortality were aged 60 y and older (odds ratio, 2.71; 95% confidence interval [95% CI], 1.26-5.82; $P = 0.011$), blunt trauma (odds ratio, 4.03; 95% CI, 2.72-5.98; $P < 0.001$), prehospital pulse <60 bpm (odds ratio, 3.43; 95% CI, 1.73-6.79; $P < 0.001$), emergency department pulse <60 bpm (odds ratio, 4.70; 95% CI, 2.47-8.94; $P < 0.001$), and no SOL on emergency department arrival (odds ratio, 3.64; 95% CI, 1.08-

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12.24; $P = 0.037$). Blunt trauma was associated with a higher median hospital LOS compared with penetrating trauma (28 d *versus* 13 d; $P < 0.001$), higher median intensive care unit LOS (19 d *versus* 6 d; $P < 0.001$), higher median number of complications (2 *versus* 1; $P = 0.006$), and more likelihood to be discharged to a rehabilitation facility instead of home (72.6% *versus* 28.7%; $P < 0.001$). ERT had the highest survival rates in patients younger than 60 y who present with SOL after penetrating trauma. None of the patients with blunt trauma who presented with no SOL survived.

Conclusions: The survival rates of patients after ERT in recent years are higher than classically reported, even in the patient with blunt trauma. However, ERT remains futile in patients with a blunt trauma presenting with no SOL.

Introduction

Emergency resuscitative thoracotomy (ERT) remains a last resort procedure to resuscitate the critically injured trauma patient. Its multiple components, specifically left anterolateral thoracotomy, pericardiotomy, aortic crossclamping, and open cardiac massage, serve to release cardiac tamponade if present, control hemorrhage, divert blood flow to the brain, and manually restore cardiac output. Since its initial introduction in the late 1800s on animal studies[1] and application on a patient with penetrating cardiac injuries in the 1960s,[2] ERT has been the subject of much controversy. Most ERT studies are of low quality with a small sample size and show a wide range of post-ERT survival rates. In a systematic review of published studies, Rhee et al.[3] suggested that the overall survival after ERT ranges between 1.8% and 27.5%. A more recent literature review by the Eastern Association for Surgery of Trauma showed an overall survival rate of 8.5%; 2.3% for blunt and 10.6% for penetrating injury.[4] Another review of 37 articles from 2000 to 2014 showed an overall survival rate of 8% (range, 0-33.3): 9.8% (range, 0-45.5) for penetrating and 5.2% (range, 0-12.2) for blunt injury.[5] For penetrating injuries, patients with a stab wound (SW) have been shown to have a higher survival rate compared with a gunshot wound (GSW).[3,6-10]

With most individual studies suffering from either small sample size or unclear inclusion criteria, we sought to assess ERT outcomes and predictors of futility using the nationwide American College of Surgeons (ACS) Trauma Quality Improvement Program (TQIP) trauma database spanning 7 y of collected data. Because of recommendations and guidelines published by major trauma societies in the past 2 decades for better patient selection for the procedure, we hypothesized improved outcomes of ERT in recent years.

Methods

Patient population and inclusion criteria

Patients who underwent an ERT in the ACS-TQIP database between 2010 and 2016 were included. ERT was defined using *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) and *International Classification of Diseases, Tenth Revision, Clinical Modification* (*ICD-10-CM*) procedure codes. For *ICD-9-CM* codes, the inclusion criteria were as follows: exploratory thoracotomy (34.02) with open-chest cardiac massage (37.91) or exploratory thoracotomy with pericardiotomy (37.12), or exploratory thoracotomy with open-chest cardiac massage and pericardiotomy. Starting in 2015, *ICD-10-CM* was added to the database in parallel to *ICD-9-CM* codes. For *ICD-10-CM* codes, we used procedure code 02JA0ZZ: inspection of heart, open approach, excluding those with 0P800ZZ: Division of sternum, open approach. Only patients whose procedures were performed within 60 min of emergency department (ED) presentation were included.

Primary and secondary outcomes

We defined the primary outcome as survival to hospital discharge and secondary outcomes (for those who survived) as hospital length of stay (LOS), intensive care unit (ICU) LOS, number of complications, and discharge destination (home *versus* nursing, long-term or rehabilitation facility). For patients who did not survive, we assessed the location of death: ED, operating room (OR), or ICU.

Data variables

The following data points were collected from the database: demographics: gender, age, race, and ethnicity; total emergency medical service (EMS) time from dispatch to ED arrival; vital signs measured by EMS on scene and on arrival to the ED (e.g., Glasgow Coma Scale [GCS], heart rate, and systolic blood pressure [SBP]); signs of life (SOL) on ED arrival; Injury Severity Score (ISS); mechanism of injury: blunt or penetrating, with GSW or SW as subdivisions for penetrating; location of injury based on the Abbreviated Injury Scale (AIS) score; and AIS severity score. The very few patients with both blunt and penetrating injuries (20 patients) were classified as having a penetrating injury mechanism, and those with both GSW and SW (two patients) were classified as having a GSW mechanism. TQIP has a separate variable showing patients who died in the ED but not for those who died in the OR or in the ICU. As such, death in the OR was defined as patients who were admitted to the OR, died, and ICU LOS was nonapplicable (meaning that they were not admitted to the ICU despite having an ERT). Death in the ICU was defined as death in patients with a difference between hospital LOS and ICU LOS being less than 1 d. Patients with missing data that did not allow clear categorization were classified as missing.

Table 1 – The characteristics of the study population.

Characteristics	Total ($n = 2012$)	Survived ($n = 400$)	Died ($n = 1612$)	P
Gender, n (%)				0.004
Female	322 (16.0)	45 (14.0)	277 (86.0)	
Male	1690 (84.0)	355 (21.0)	1335 (79.0)	
Age, y ($n = 1965$)				
Median age (IQR)	32 (23-46)	30 (23-42)	32 (23-47)	0.002
Age 60 and older, n (%)	204 (10.4)	19 (9.3)	185 (90.7)	<0.001
Age younger than 60, n (%)	1761 (89.6)	377 (21.4)	1384 (78.6)	
Age range, y ($n = 1965$)				0.002
16-19	208 (10.59)	46 (22.12)	162 (77.88)	
20-29	689 (35.06)	148 (21.48)	541 (78.52)	
30-30	374 (19.03)	89 (23.80)	285 (76.20)	
40-49	289 (14.71)	53 (18.34)	236 (81.66)	
50-59	201 (10.23)	41 (20.40)	160 (79.60)	
60-69	134 (6.82)	17 (12.69)	117 (87.31)	
70-79	47 (2.39)	2 (4.26)	45 (95.74)	
80-89	23 (1.17)	0 (0.00)	23 (100.00)	
Race ($n = 1910$)				0.183
African American	814 (42.6)	178 (21.9)	636 (78.1)	
White	763 (40.0)	141 (18.5)	622 (81.5)	
Asian	36 (1.9)	5 (13.9)	31 (86.1)	
Other	297 (15.5)	68 (22.9)	229 (77.1)	
Hispanic, n (%) ($n = 1790$)	331 (18.5)	68 (20.5)	263 (79.5)	0.972
Prehospital CPR ($n = 1574$)	70 (4.5)	4 (5.7)	66 (94.3)	<0.001
EMS vitals				
Mean heart rate (SD), bpm ($n = 1552$)	96.9 (43.8)	108.4 (31.9)	94.2 (45.7)	<0.001
Median heart rate (IQR), bpm ($n = 1552$)	107 (72-128)	110 (90-130)	104 (68-128)	<0.001
Pulse <60 bpm, n (%) ($n = 1552$)	276 (17.8)	13 (4.7)	263 (95.3)	<0.001
Mean SBP (SD), mm Hg ($n = 1331$)	87.4 (51.0)	100.5 (37.1)	84.4 (53.3)	<0.001
Median SBP (IQR), mm Hg ($n = 1331$)	90 (68-122)	98 (80-124)	90 (60-122)	<0.001
SBP <90 mm Hg, n (%) ($n = 1331$)	605 (45.5)	95 (15.7)	510 (84.3)	<0.004
Median GCS (IQR) ($n = 1576$)	8 (3-14)	14 (9-15)	6 (3-14)	<0.001
Median total EMS time (IQR), min ($n = 1558$)	30 (22-43)	29.5 (23-42)	30 (22-43)	0.919
Mean total EMS time (SD), min ($n = 1558$)	37.5 (31.6)	36.1 (21.9)	37.8 (33.4)	0.395
ED vitals				
Mean heart rate (SD), bpm ($n = 1813$)	95.5 (47.8)	111.1 (32.2)	91.3 (50.4)	<0.001
Median heart rate (IQR), bpm ($n = 1813$)	106 (68-131)	114 (93-133)	102.5 (56-130)	<0.001
Pulse <60 bpm, n (%) ($n = 1813$)	386 (21.3)	17 (4.4)	369 (95.6)	<0.001
Mean SBP (SD), mm Hg ($n = 1720$)	89.3 (52.3)	103.6 (40.8)	85.4 (54.4)	<0.001
Median SBP (IQR), mm Hg ($n = 1720$)	91 (60-126)	101 (78-130)	89 (54-126)	<0.001
SBP <90 mm Hg, n (%) ($n = 1720$)	813 (47.3)	140 (17.2)	673 (82.8)	<0.001
Median GCS (IQR) ($n = 1922$)	3 (3-12)	14 (3-15)	3 (3-8)	<0.001
SOL on arrival, n (%) ($n = 1792$)*				<0.001
Yes	1629 (90.9)	356 (21.9)	1273 (78.1)	
No	163 (9.1)	7 (4.3)	156 (95.7)	
Median ISS (IQR)	26 (19-41)	25 (17-34)	29 (20-41)	<0.001

For variables with missing values, percentages are out of the total number of patients having data on the variable.
For columns: survived and dead, row percentages are reported.
IQR = interquartile range; SD = standard deviation.
*SOL variable collection started in 2011 and beyond.

Table 2 – The injury characteristics of the study population.

Injury characteristics	Total ($n = 2012$)	Survived ($n = 400$)	Died ($n = 1612$)	P
ISS ≥16, n (%)	1803 (89.6)	342 (19.0)	1461 (81.0)	0.003
Injury mechanism, n (%)				
Blunt	669 (33.3)	51 (7.6)	618 (92.4)	
Penetrating	1343 (66.7)	349 (26.0)	994 (74.0)	<0.001
Penetrating mechanism, n (%) ($n = 1343$)				
GSW	979 (72.9)	183 (18.7)	796 (81.3)	
SW	364 (27.1)	166 (45.6)	198 (54.4)	<0.001
Location of injury AIS				
Thorax, n (%)	1728 (85.9)	385 (22.3)	1343 (77.7)	<0.001
Median thorax AIS severity score (IQR)	3 (3-4)	3 (3-5)	3 (3-4)	<0.001
Abdomen, n (%)	1183 (58.8)	192 (16.2)	991 (83.8)	<0.001
Median highest abdomen AIS severity score (IQR)	2 (0-3)	0 (0-3)	2 (0-4)	<0.001
Head/neck, n (%)	544 (27.0)	80 (14.7)	464 (85.3)	<0.001
Median highest head/neck AIS severity score (IQR)	0 (0-1)	0 (0-0)	0 (0-1)	<0.001
Extremity, n (%)	1024 (50.9)	160 (15.6)	864 (84.4)	<0.001
Median highest extremity AIS severity score (IQR)	2 (1-3)	2 (1-3)	2 (1-3)	0.198

For columns: survived and dead, row percentages are reported.
IQR = interquartile range.

Missing data

Multiple imputations by chained equations (MICE) were performed as sensitivity analyses to account for the missing data, when applicable. TQIP defines a patient with no SOL on arrival as one having none of the following: organized electrocardiogram activity, pupillary responses, spontaneous respiratory attempts or movement, and unassisted blood pressure. However, the variable SOL on arrival started to be recorded in the database in the year 2011, leaving 220 of the total 2012 patients with no recorded data for SOL. We followed the definition used for the variable to manually impute by deriving the SOL on arrival for those 220 patients, using the present data of their vitals on arrival to the ED (ED SBP, ED heart rate, and ED GCS score); 11 patients remained without recorded SOL on arrival and missing ED vitals, but considering that they had high ISS and were all dead on discharge, they were put as having no SOL. Missing data in ED vitals were filled in using the available data in SOL (i.e., a patient presenting to the ED with no SOL was filled with a value of 0 bpm and 0 mm Hg for ED heart rate and SBP, respectively). For patients who did not have the information needed to derive ED heart rate, MICE was used. All vital variables were changed into binomial variables when running the estimation model, in addition to when imputing them.

MICE was performed on the following variables: age 60 y and older, EMS pulse <60 bpm, and ED pulse <60 bpm. About 15 imputations were run, with predictor variables being survival to discharge, ISS, injury mechanism, and SOL. Missing ISS were manually calculated from the individual AIS region scores.

Statistical analysis

For continuous parametric variables, results were reported in mean (with standard deviation), and Student *t*-test was performed. For nonparametric continuous variables, results were reported in median (with interquartile range), and the Mann-Whitney *U* test was performed. Shapiro-Wilk normality test was performed to assess if a variable was parametric or not. Chi-square test was used for categorical variables. A univariate analysis was performed to assess if there was a significant difference for each variable between survivors and nonsurvivors. Variables that showed a $P < 0.2$ were used in the backward stepwise multivariate logistic regression model to assess the predictors of mortality of ERT. Clustering by region was accounted for by mixed effects regression model for clustered data. An additional multivariate logistic regression model was run with the imputed variables as a sensitivity analysis for the original model. All initial analyses were

Table 3 – Survival rate to discharge in blunt and penetrating.

Outcome	Total ($n = 2012$)	Blunt ($n = 669$)	Penetrating ($n = 1343$)	P	Penetrating ($n = 1343$)		P
					GSW ($n = 979$)	SW ($n = 364$)	
Survived, n (%)	400 (19.9)	51 (7.6)	349 (26.0)	<0.001	183 (18.7)	166 (45.6)	<0.001

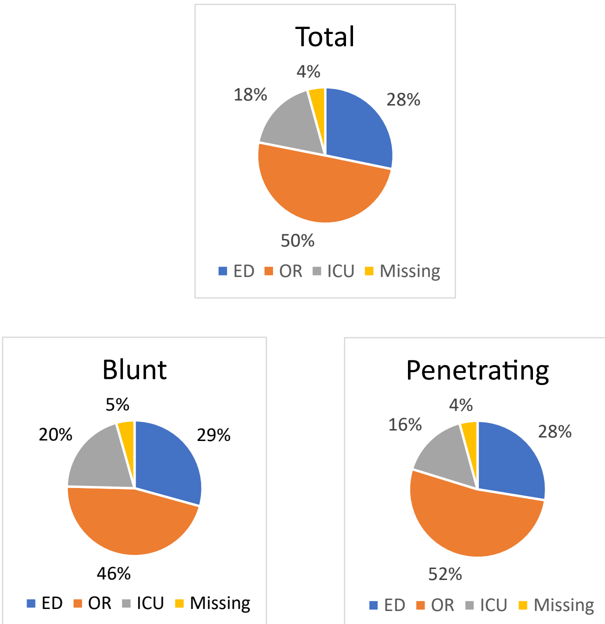

Fig. 1 – Location of death in total population and in blunt and penetrating trauma. P = 0.029 for death location difference in blunt *versus* penetrating. About 69 of 1612 (4%) patients who died did not fit in either of the categories (ED, OR, and ICU) and were put as missing. They were patients with either missing data or recorded data with discrepancies (e.g., ICU LOS > total hospital LOS). Only six of these patients were assumed to have died in floor bed (hospital LOS was greater than ICU LOS), but because of the low number, no separate category was made for death in floor bed. (Color version of figure is available online.)

performed with the raw data without imputation or educated guessing. $P < 0.05$ was set as significant. All statistical analyses were performed using STATA, version 15.1 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). The study was submitted for institutional review board approval but was deemed exempt as there were no patient identifiers in the national database used.

Results

Of a total of 1,403,470 patients, 2012 patients met the inclusion criteria. The demographics, vitals, and injury parameters of the study population are summarized in Tables 1 and 2. In summary, the median patient age was 32 y, 84.0% were male, and 40.0% were white. The median SBP measured by EMS was 90 mm Hg, with 45.5% having an SBP <90 mm Hg, and the median EMS pulse rate was 107 bpm, with 17.8% having a pulse <60 bpm. A total of 90.9% of the patients presented to the ED with SOL, with a median pulse of 106 bpm. The median SBP measured in the ED was 91, with 47.3% having an SBP <90 mm Hg. The median ISS was 26; 1343 patients (66.7%) had a penetrating mechanism of injury, out of which 72.9% had GSW and 27.1% had SW.

Table 4 – Backward stepwise multivariable logistic regression analysis with death as the dependent variable (N = 1146).

Death	OR	P	95% CI
Blunt injury	4.03	<0.001	2.72-5.98
No SOL	3.64	0.037	1.08-12.24
Age 60 y and older	2.71	0.011	1.26-5.82
EMS pulse <60 bpm	3.43	<0.001	1.73-6.79
ED pulse <60 bpm	4.70	<0.001	2.47-8.94
ISS ≥16	1.52	0.091	0.93-2.49

The model removed female ($P = 0.583$) and ED SBP <90 mm Hg ($P = 0.757$) because they were found to be nonsignificant.

Tables 1 and 2 also show the univariate analyses comparing survivors and nonsurvivors. In summary, we observed significantly higher survival in males ($P = 0.004$), and in patients younger than 60 ($P < 0.001$), or arriving with SOL ($P < 0.001$). Survival was significantly lower in patients with EMS and ED pulse <60 bpm as well as EMS and ED SBP <90 mm Hg (<0.001 and <0.001, 0.004, and <0.001, respectively). Only 5.7% of patients who received prehospital cardiopulmonary resuscitation (CPR) survived ($P < 0.001$). There was no significant difference between survivors and nonsurvivors for EMS total time from dispatch to ED arrival, race, and ethnicity.

The overall survival to discharge rate of our patient population was 19.9%: 26.0% in penetrating and 7.6% in blunt ($P < 0.001$). Survival in penetrating injuries was 18.7% for GSW and 45.6% for SW ($P < 0.001$) (Table 3). Of those who did not survive, 28% died in the ED, 50% in OR, and 18% in the ICU. A significant difference was observed in the location of death between patients with penetrating injuries compared with those with blunt injuries ($P = 0.029$): patients with a penetrating injury had a higher percentage of death in the OR compared with those with blunt (52% *versus* 46%) and a lesser percentage of death in the ICU (16% *versus* 20%). Death in the ED was nearly the same between penetrating and blunt injuries (28% and 29%, respectively) (Fig. 1).

The backward stepwise multivariate logistic regression model with mortality as the dependent variable is shown in Table 4. The independent predictors of mortality were age 60 and older (odds ratio, 2.71; 95% confidence interval [95% CI], 1.26-5.82; $P = 0.011$), blunt trauma (odds ratio, 4.03; 95% CI, 2.72-5.98; $P < 0.001$), prehospital pulse <60 bpm (odds ratio, 3.43; 95% CI, 1.73-6.79; $P < 0.001$), ED pulse <60 bpm (odds ratio, 4.70; 95% CI, 2.47-8.94; $P < 0.001$), and no SOL on ED arrival (odds ratio, 3.64; 95% CI, 1.08-12.24; $P = 0.037$). The area under a receiver operating characteristic curve of the regression model is 0.7431 (Fig. 2).

Table 5 shows an additional multivariate logistic regression run as a sensitivity analysis with the missing data corrected via multiple imputations, when appropriate.

We assessed secondary outcomes for patients who survived to discharge (Table 6). Compared with penetrating trauma, blunt trauma was associated with a higher median hospital LOS (28 d *versus* 13 d; $P < 0.001$), higher median ICU LOS (19 d *versus* 6 d; $P < 0.001$), higher median number of complications (2 *versus* 1; $P = 0.006$), and more likelihood of

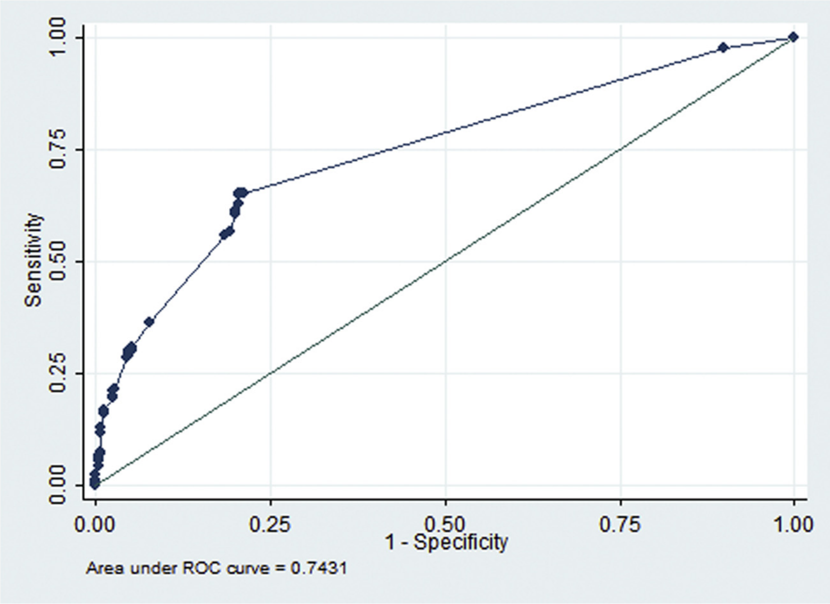

Fig. 2 – Receiver operating characteristic (ROC) curve for the stepwise multivariable logistic regression model. (Color version of figure is available online.)

discharge to a rehabilitation facility instead of home (72.5% *versus* 28.7%; $P < 0.001$). A subanalysis of penetrating trauma showed GSW to be associated with a higher median hospital LOS compared with SW (18.5 d *versus* 9 d; $P < 0.001$), a higher median ICU LOS (10 d *versus* 4 d; $P < 0.001$), and a higher likelihood of discharge to a rehabilitation facility instead of home (33.3% *versus* 23.5%; $P = 0.042$).

Figure 3 describes the patient population and respective survival rates according to age, SOL, and mechanism of injury. In summary, ERT had the highest survival rates in patients younger than 60 y who present with SOL after penetrating trauma. None of the patients with blunt trauma and no SOL survived.

Discussion

To the best of our knowledge, this is the first study to assess ERT outcomes using the nationwide ACS-TQIP trauma database with clear and strict inclusion criteria. Our study shows significantly improved outcomes for ERT compared with the classical literature. We attribute this mainly to the better prehospital and ED vitals of the patient population, and a higher number of patients presenting with SOL, thus a higher likelihood for better outcomes. This might be due, at least partially, to better patient selection for the procedure following the recommendations and guidelines published by the major trauma societies in the past 2 decades. A significant part to emphasize is the higher survival in patients with blunt trauma than classically reported. We showed that when stratified by age, SOL, and injury mechanism, survival in blunt can reach up to 9.0% in patients with age younger than 60 y who arrive with SOL. Survival is also significant in the older group of patients with a blunt injury who arrive with SOL. However, ERT in patients arriving with no SOL and blunt trauma remains futile with none of them surviving in our study.

A recent study by Joseph *et al.*[11] used the ACS-TQIP database from 2010 to 2014 to assess outcomes of ERT, with the inclusion criterion being *ICD-9-CM* procedure code 34.02: exploratory thoracotomy, performed within the first hour of ED presentation. However, this criterion would also include patients who had a right thoracotomy as a hemorrhage control maneuver, clearly not an ERT, which we showed using *ICD-10-CM* procedure codes. As such, we conclude that not all patients in that study were ERT patients. Another study used the National Trauma Data Bank from 2008 to 2012, with an inclusion criterion of *ICD-9-CM* procedure code denoting exploratory thoracotomy within 15 min of ED presentation, and time to procedure less than the total time spent in ED.[12] In addition to this *ICD-9-CM* procedure code not capturing only ERT patients, a time to procedure of 15 min would be capturing the most severe patients, and thus not giving the

Table 5 – Multivariable logistic regression analysis with death as dependent variable using imputed data ($N = 2012$).

Death	OR	P	95% CI
Blunt injury	4.40	<0.001	3.18-6.09
No SOL	1.92	0.064	0.96-3.85
Age 60 y and older	1.67	0.054	0.99-2.82
EMS pulse <60 bpm	4.15	<0.001	2.09-8.22
ED pulse <60 bpm	5.74	<0.001	3.33-9.88
ISS ≥16	1.65	0.006	1.15-2.35

Table 6 – Outcomes of survivors based on mechanism of injury.

Outcomes	Total (n = 400)	Blunt (n = 51)	Penetrating (n = 349)	P	GSW (n = 183)	SW (n = 166)	P
Median hospital LOS (IQR) (n = 398)	15 (8-28)	28 (16-40)	13 (8-26)	<0.001	18.5 (11-31)	9 (6-15)	<0.001
Median ICU LOS (IQR) (n = 384)	8 (4-18)	19 (10-27)	6 (4-15)	<0.001	10 (5-21)	4 (3-8)	<0.001
Median number of complications (IQR) (n = 398)	1 (0-2)	2 (0-3)	1 (0-2)	0.006	1 (0-3)	1 (0-1)	<0.001
Discharge location				<0.001			0.042
Medical care facility	137 (34.3)	37 (72.5)	100 (28.7)		61 (33.3)	39 (23.5)	
Home*	263 (65.7)	14 (27.5)	249 (71.3)		122 (66.7)	127 (76.5)	

IQR = interquartile range.
*With or without assistance.

whole picture of ERT. This is shown by the low overall survival rate of 7.2% they report, with 5.1% for blunt and 7.7% for penetrating. Most of the other case series are limited by the low number of patients from a single institution.

Hence, the unique algorithm of *ICD-9-CM* and *ICD-10-CM* procedure codes we created arguably allows a larger number of patients to be included without jeopardizing the certainty of occurrence of an ERT.

A recent survey assessing ERT practice in trauma surgeons showed that most would perform ERT in patients with penetrating trauma with loss of vitals shortly before arrival. For patients with blunt trauma, the survey showed that nearly half of the respondents would perform ERT only in patients who arrived with SOL but lost vitals in the ED. These lead to better patient selection and increased survival rates. However, the survey also showed that 20.6% of the respondents would never perform ERT in patients with blunt trauma, regardless of SOL on arrival.[13] We have shown that when SOL on arrival is taken into consideration, there is still hope for the critically injured patients with blunt trauma arriving with SOL.

Predictors of outcomes have been reported to be mechanism of injury,[3,4,7,11,14-18] prehospital and ED vitals and SOL,[3,4,7,11,16-20] location of injury,[3,4,7,16,17,21] and CPR and its duration,[11,17-19] with other studies reporting additional predictors such as gender,[19] ISS,[11] GCS,[15] and pericardial tamponade.[22] However, there are conflicting data among studies regarding the significance of each predictor, in addition to the absence of analyses of multiple predictors at the same time in some, putting into question the applicability in a clinical setting.[4]

Age 60 y and older was one of the independent predictors of mortality in our study, a factor not previously described. Additional significant independent predictors of mortality in our study were blunt trauma, prehospital pulse <60 bpm, ED pulse <60 bpm, and no SOL on ED arrival, which are in accordance to reported predictors in the literature.

The increased survival rate in our study is also because of the 315 patients who had received a thoracotomy and pericardiotomy but no open cardiac massage and had a survival rate of 64.1%. We predict that these are patients with an SW to the heart, and when ERT was performed and the pericardial tamponade released, they regained their vitals without the need of an open cardiac massage. Overall survival of the patient population in the study without these patients was found to be 11.67%.

We still think that clinical judgment is essential for the decision to perform an ERT or not. Several studies have reported risks and costs associated with ERT, such as exposure of the health care provider to blood-borne pathogens, risk of provider injury during the aggressive maneuver, increased societal, EMS, and hospital resource costs, in addition to the cost of salvaging a patient potentially with severe neurologic

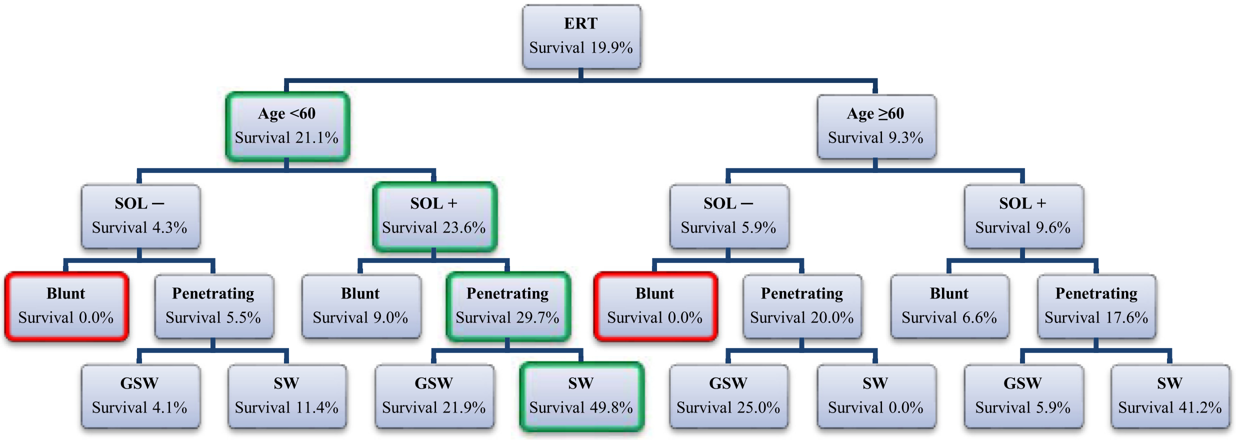

Fig. 3 – Survival in ERT patients based on age, SOL, and injury mechanism. SOL+: Presenting with signs of life to the ED; SOL−: Presenting without signs of life to the ED. (Color version of figure is available online.)

impairment.[14,23-26] As such, correct patient selection is needed to balance the risks and costs with patient outcomes.

Our study has a few limitations. First, it is a retrospective study with potential residual confounders. Second, patients who had received ERT in hospitals who do not have a trauma center or in hospitals that do not participate in TQIP were not included in the database, causing a potential selection bias. Third, the database lacks variables assessing the duration of prehospital CPR and postsurvival neurologic outcome. Fourth, despite our best efforts at optimizing the algorithm of *ICD* codes to detect true ERT, it is plausible that some cases were still not true ERT in the strictest trauma sense. Fifth, multiple imputations were used as additional sensitivity analyses to account for the missing data in some variables.

Conclusion

By using 7 y of collected data in the ACS-TQIP national trauma database and a novel *ICD* algorithm, we have shown that the survival rates of patients after ERT in recent years are higher than classically reported, even in the blunt trauma patient. However, ERT remains futile in patients with a blunt trauma presenting with no SOL. Future studies should focus on long-term neurologic and functional outcomes in addition to survival to discharge to improve the appropriate use of this procedure.

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Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article. The authors have no disclosures or related conflicts of interest to declare.

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