Eur J Trauma Emerg Surg (2012) 38:151–156
DOI 10.1007/s00068-011-0138-x

ORIGINAL ARTICLE

Emergency thoracotomies in the largest trauma center in Denmark: 10 years' experience

K. Kandler · L. Konge · S. Rafiq · C. F. Larsen · J. Ravn

Received: 23 February 2011 / Accepted: 11 July 2011 / Published online: 2 August 2011
© Springer-Verlag 2011

Abstract
Aim The aim of our study was to investigate the outcome in terms of 30-day survival and to determine whether preoperative factors could predict the outcome.
Methods All patients who underwent an emergency thoracotomy (ET) during the period 2000 to 2009 were included. The patients were divided into two groups: emergency department thoracotomy and operating room thoracotomy. Data on demographics, mechanism of injury, intraoperative data, Injury Severity Scores (ISS), probability of survival, signs of life, transportation time, indications, and outcome were collected.
Results Forty-four ETs were performed. The mechanisms of injury were penetrating in 28 (64%) and blunt in 16 (36%) cases. In the emergency department thoracotomy group, the survival was 45 versus 20% for penetrating and blunt trauma, respectively. The total survival was 33%. In the operating room thoracotomy group, the survival was 83%. The survivors had a significantly lower ISS and a higher calculated probability of survival. The calculated mean probability of survival was 44 and 84% in the emergency department thoracotomy and operating room thoracotomy groups, respectively. The actual survival was similar, with 33% in the emergency department thoracotomy group and 83% in the operating room thoracotomy group.
Conclusions The probability of survival and ISS are good predictors of survival in these patients and should be included in the future in order to make upcoming studies easier to compare. Patients with very high ISS or low probability of survival survived, justifying the procedure in our center.

Keywords Emergency thoracotomy · Resuscitation · Penetrating · Blunt · Survival

K. Kandler (✉) · L. Konge · S. Rafiq · J. Ravn
Department of Cardiothoracic Surgery, Rigshospitalet, Copenhagen University Hospital, Webersgade 5, 1. th., 2100 Copenhagen Ø, Denmark
e-mail: kristiankandler@gmail.com

C. F. Larsen
Trauma Centre, Rigshospitalet, Copenhagen University Hospital, Copenhagen, Denmark

Introduction

The emergency thoracotomy (ET) was reintroduced in the 1960s. Since then, the indications and procedures have broadened from simple direct hemostatic procedures to aortic cross-clamping in the case of profound bleeding, pericardial decompression, and open cardiac massage, etc. [1–4]. Its use, indications, and risks are still unclear and debated. The best chance of survival is found among patients subjected to penetrating trauma [4, 5].

Most studies and recommendations are from, or rely largely upon, data from the last century and come from centers outside Europe [1, 4].

Only a few studies have been published from Scandinavian countries and they consist of studies from the largest trauma centers [6–8], with the exception of one [9], which reports an overall survival of 0% ($n = 10$) for penetrating and blunt trauma. The latest, and largest, Scandinavian contribution is from Norway and includes 109 patients over a 6-year period [10]. This is the first Danish study on the subject.

In Denmark, gunshot wounds and stab wounds are very rare and are often headline stories in the press. During the past few years, however, there has been an increased focus

on the subject because of gang war outbreaks. There is also a general perception by the public that violence is increasing in Denmark.

The aim of the study was to investigate the outcome in terms of the 30-day survival of patients who underwent ET and explore whether preoperative factors could predict the outcome. We also wanted to analyze if the numbers of ET were increasing.

Materials and methods

All patients who underwent an ET during the period 2000–2009 were included. All data were collected in a retrospective manner. All patients who were registered with a procedure code for thoracotomy during this period were found in the Trauma Audit Research Network (TARN) and the Patient Analysis and Tracking System (PATS) registry. All patients that did not fit the criteria for ET were excluded. The Injury Severity Score (ISS) [11, 12] and probability of survival (PS) [13] were calculated by and retrieved from TARN. The prehospital Glasgow Coma Score (GCS) was used since many patients were intubated on arrival to the ED.

In Denmark, all residents can be tracked by their unique personal identification number, and this number was used to find the medical records, including the chart from the trauma center, prehospital data, mechanism of trauma, and intraoperative data. The charts from the prehospital staff and trauma center provided information on indications for ET, data on signs of life (SOL), and time from the emergency call to ET. The 30-day mortality was cross-checked by using the unique personal identification number and searching the Danish Registry of Deaths.

The indications used when performing ET were as follows; penetrating trauma with pulseless electrical activity (PEA) within the last 5 min, unstable patients with ongoing intrathoracic bleeding, and as means of clamping the descending thoracic aorta as a step in the initial resuscitation.

The trauma team leaders were all Advanced Trauma Life Support (ATLS)-certified anesthesiologists. The trauma team leader made the ultimate decision regarding whether or not to perform an ET. This practice is commonly used in Scandinavian countries. The most experienced surgeon present, from the Department of Cardiothoracic Surgery, performed the ET. This was usually a resident in cardiothoracic surgery. A senior resident or attending surgeon on call subsequently assisted when needed.

To make our study more comparable with the current literature, we subdivided our patients into emergency department thoracotomies (EDT) and emergency resuscitative thoracotomies (operating room thoracotomies, ORT). EDT was defined as a procedure conducted in the emergency department (ED). ORT were defined as a procedure conducted in the operating room (OR), as an integral part of the initial resuscitation [14].

SOL at arrival to the ED were defined as having one or more of the following: spontaneous respiration, any cardiac activity, including electrocardiogram (ECG) findings other than asystole, measurable blood pressure, pupillary response, eye movements, or spontaneous movements on the time of arrival at the ED.

Statistical analysis

Continuous data are presented as means and standard deviations. The ISS and GCS are presented as median and range. Independent samples *t*-test and Fisher's exact test were used to investigate whether preoperative factors could predict the outcome. Pearson's correlation test was used to explore whether the number of ET were increasing during the study period. Statistical analysis was performed using the statistical software package SPSS, version 18.0 (SPSS, Inc., Chicago, IL). Differences were considered to be statistically significant when the p-value was <0.05.

Results

Rigshospitalet, Copenhagen, has the largest Level 1 trauma center in Denmark and receives all major thoracic trauma patients from eastern Denmark. Nine hundred patients are received annually at Rigshospitalet which require trauma

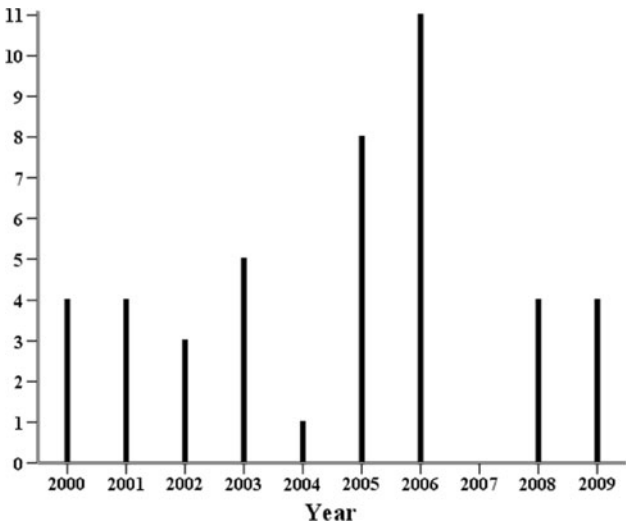

Fig. 1 Number of emergency thoracotomies (ETs) by year. Linear regression coefficient = 0.003

Table 1 Baseline characteristics

Variable	EDT ($n = 21$)	Missing	ORT ($n = 23$)	Missing
Sex, males	17		23	
Age (years)	40 ± 15		31 ± 13	
Time from emergency call to thoracotomy (min)	39 ± 49	3	101 ± 113	3
Penetrating	11 (52)		17 (74)	
Knife	7 (33)		13 (57)	
Gunshot	4 (19)		4 (17)	
Blunt	10 (48)		6 (26)	
Traffic accidents	8 (38)		6 (26)	
Fall accidents	2 (10)		0 (0)	
Injury Severity Score	34 (25–48)[a]		20 (16–29) [a]	
Probability of survival	44 ± 32		84 ± 27	
Systolic blood pressure at arrival to the emergency department	46 ± 41	1	103 ± 29	
Glasgow Coma Score at scene of accident	3 (3–14)[a]		14 (9–15)[a]	
Glasgow Coma Score at arrival to the emergency department	3 (3–11)[a]	1	15 (4–15)	
Intubated prior to arrival at the emergency department	8 (38)	1	4 (17)	
No signs of life at arrival to the emergency department	1 (5)		0 (0)	

All of the values are given as n (%) or mean ± standard deviation (SD), unless otherwise specified

[a] Presented as median and (quartile range)

team activation; around 245 of them are severely injured (ISS > 15).

During the 10-year study period, 44 ETs were performed. The number of ETs per year is shown in Fig. 1. No increasing or decreasing tendency was found regarding the frequency of ETs performed. The overall incidence was 4.4 ETs per year, giving an incidence of 1.8 per 100 severe trauma cases.

Table 1 shows the baseline characteristics divided into the two groups, EDT and ORT.

The mean age was 32 years (SD ± 14). Only four women underwent ET. In six patients, data regarding the time from trauma to ET were not available. Thirty-one (70%) patients survived the ET initially. Five (11%) of these died postoperatively, giving a 30-day mortality of 41% overall. Four patients died in the intensive care unit (ICU) and one patient died in the ward. The mechanisms of injury were penetrating in 28 (64%) and blunt in 16 (36%) patients. Five patients survived in the blunt trauma group and 21 survived in the penetrating trauma group. In the EDT group, eight cases arrived in cardiac arrest. Two of these cases survived. No patients arrived in cardiac arrest in the ORT group.

The survivors had a significantly lower ISS and higher PS score than the non-survivors, being $p = 0.02$ and $p < 0.001$, respectively, when looking at both ORT and EDT together (Fig. 2a, b).

Tables 2 and 3 show the two groups, grouped by outcome. The only significant differences found were ISS and PS in the ORT group.

One patient in the EDT and ten patients in the ORT group had a GCS of 15 at the scene of accident. All of these patients survived. In both groups, all cases that were intubated at the scene of accident had a GCS of <9. The patient in the EDT group underwent thoracotomy by means of cross-clamping the descending aorta. Out of the ten patients in the ORT group, seven had penetrating knife lesions, two were involved in traffic accidents, and one had been shot. Five had lung lesions, one combined heart and lung lesion, one tracheal lesion, two had smaller vascular lesions combined with lesion of the diaphragm and underwent laparotomy as well, and the final patient had a tracheal lesion due to a gunshot wound, found by bronchoscopy.

One patient had no SOL at arrival to the ER and did not survive. Six cases underwent thoracotomy due to SOL. Five of these had cardiac activity and one had spontaneous movement as the only SOL. One of these six cases survived a gunshot wound. The remaining five cases suffered stab wounds in three cases, one gunshot wound, and one traffic accident.

The intraoperative data are shown in Table 4. The dominating surgical approach was the left anterior thoracotomy, and the second most frequent was right anterior thoracotomy. Sternotomy was performed in five patients. In four patients, a combination of approaches was used; none of these patients survived.

In two cases, the ET were used as measures of aortic cross-clamping to control intraabdominal bleeding. One of these two patients survived. Nineteen of the patients also

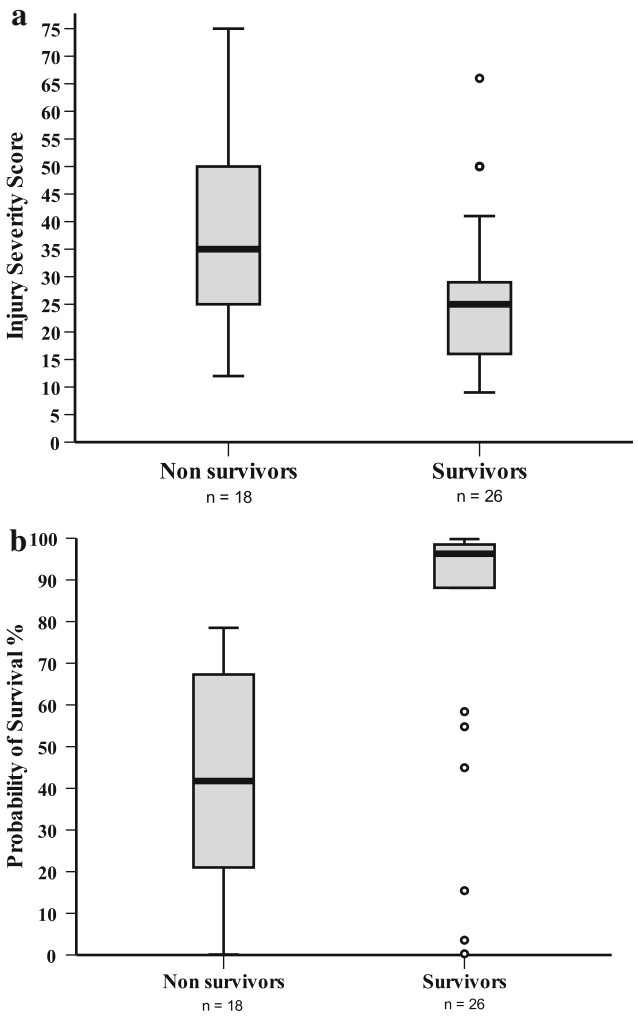

Fig. 2 **a** Box plot of the Injury Severity Score (ISS) and outcome. **b** Box plot of the probability of survival (PS) and outcome

underwent a laparotomy. Of these, nine patients survived for at least 30 days. The intraoperative data for these patients are shown in Table 5.

The calculated mean PS in our study was 44 and 84% in the EDT and ORT groups, respectively. Our actual survival was similar, with 33% in the EDT group and 83% in the ORT group.

Discussion

Our results on patient survival percentages were satisfactory and comparable with a study at a similar center, where Pahle et al. found a 37 and 12% survival rate for penetrating and blunt trauma, respectively, and a total survival of 18% (out of $n = 109$) [10]. In our study, we found 45 versus 20% survival rates for penetrating and blunt trauma, with a total survival of 33%, when looking at EDT only. The differences seen are probably due to our smaller sample size and a more liberal attitude towards ET at their center. Worth noting is also that 82 out of the 109 patients included in this study were subjected to blunt trauma. Comparing SOL, 93 and 100% of the nonsurvivors and survivors, respectively, had SOL on arrival to the ED in our study. Pahle et al. report rates of 75 and 95%; however, these numbers are on SOL at the scene of accident. Interestingly, in our study, the mean ISS score was 34 for both nonsurvivors and survivors in contrast to a mean score of 42 and 26, respectively, found by Pahle et al.

A study similar to ours, although from 1992, looked at both EDT and ORT [called ERTs (emergency resuscitative thoracotomies) in their study] and found a combined survival of 22.5% ($n = 200$), as opposed to the 59% found in

Table 2 Emergency department thoracotomies (EDT) grouped by outcome

Variable	Non-survivors ($n = 14$)	Survivors ($n = 7$)	p-value	Missing
Age	35 ± 16	32 ± 12	0.646	
Sex, males	11 (52)	6 (29)	0.593	
Penetrating	6 (55)	5 (46)	0.361	
Blunt	8 (80)	2 (20)		
Injury Severity Score	34 (21–46)[a]	34 (25–50)[a]	0.752	
Probability of survival	37 ± 28	57 ± 39	0.196	
Glasgow Coma Score	3 (3–12)[a]	8 (3–14)[a]	0.356	
Signs of life at arrival to the emergency department	13 (93)	6 (86)	0.494	
Thoracotomy <30 min after the emergency call	7 (58)	5 (42)	0.600	3[b]
Thoracotomy >30 min after the emergency call	5 (83)	1 (17)		

All of the values are given as n (%) or mean ± standard deviation (SD), unless otherwise specified

[a] Presented as median and (quartile range)

[b] Total number of patients with missing data on trauma to emergency thoracotomy (ET) time

Table 3 Operating room thoracotomies (ORT) grouped by outcome

Variable	Non-survivors ($n = 4$)	Survivors ($n = 19$)	p-value	Missing
Age	45 ± 23	28 ± 8	0.232	
Sex, males	4 (0)	19 (100)	–	
Penetrating	1 (6)	16 (94)	0.04	
Blunt	3 (50)	3 (50)		
Injury Severity Score	46 (36–50)[a]	16 (13–26)[a]	0.003	
Probability of survival	53 ± 20	90 ± 23	0.007	
Glasgow Coma Score	8 (4–13)[a]	12 (10–15)[a]	0.226	
Signs of life at arrival to the emergency department	4 (100)	19 (100)	–	
Thoracotomy <30 min after the emergency call	0 (0)	11 (58)	0.074	3[b]
Thoracotomy >30 min after the emergency call	3 (75)	6 (32)		

All of the values are given as n (%) or mean ± standard deviation (SD), unless otherwise specified

[a] Presented as median and (quartile range)

[b] Total number of patients with missing data on trauma to emergency thoracotomy (ET) time

Table 4 Intraoperative data

Variable	Total	Survivors[a]	Missing
Surgical approach			2
Left anterior thoracotomy	23 (52%)	14 (61%)	
Right anterior thoracotomy	10 (23%)	8 (80%)	
Sternotomy	5 (11%)	2 (40%)	
Combined	4 (9%)	0 (0%)	
Known lesions			
Cardiac	5 (11%)	3 (60%)	
Lung	23 (52%)	14 (61%)	
Greater arteries	7 (16%)	3 (43%)	
Greater veins	2 (5%)	1 (50%)	
Smaller vessels[b]	12 (27%)	10 (83%)	
Rib fractures	5 (11%)	3 (60%)	
Other	12 (27%)	9 (75%)	
None[c]	2 (5%)	0 (0%)	

[a] The values in the parentheses are given as percentages of the total numbers in the subgroups

[b] Vessels smaller than the internal mammary artery in diameter

[c] One of these patients underwent laparotomy and had injuries to the spleen and intestines

Table 5 Combined thoracotomy and laparotomy intraoperative data

Variable	Total ($n = 19$)	Survivors[a] ($n = 9$)	Missing
Mechanism of injury			
Penetrating	10 (53%)	7 (70%)	
Blunt	9 (47%)	2 (22%)	
Subgroup			
EDT	11 (58%)	4 (36%)	
ORT	8 (42%)	5 (63%)	
Known thoracic lesions			
Cardiac	2 (11%)	1 (50%)	
Lung	10 (53%)	5 (50%)	
Greater arteries	2 (11%)	1 (50%)	
Smaller vessels[b]	5 (26%)	3 (60%)	
Other	1 (5%)	1 (100%)	
None	1 (5%)	0 (0%)	
Known intraabdominal lesions			1
Liver	8 (42%)	2 (25%)	
Spleen	5 (26%)	1 (20%)	
Intestines	5 (26%)	2 (40%)	
Larger vessels	4 (21%)	2 (50%)	
Other	1 (5%)	1 (100%)	

[a] The values in the parentheses are given as percentages of the total numbers in the subgroups

[b] Vessels smaller than the internal mammary artery in diameter

our study [15]. Survival in the ORT group was 49% compared to 83% in our study. There are, however, no ISS or PS scores available from this study, so the patients might be more severely injured than in our study. Our superior results are likely due to advances not only in the perioperative care of the patient, but, in particular, to prehospital and intensive care.

In contrast, a review of 24 studies which included 4,620 cases made by Rhee et al. found an overall survival of 7.4% [4]. Survival rates for penetrating versus blunt injuries were found to be 8.8 and 1.4%, respectively. This study looked at EDT only and included patients from 1978 to 1998. The lower survival rates might be explained by the inclusion of these older cases. There are no data on the ISS on these patients. Only 2.6% of these patients survived if they presented with no SOL at arrival to the ED compared to 0% in our study.

In our study, the numbers of ETs were fluctuating with no increasing or decreasing tendency during the 10-year

period. As mentioned earlier, the PS is scored externally. This reduces the risk of observer bias and could produce a higher PS score compared to other studies that use internal scoring. Our study clearly shows that a fraction of our patients with low PS score and high ISS survived, as evident by Fig. 2a, b. These data justify a more liberal approach towards performing ET at our center. Our calculated PS and observed survival were similar. This suggests that PS is a good predictor of the outcome in these patients and, thus, could be used as a tool when comparing studies.

Seamon et al. suggest that EDT should be performed as long as SOL were present in the field, even without SOL in the ED, in penetrating trauma with a short prehospital transport time [16]. We could not obtain data regarding prehospital SOL. Rhee et al. suggest that ET is contraindicated in patients without SOL in the field, regardless of the trauma mechanism [4]. The single case in our study who had no SOL on arrival supports this suggestion.

Interestingly, as mentioned before, ten patients in the ORT group had a GCS of 15 at the scene of accident. Eight of them arrived at the ED <30 min after the emergency call, which could form part of the explanation. In the ORT group, all patients who underwent thoracotomy within 30 min survived (Table 3). This might suggest that a fast preparation in the ER and immediate transport to the OR is favorable in selected patients.

An important aspect regarding ET is the potential outcome of organ donation among these patients. A study recently published by Schnüriger et al. included a total of 263 EDT [17]. All injured patients arriving to the resuscitation area with an unobtainable pulse underwent EDT. Forty-eight patients reached the ICU alive. Interestingly, 11 of these patients became potential organ donors. Although only three patients became actual donors, donating a total of 11 organs, there might be a great potential here provided by an increased awareness on the subject.

Limitations of our study are the small population, retrospective design, and only 30 days follow up. Newer studies are required to evaluate the need for and the success rate of the procedure, especially since there have been major advances in both the prehospital and postoperative care of the patients. Newer studies should also include an ISS and a PS score in order to make the results easier to compare with other studies.

Conclusions

In conclusion, we found that emergency thoracotomy (ET) saves lives, even in blunt trauma and in cases that are later recognized as having a high Injury Severity Score (ISS) or low probability of survival (PS), favoring a more aggressive approach towards ET. Our results also indicate a higher survival rate when the transport time was less than 30 min.

Conflict of interest None.

References

1. Working Group, Ad Hoc Subcommittee on Outcomes, American College of Surgeons, Committee on Trauma. Practice management guidelines for emergency department thoracotomy. J Am Coll Surg. 2001;193:303–9.
2. Hopson LR, Hirsh E, Delgado J, Domeier RM, Krohmer J, McSwain NE Jr, Weldon C, Friel M, Hoyt DB. Guidelines for withholding or termination of resuscitation in prehospital traumatic cardiopulmonary arrest. J Am Coll Surg. 2003;196:475–81.
3. Meredith JW, Hoth JJ. Thoracic trauma: when and how to intervene. Surg Clin North Am. 2007;87:95–118, vii.
4. Rhee PM, Acosta J, Bridgeman A, Wang D, Jordan M, Rich N. Survival after emergency department thoracotomy: review of published data from the past 25 years. J Am Coll Surg. 2000;190:288–98.
5. Søreide K, Petrone P, Asensio JA. Emergency thoracotomy in trauma: rationale, risks, and realities. Scand J Surg. 2007;96:4–10.
6. Rashid MA, Wikström T, Ortenwall P. Cardiac injuries: a ten-year experience. Eur J Surg. 2000;166:18–21.
7. Rashid MA, Wikström T, Ortenwall P. Outcome of lung trauma. Eur J Surg. 2000;166:22–8.
8. Rashid MA, Wikström T, Ortenwall P. Thoracic vascular injuries: a major problem in trauma. Scand Cardiovasc J. 2001;35:285–7.
9. Søreide K, Søiland H, Lossius HM, Vetrhus M, Søreide JA, Søreide E. Resuscitative emergency thoracotomy in a Scandinavian trauma hospital—is it justified? Injury. 2007;38:34–42.
10. Pahle AS, Pedersen BL, Skaga NO, Pillgram-Larsen J. Emergency thoracotomy saves lives in a Scandinavian hospital setting. J Trauma. 2010;68:599–603.
11. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:187–96.
12. Champion HR, Sacco WJ, Copes WS. Injury severity scoring again. J Trauma. 1995;38:94–5.
13. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma. 1987;27:370–8.
14. Hunt PA, Greaves I, Owens WA. Emergency thoracotomy in thoracic trauma—a review. Injury. 2006;37:1–19.
15. Jurkovich GJ, Esposito TJ, Maier RV. Resuscitative thoracotomy performed in the operating room. Am J Surg. 1992;163:463–8.
16. Seamon MJ, Fisher CA, Gaughan JP, Kulp H, Dempsey DT, Goldberg AJ. Emergency department thoracotomy: survival of the least expected. World J Surg. 2008;32:604–12.
17. Schnüriger B, Inaba K, Branco BC, Salim A, Russell K, Lam L, Plurad D, Demetriades D. Organ donation: an important outcome after resuscitative thoracotomy. J Am Coll Surg. 2010;211:450–5.