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Emergency thoracotomy as a rescue treatment for trauma patients in Iceland

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ABSTRACT

Objective: Emergency thoracotomy (ET) can be life-saving in highly selected trauma patients, especially after penetrating chest trauma. There is little information on the outcome of ET in European trauma centres. Here we report our experience in Iceland.

Material and methods: This was a retrospective analysis of all patients who underwent ET in Iceland between 2005 and 2010. Patient demographics, mechanism, and location of major injury (LOMI) were registered, together with signs of life (SOL), the need for cardiopulmonary resuscitation (CPR), and transfusions. Based on physiological status from injury at admission, the severity score (ISS), revised trauma score (RTS), and probability of survival (P_S) were calculated.

Results: Of nine ET patients (all males, median age 36 years, range 20–76) there were five long-term survivors. All but one made a good recovery. There were five blunt traumas (3 survivors) and four penetrating injuries (2 survivors). The most frequent LOMI was isolated thoracic injury ($n = 6$), but three patients had multiple trauma. Thoracotomy was performed in five patients, sternotomy in two, and two underwent both procedures. One patient was operated in the ambulance and the others were operated after arrival. Median ISS and NISS were 29 (range 16–54) and 50 (range 25–75), respectively. Median RTS was 7 (range 0–8) with estimated P_S of 85% (range 1–96%). Median blood loss was 10 L (range 0.9–55). A median of 23 units of packed red blood cells were transfused (range 0–112). For four patients, CPR was required prior to transport; two others required CPR in the emergency room. Three patients never had SOL and all of them died.

Conclusion: ET is used infrequently in Iceland and the number of patients was small. More than half of them survived the procedure. This is especially encouraging considering how severely injured the patients were.

Introduction

In most developed countries, trauma is one of the leading causes of death in all age groups, with thoracic trauma accounting for 25–50% of all fatal injuries.[1] Most patients with thoracic trauma can be managed non-operatively, with or without chest tube insertion. However, a small number of patients, especially those with penetrating chest trauma, may require emergency thoracotomy (ET).[2] ET allows direct evacuation of tamponating haemorrhage, immediate control of haemorrhage, and repair of injury and direct cardiac massage can be performed.[3] The indications for ET are still under debate, especially in the case of blunt trauma where less than 2% of patients survive the procedure (range 0–2%). It is therefore rarely indicated, as stated in the eighth edition of the advanced trauma life support (ATLS) guidelines.[4,5] Outcome of ET for penetrating trauma has been more encouraging, however, especially if it is affecting the heart, and an average survival rate of 19% (range 5.1–72.2%) for penetrating trauma was reported from a meta-analysis by Rhee et al.[6]

With more efficient out-of-hospital resuscitation and more efficient transport of trauma patients, more patients are still alive when they arrive at hospital following major trauma.[2] ET has become an established procedure for some of these patients, and when performed for the right indications, it appears to save lives. However, the costs and the risk of blood-borne infections to the operating team are not negligible.[3,7,8] Thus, analysis of the outcome of ET is important for trauma units, both large and small. So far, experience with ET has mostly been gained in large trauma centres in the USA and South Africa, countries in which penetrating chest trauma is far more common than in Europe.[2,9] Furthermore, there has been a lack of European studies on ET, especially from smaller trauma centres where blunt trauma is more common than penetrating, such as trauma centres in

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Scandinavia.[9] Studies on isolated cardiac and lung trauma have been reported from Sweden.[10] Furthermore, two Norwegian reports have described the outcome of ET for thoracic trauma patients: one from a trauma unit in Stavanger with none of 10 patients surviving the procedure[9] and another from Oslo with 18% survival out of 105 ETs performed.[11]

Our aim was therefore to investigate the use of ET in a whole nation over several years, by making use of the centralized trauma and operation registries in Iceland.

Materials and methods

This was a retrospective case series involving consecutive patients who underwent ET for major thoracic trauma in Iceland between January 1, 2005 and December 31, 2010.

In Iceland, which had a population of 310,000 in December 2010, primary trauma care is provided in small hospitals in each quarter of the country. The only tertiary trauma hospital, Landspitali, is located in the capital (Reykjavik). About 170,000 people live within 7 min of ambulance transport to the hospital.[12]

All specialities are represented at Landspitali, including cardiothoracic surgery and neurosurgery. Patients are transported to the hospital either in an ambulance escorted by a paramedic or in a helicopter escorted by a physician. Each year, over 25,000 trauma patients are seen in Landspitali, with around 70 of them (0.003%) presenting with severe injuries (ISS score above 16).[13] There is an advanced trauma life support (ATLS) certified trauma team that includes a senior emergency doctor, an anaesthetist, and a general surgeon with immediate consultations available from all other specialities, including cardiothoracic surgery.

Included in the study were patients who underwent ET either for penetrating trauma or for blunt trauma. All ETs performed for non-traumatic indications (e.g. following open heart surgery or ruptured aortic aneurysms) were excluded.

Patients were identified using the centralized, computerized trauma database and the operation registry at Landspitali University Hospital, the only centre performing cardiothoracic surgery in Iceland. In addition, we contacted surgeons from other hospitals in Iceland if ET had been performed for trauma at their hospitals during the study period.

Baseline demographic information and clinical data were collected from pre-hospital reports, patient charts, surgical descriptions, and autopsy reports using a standardized data sheet. Data collected included information on age, gender, mechanism of injury (gunshot wound, stab wound, motor vehicle accident, compression, or fall) and location of major injury (LOMI). The presence of signs of life (SOL) was registered during the pre-hospital phase and transportation of the patient, and also on arrival at the emergency department. SOL was defined as being at least one of the following: spontaneous respiratory effort, pupillary response, extremity movement, measurable or palpable blood pressure, or cardiac electrical activity. For each patient, the need for cardiopulmonary resuscitation (CPR) and transfusions was registered together with the length of hospital stay. Injury severity score (ISS) and new injury severity score (NISS) were calculated for all patients based on the abbreviated injury scale (AIS) code. The AIS is an anatomical scoring system that provides reasonably accurate ranking of the severity of injury.[14] ISS is an anatomical scoring system that provides an overall score for patients with multiple injuries. The final score is based on AIS score for each patient. The ISS and NISS score takes values from 0 to 75. An ISS and NISS score higher than 15 is considered to represent severe injury, but NISS is a considered statistically outperform ISS score when analysing patients with multiple injuries within the same body region.[15,16] Based on physiological status on first medical contact in the ambulance (Glasgow coma scale, respiratory rate, and systolic blood pressure), we calculated both the revised trauma score (RTS) and the chance of survival (P_S) using the TRISS methodology.[17]

The procedures usually consisted of left or right thoracotomies, sternotomy, or both – and often included pericardiotomy and open heart massage. All the cases were true emergency cases and six were resuscitative. The ETs were usually performed in the emergency room or in the operating room (OR) next to the emergency room. If the patients survived the ET, they were transferred to the main operating room for definitive control of bleeding and repair of the injury. Information on the exact timing of the ET after arrival (in minutes) was not registered for all patients. In most cases, however, the surgeries were performed straight after arrival at the hospital, and usually within 30 min.

The decision to perform ET was based on the discretion of the attending cardiothoracic (CT) or trauma surgeon. During the study period, FAST (focused abdominal sonography in trauma) examination was not available in Iceland for the diagnosis of tamponade, and the diagnosis was therefore clinically based. All the ETs, except one performed by a junior trauma fellow in the ambulance, were done by three surgeons (two CT surgeons and one general surgeon) using a standardized technique for both anterolateral thoracotomy (above costae 4 or 5) and sternotomy (with a sternal saw).

The primary outcome analysed was hospital mortality together with long-term survival and neurological outcome. Normal neurological outcome was defined as functional status without any major sequelae and the ability to perform activities of daily living without difficulty.

Microsoft Excel was used for descriptive statistics, both for continuous and categorical variables. All patients were followed up regarding survival (December 31, 2010) by using data from the Icelandic National Population Registry. Median follow-up time for the 5 survivors was 12 months (range 12–24 months). The incidence was age-standardized to the WHO Europe (Scandinavia) population using the Epitools package in R (www.r-project.org).

The study was approved by the Icelandic National Bioethics Committee and the Data Protection Authority. As individual patients were not identified, the need for individual consent was waived.

Results

Nine patients underwent ET for trauma during the six-year study period, one patient in 2005, two in 2006, and 6 in 2007, giving an incidence (age-standardized to the WHO) of 1.3 per 100,000 inhabitants per year (95% CI 0.61–2.62). There were five long-term survivors; three made a good recovery without any neurological sequelae, but one sustained mild anoxic brain injury. Additionally, one patient had paraplegia related to spinal injury that was part of the multiple injuries incurred from a motor vehicle accident.

Baseline characteristics of the patients are given in Table 1. All the patients were males and their median age was 36 years (range 20–76). There were five blunt traumas, three of them motor vehicle injuries. In addition, there were four penetrating injuries: two patients had gunshot wounds and two patients had stab wounds. Three of 9 patients were injured outside the capital of Reykjavik; two of these patients were transported to the emergency department by ambulance and the third patient was transported by air ambulance.

The most frequent LOMI was the thorax (isolated thoracic injury, $n = 6$), but three patients had multiple trauma. The most common indication for ET was either suspected ($n = 6$) or confirmed pericardial tamponade ($n = 1$). Thoracotomy was performed in five patients, sternotomy in two, and other two underwent both procedures. One patient had ET in the ambulance

Table 1
Baseline characteristics of 9 patients who underwent ET in Iceland 2006–2010, including mechanism of injury, location, type of surgical approach, severity scores, and estimated chance of survival.

Case no	Age/sex	MOI	LOMI	Sternotomy/Thoracotomy	ISS	NISS	RTS	P_S (%)	Outcome
1	48/M	Penetrating, thoracic GSW	Multiple	N/Y	42	57	7.84	89	Lived
2	47/M	Penetrating, thoracic SW	Thoracic	Both	29	29	6.9	90	Lived
3	32/M	Blunt, MVA	Thoracic	Both	54	75	6.38	55	Lived
4	29/M	Blunt, MVA	Multiple	N/Y	50	50	7.84	85	Died
5	39/M	Blunt, fall > 4 m	Thoracic	N/Y	26	66	6.9	96	Lived
6	36/M	Blunt, compression	Thoracic	N/Y	41	75	7.84	92	Lived
7	35/M	Penetrating, thoracic GSW	Thoracic	Y/N	16	26	0.00	4	Died
8	76/M	Blunt, MVA	Thoracic	N/Y	25	25	0.00	1	Died
9	20/M	Penetrating, thoracic SW	Multiple	Y/N	20	34	0.00	3	Died

MOI, mechanism of injury; LOMI, location of major injury; ISS, injury severity score; NISS, new injury severity score; RTS, revised trauma score; P_S, chance of survival; M, male; GSW, gunshot wound; SW, stab wound; MVA, motor vehicle accident; N, no; Y, yes.

prior to arrival at the hospital but the other eight patients were operated on after arrival, four in the emergency room and the other four in an operating room close to the emergency room. CPR was required at the scene for four patients and for two others in the emergency room. For three patients, there were never any SOL and all of them died. All of the five survivors had GCS $\geq$ 10 (range 10–15) and SBP $\geq$ 100 mmHg (range 100–144) at first medical contact in the ambulance. Three of those who died had asystole and GCS below 4 (Table 3).

Median ISS and NISS were 29 (range 16–54) and 50 (range 25–75), respectively, indicating severe injury (Fig. 1). Median RTS was 7 (range 0–8) with an estimated chance of survival (P_S) of 85% (range 1–96) (Table 1).

Table 2 shows estimated blood loss and transfusion requirements for the patients. Median blood loss was 10 L (range 0.9–55) and a median of 23 units of packed red blood cells (RBCs) were transfused (range 0–112). For one patient (no. 5), blood loss was only 0,9 L and transfusion was not needed. In four patients (none of whom survived), blood loss was inadequately documented; however, major bleeding was present in all cases (Table 2).

ET was the only procedure performed in five patients, but four required further surgery. One of them (no. 1) needed transverse colectomy and colostomy together with splenectomy and repair of a diaphragmatic rupture. Two patients (nos. 3 and 6) were operated later, after they had been hemodynamically stabilized. The fourth patient (no. 9) needed both sternotomy for thoracic injuries and laparotomy to control severe liver injury, and was declared dead in the emergency room (see Fig. 2).

Autopsy was performed in the four patients who did not survive and revealed severe injuries and major bleeding as the cause of death in all cases. Three of the four patients who died had the lowest ISS and NISS scores of all the patients, but the mean ISS and NISS values for survivors were 41 and 66, respectively, as opposed to 23 and 30 for non-survivors (Table 1).

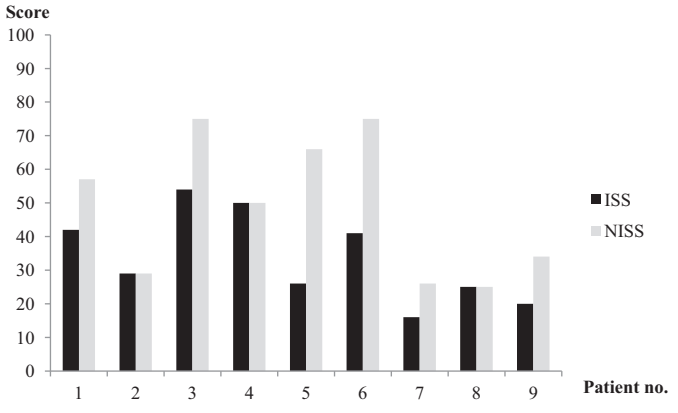

Fig. 1. ISS and NISS scores for 9 patients who underwent ET for thoracic trauma in Iceland between 2005 and 2006. The median ISS and NISS scores were 29 and 50, respectively.

Discussion

The main findings of this study are that five out of nine patients who were operated on with ET survived the procedure and were discharged home, most of them in good health. All nine patients had sustained serious injuries, and the ET was performed as a last resort treatment on life-saving indications.

Our results are encouraging compared to several larger series from the USA and South Africa, where survival rate of 1.8–25.5% after ET have been reported. In contrast to our study and most other studies from Europe, penetrating trauma was more common in those studies (often in the 37–68% range). This is important, since outcomes following ET are more favourable after penetrating trauma (2.7–30.8%) than after blunt trauma (0–12.5%).[18] In a recent study by Pahle et al., the survival of patients with penetrating trauma was 37% as compared to 12% for blunt trauma, and penetrating injury constituted 25% of the cases.[11] Furthermore, in a study by Cothren et al., patients with penetrating cardiac wounds that presented in hypovolemic shock in the emergency department had approximately 35% survival and 15% for all patients with penetrating wounds. The worst outcome for ET was documented after blunt trauma: 2% survival for patients in shock and less than 1% if the patient had no SOL.[4]

Soreide et al. reported no survivors in a series of 10 ETs performed over a five-year period in a West-Norwegian community hospital, which was of similar size to that of our trauma centre at Landspitali.[9] The authors questioned whether ET was justified in a small Scandinavian hospital, and called for additional outcome analysis on ET from small European trauma centres. Pahle et al.

Table 2
Number of transfusions and outcome for patients who underwent ET for thoracic trauma in Iceland between 2005 and 2010.

Case no	Blood loss (L)	RBCs (units)		FFP (units)	Platelets (bags)	Outcome
		O neg	Matched			
1	30	11	26	31	4	Lived
2	10	8	15	10	1	Lived
3	55	12	100	46	4	Lived
4	[a]	8	[b]	[b]	[b]	Died
5	0.9	[b]	[b]	[b]	[b]	Lived
6	4.7	12	16	26	2	Lived
7	[a]	23	[b]	[b]	[b]	Died
8	[a]	8	[b]	[b]	[b]	Died
9	[a]	5	[b]	[b]	[b]	Died

RBCs: packed red blood cells, FFP: fresh frozen plasma.
[a] Information on blood loss incomplete.
[b] Did not receive transfusions.

Table 3
Emergency thoracotomy descriptives for 9 patients who underwent ET for thoracic trauma in Iceland between 2005 and 2010.

Case no	Clinical indication	CC-CPR/ DCM		SOL				ET location	Outcome
		PH	ER	SBP (mmHg) GCS	On-scene	Transport	ER		
1	Suspected tamponade	N/N	Y/N	100 13	Y	Y	Y	ER	Lived
2	Suspected tamponade, CA	N/N	Y/Y	110 10	Y	Y	Y	ER	Lived
3	Pericardial tamponade, traumatic aortic dissection	N/N	N/N	100 14	Y	Y	Y	OR	Lived
4	Suspected tamponade, CA	Y/N	Y/Y	110 15	Y	Y	N	ER	Died, ER
5	Myocardial rupture	N/N	N/N	144 12	Y	Y	Y	OR	Lived
6	Hemothorax, suspected tamponade, traumatic aortic dissection	N/N	N/N	135 15	Y	Y	Y	OR	Lived
7	Suspected tamponade, CA	Y/N	Y/Y	Asystole 3	N	N	N	ER	Died, ER
8	Suspected tamponade, CA	Y/N	Y/Y	Asystole 3	N	N	N	Transport	Died, ER
9	Suspected tamponade, CA	Y/N	Y/Y	Asystole 3	N	N	N	OR	Died, OR

CC-CPR, closed-chest cardiopulmonary resuscitation; DCM, direct cardiac massage; SOL, signs of life; ET, emergency thoracotomy; PH, pre-hospital; ER, emergency room; N, no; Y, yes; CA, cardiac arrest; OR, operating room; SBP, systolic blood pressure; GCS, Glascow coma scale.

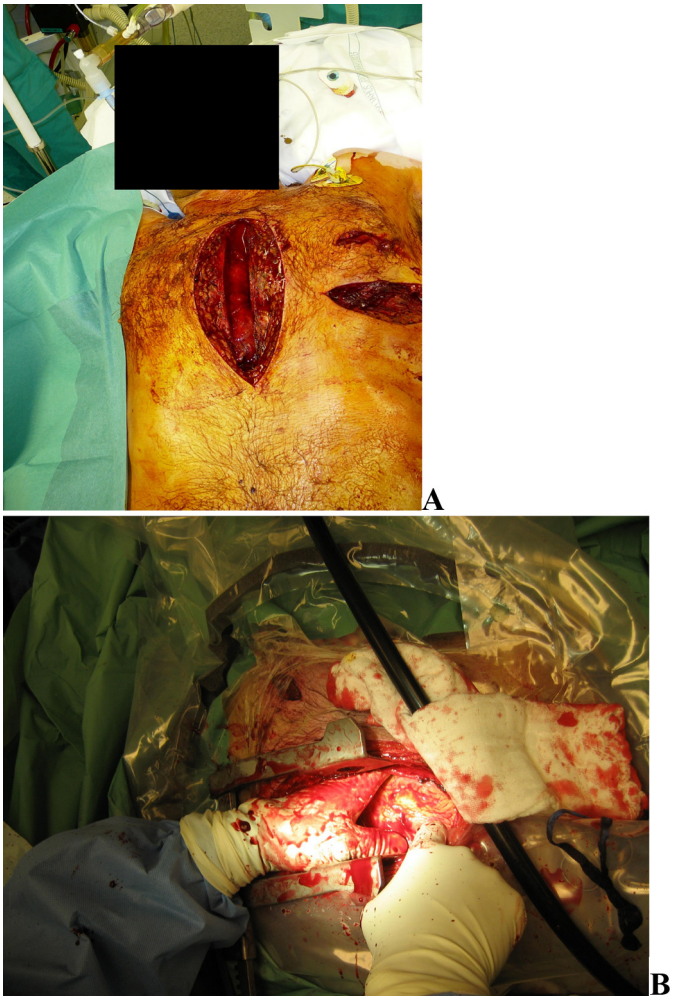

Fig. 2. Photographs taken in the emergency room of Landspitali Hospital when ET was performed for stab wound injury causing acute pericardial tamponade and cardiac arrest (patient no. 2). A. The injury on the thoracic wall (arrow). B. The right index finger of the surgeon can be seen covering the 2-cm hole in the right ventricle. First, an anterolateral thoracotomy was performed to remove pericardial tamponade and give direct cardiac massage. Directly afterwards, a sternotomy was performed to close the hole in the right ventricle with patched sutures. The patient had uneventful recovery.

came to another conclusion, and with their 18% survival suggested a liberal attitude to ET on the agonal patient by a trained trauma team.[11]

Our favourable outcome could be related to the short transportation time in Reykjavik (less than 7 min on average[12]) and the readily available cardiothoracic services. Furthermore, at Landspitali Hospital, the trauma teams have been trained according to the ATLS protocol since the two emergency departments at Landspitali for adults were merged in the year 2000.

This study shows that ET is rarely used in Iceland, with only 9 operations performed in a six-year period, giving an annual incidence of 1.3 in 100,000. This is in line with other studies, including the study by Soreide et al.[9] Our figures represent a whole nation, and to our knowledge such population-based figures for ET have not been reported before. The incidence of ET depends on the indications for ET in trauma patients, but in Iceland no formal guidelines for ET have been introduced yet. Furthermore, the indications for ET in the literature vary widely.[8] This is reflected in publications on ET, but for the past three decades there has been a significant clinical shift in the performance of ET, from being almost obligatory as a last resort to being performed in a highly selected population of trauma patients.[19,20] However, recent studies have suggested that ET is contraindicated in multitrauma blunt injuries with thoracic trauma, injuries with no witnessed cardiac activity, and severe head injuries.[8,20]

Four of the patients in the present study had penetrating injuries and two of them died both without any SOL. One of these patients had a gunshot injury to the main stem of the right pulmonary artery and was exsanguinated on arrival at the emergency department. Five patients had blunt trauma and two of them died, including one without any SOL when the paramedics arrived on the scene. The indication for ET in that case could be argued, especially as the time of transport from the scene to the emergency department exceeded 30 min. All patients without SOL at admission died. This is in line with the study by Lustenberger et al. where none of 13 patients without SOL survived the ET.[21] The length of pre-hospital CPR has also been shown to be of importance when deciding whether to perform ET, and in the study by Moore et al., ET was considered futile care if CPR before arrival at the ER exceeded 10 min after blunt trauma or exceeded 15 min after penetrating trauma without SOL.[22] In the present study, the length of CPR was not properly documented for all cases.

Interestingly, three of the four non-survivors in the present study had the lowest ISS scores and two had the lowest NISS score. These scores, which should indicate the severity of a patient's injury,[15,16] did not therefore reflect the physical stability of the patients at first medical contact or the transportation time to hospital. In contrast, these patient had the lowest P_S, where the patient's age, type of trauma (blunt vs. penetrating), physical stability at first contact, GCS score, systolic blood pressure, and breaths per minute are taken into consideration.[17] We have no good explanation for this inconsistency in NISS and RTS scores; however, it has to be remembered that the ET patients were highly selected. Patients who are injured in rural areas are less likely to be candidates for ET, as transport time is often extended and the decision to perform ET is usually not taken at the scene of the trauma. This could have generated a better outcome. In the study by Pahle et al., survivors of penetrating injury had lower ISS scores and higher RTS and GCS scores, but no such association was found for blunt trauma.[11]

Although the survival of patients who undergo ET is often low, the survivors most often have a good neurological outcome, ranging between 50% and 100% in different studies.[23,24] Of the five long-term survivors in the present study, three had good neurological recovery. This is in line with other studies, including the study by Rhee et al. where normal neurological function was reported in 92% of 303 survivors.[6]

Three of the patients had multiple injuries. The others had isolated thoracic trauma but often with severe bilateral injuries. The fastest and safest opening was chosen, as was the type of ET based on the discretion of the attending surgeon. As most cases were performed by an experienced CT surgeon, the number of sternotomies was higher than described in many other series.[11,21] We are not advocating sternotomy as the first choice for trauma patients, although this strategy appears to have worked for several of our patients. We recommend following guidelines that propose left thoracotomy in most instances, especially if the ET is not performed by a CT surgeon.

The strength of this study was its nationwide design, with all patients treated in a single tertiary referral trauma centre. The limitations were the limited number of patients, the retrospective collection of data, and the fact that only six years were studied.

In summary, this study has shown that ET is rarely used for trauma in Iceland where blunt trauma predominates. Although the number of patients in this series was small, our results are encouraging, with five out of 9 patients surviving the procedure. This is especially true when considering how severely injured these patients were.

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Conflict of interest

The authors declare that there is no conflict of interests.

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