

Emergency Thoracotomy in a Swedish Setting: A Consecutive Series of 45 Patients from a Scandinavian Trauma Hospital

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Abstract

Background: Emergency thoracotomy (ET) has previously been studied and evaluated in an American and African perspective. The mechanism of injury (MOI) varies between different parts of the world. In the Northern European setting, blunt trauma is the most common MOI. Regarding penetrating thoracic injuries stab wounds comprises the majority whereas gunshot wounds (GSW) are relatively scarce. The aim of this study was to describe the situation at a Scandinavian Trauma Hospital.

Method: This study was a retrospective case series involving all patients who underwent an ET between 2004 and 2011 at a single centre. Patients were identified and data collection of demographics, trauma scores and physiological values were retrieved from hospital charts and trauma registry. Statistical analyses were performed.

Results: A total of 45 ET patients were identified. The patients were predominately male (82%), and severely injured with median ISS of 48. The overall survival rate was 31%. Blunt trauma accounted for 60% of the patients. Survival following penetrating thoracic trauma had a 50% survival rate, whereas blunt trauma had a 19% survival rate.

Conclusion: The injury pattern preceding ET is different between America and Europe. Blunt trauma accounts for the majority of cases. Penetrating trauma is mostly caused by stab wounds which carry a better prognosis than gunshot wounds (GSW). There is clearly a value in performing ET for selected cases following penetrating thoracic violence. Most of the surviving cases of thoracotomy for blunt trauma were for aortic cross clamping to control abdominal bleeding. Isolated blunt trauma to the chest carried a dismal prognosis.

Keywords: Emergency thoracotomy; Injury; Stab wounds

Introduction

Penetrating or blunt trauma to the chest resulting in emergency thoracotomy has long been considered the epitome of trauma surgery in the mind of trauma surgeons and the population in general. Emergency Thoracotomy (ET) established its place in the therapeutic arsenal as a treatment for intrathoracic injuries in the late 1960s following the experiences from WWII and the Vietnam War. The pendulum has gradually swung from an initial eagerness for ET, over a period of conservative approach, back to a more selective and restrictive treatment based on newer including several meta analyses of a substantial number of cases [1,2]. Data regarding ET as a primary treatment for penetrating chest trauma might be considered encouraging, whereas blunt injury to the chest carries a dismal prognosis following ET [3-7]. Later studies from high-volume trauma centres in America have established relatively firm criteria and indications for when surgery is feasible with a reasonable success rate [8]. Extensive data collection has distinctly shown the importance of proper patient selection, limiting the previous far-reaching indications that at the time caused ethical concern and risked to put the procedure to disrepute [9-11]. Current guidelines, with timeframes, and with regard to sign of life (SOL) on the scene of accident and the adoption of ATLS have had an impact on the indication, and the concurrent results regarding survival [8].

The rate of severe chest injury requiring emergency treatment in Sweden is exceptionally low in an international perspective. This fact might be due to strict gun laws, a high degree of traffic safety improvements and a relatively equal socio-economic society in general.

Despite the low rate of traumatic injuries, trauma is still by far the leading cause of mortality and morbidity in the population aged 15-44. Deaths attributable to violence (gun shot or stab wounds) accounts for 0.9/100000 death causes annually.

The majority of thoracic trauma patients can be managed by simple interventions like chest tube insertions, drainage and debridement, whereas a small percentage of trauma patients requires a thoracotomy for survival [12].

In Scandinavia the majority of trauma patients with thoracic injuries have sustained blunt trauma whereas the opposite is true in the American setting. Previous studies originating from major trauma centres in USA, may thus not be applicable in a northern European setting [13-17]. The American trauma centres are mostly located in big city areas, and with a brief pre-hospital time span before delivery to the ER. This seldom is the case in Sweden. With the different panorama of mechanism of injury (MOI), longer transport time, and with less frequently activated trauma teams, it is of interest to study the Northern European situation.

Currently only a small number of European and Scandinavian studies exists, mostly low volume case series from single institutions with disparate data and conclusions [18-22]. There is a call for further studies in Northern Europe to investigate and evaluate ET in this setting [18]. Despite ATLS algorithms and mandatory continuous medical training

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for experienced trauma surgeons there has over the last couple of years been no tendency in Sweden to more liberally perform a thoracotomy as an emergency procedure which currently has an incidence of 0.13 procedures /100.000 inhabitants a year. Trauma related deaths affecting the population between 15-74 years of age are at 30/100.000 inhabitants on a yearly basis. In light of these numbers, emergency thoracotomy might be a neglected procedure given its low usage rate in Scandinavia.

Population and trauma hospital

Sweden being the fourth largest country in Western Europe but with only a mere 1.5% of the inhabitants, have large rural areas and scattered areas of more dense population, this leading to a relatively long transfer time from the place of accident to the nearest hospital. The county manages healthcare and pre-hospital service.

Sahlgrenska University Hospital (SU), is the major trauma hospital for 950 000 citizens and the trauma referral centre for a broader population of 1.75 million people in Western Sweden. The hospital has a total of 2100 berths, and about 500 visits to the emergency department (ED)/day. All specialities are represented at the hospital including Neurosurgery, Thoracic Surgery and Trauma Surgery.

Trauma team at Sahlgrenska University Hospital

The hospital has a designated trauma team consisting of a senior general surgeon-in-training, orthopaedic surgeon-in-training, anaesthesiologist-in-training, emergency nurse, anaesthesiology nurse, radiology technician and secretary. The severity of the trauma is graded accordingly to the mechanism and forces of violence in the methodology METTS/RETTTS, and in the case of high energy trauma a senior General Surgeon and Anaesthesiologist joins the team [23]. The trauma team is present in the emergency room at the arrival of the patient. Other consultants' i.e. cardiothoracic surgeon / neurosurgeon are requested when needed by the trauma leader. The trauma team members are ATLS certified. The trauma team is activated approximately 1000 times a year, leading to approximately 500 admissions to the ICU and trauma ward on a yearly basis. The decision to perform ET is on behalf of the trauma leader, with the current version of ATLS manual used as guidelines.

Emergency thoracotomy at the study hospital

The trauma leader performed the majority of the ETs in the current study inside the Emergency Room. Some of the procedures were performed en route to the adjacent OR. There were no ETs taking place in EMS service or outside of hospital. ETs were performed by a number of different surgeons in different levels of training and expertise, senior residents as well as qualified vascular, thoracic and trauma surgeons.

Our standard ET technique is an anterolateral incision for cross clamping of the thoracic aorta and open cardiac massage, cardiac suture or major vessel repair, and this was performed in the majority of cases. However, in the study material different kind of primary approaches exist, relating to the mechanism and extent of injury. Primary clamshell as well as right sided anterolateral approaches and regular sternotomies is infrequently used throughout the series.

Study design

The present study is a retrospective consecutive case series including all the patients arriving at Sahlgrenska University Hospital in extremis that had an ET 2004-2011. Patients in the inclusion period were identified from pre-hospital charts, hospital records, operating registry, and a central trauma database.

All ETs performed on trauma patients without a vital indication

were considered urgent or immediate thoracotomies and excluded. Thoracotomies performed after a substantial delay, such as CT-scans, or with waiting time for another surgeon to arrive, were also considered urgent and excluded. The time span from accident to thoracotomy was below 2 hours in all our cases.

Data retrieval and statistical analyses

All available data was crosschecked and reviewed. Due to an almost complete computerization of charts, reports and other data, a significant amount of statistical data for each patient could be extracted, both from the pre-hospital service and in-house. All missing parameters are accounted for in the tables and charts. Any missing data was retrieved using interviews with the involved personnel. All data was gathered and compiled in Microsoft Excel 2003 for Windows and all data analysis were performed using Statistical Package for the Social Sciences, release 21.0 for Windows (SPSS, Inc., Chicago, IL). For all statistical analysis, a two-sided p-value of 0.05 was considered significant. Statistical values were calculated using the Mann-Whitney U-test and Chi-squared test. Data are displayed as medians and with interquartile range for continuous data, and for categorical data as numbers and percentages unless stated otherwise in the tables.

Demographics and clinical injury coding

Ages, gender, MOI, location of major injury (LOMI), were recorded. MOI was further subdivided in 4 categories; GSW, Stab wound, MVA or fall from height. LOMI was subdivided in 4 categories; Cardiac, Chest, Abdomen or Multiple. SOL defined as one or more of: Pupillary response, respiratory effort, spontaneous movement or cardiac activity was recorded at the scene, during transport and in the ER. Pulse, Blood pressure, Pulse Oxygenation, Respiratory Rate, GCS, RLS (REF) and volume of fluid resuscitation were retrieved from pre-hospital reports and the trauma/hospital journal. Presence of ECG denoting PEA or ventricular fibrillation were noted as well as Closed Chest Compression (CC-CPR), S(ACLS) or the use of LUCAS™ prior to ET. Time of call to the emergency service, time on scene/transport time and overall time to ET was recorded as well [24,25].

Injury severity was graded according to the injury severity score (ISS) based on the Abbreviated Injury Scale, AIS98 and recorded by a trauma AIS/ISS registrar formally educated in injury coding. The Revised Trauma Score RTS and Probability of Survival, Ps were calculated using the TRISS methodology [26-30].

Results

Throughout the 8-year study period a total of 45 ETs was recorded. An additional 13 during the inclusion period were considered urgent and immediate thoracotomies and subsequently excluded from the study. There was a tendency towards an increasing number of thoracotomies during the study period. The ET incidence was calculated at 5.7 procedures a year or the equivalent of 0.6 procedures/100.000 inhabitants, which is significantly higher than in other parts of Sweden.

There were 14 long-term survivors discharged from the hospital. According to the patient charts there was no severe neurological deficit affecting these patients relating to the thoracotomy procedure when discharged. Eight of these patients had stab wounds; one person had a combination of stab wounds and GSW, whereas five patients sustained blunt trauma-MVA or fall from height. Baseline values from all the included patients are displayed in Table 1.

The patients were predominantly young with a median age of 36

(range 13-79), though there was a significant age difference between the patients suffering blunt or penetrating trauma, where the blunt group were almost twice the age in general. All the patients were severely injured with median ISS 48 (33-59) but with a significant difference in magnitude between blunt (ISS 57) and penetrating (ISS 26) trauma. At the arrival of ambulance the majority (89%) had SOL. None of the patients without SOL on scene survived. Six patients lost SOL during transport, and of these 1 survived. This patient was also the sole survivor after CPR in the ambulance. Scrutinizing the components of SOL, only 1 patient out of 18 (6%) without normal pupillary reaction on the scene of accident survived. The single patient surviving however had a GCS score of 14, raising the question if the pupillary response in this case was correctly interpreted. There were no survivors without pulse on the scene.

During the relatively long transport time from the scene of the accident with a median time span of 30 minutes, a deterioration of status at arrival in the ED was seen with a mean SBP generally lowered to half that of the value on the scene of accident (40 vs 80). The same was true about median GCS (7 versus 3). Examining the GCS at different times; on scene, during ambulance transport and prior to ET shows a general decline in mental status. One single patient with an on scene GCS below

9 survived (4%). A GCS of 3 on scene carried 100% mortality. Out of the patients arriving in the ER with a GCS score below 7 there was only one survivor (5%). Having a GCS of 11 or above arriving in the ER predicted a survival rate of 64% (9/14). GCS also was the strongest determining factor of predicting outcome in a logistic regression analyses.

The vital signs on the 14 surviving patients at scene of injury and at decision for ERT can be seen in Table 2.

When grouped by MOI patients with penetrating injuries were significantly more likely to be younger (28 vs 49 years of age) and significantly less severely injured, (ISS 26 vs 57) with a concurrent higher survival rate as seen in Table 3.

Further specifying the MOI and subdividing the patients according to the exact mechanism of injury revealed that only one patient (1/5) with fall from height survived the procedure, whereas more than half of the patients with thoracic stab wounds survived (8/15). There was a tendency with longer transport time for blunt injuries compared to penetrating trauma. Unprotected persons, i.e. motorcyclists and pedestrians, had a survival rate of 9% (1/11) whereas other motorized victims fared better with a 27% (3/11) survival rate. The sole survivor in the unprotected group was run over by a garbage truck and sustained multiple crush injuries, but without thoracic involvement. 2 out of the 3 patients with GSW in the study died.

When investigating how LOMI and MOI affected the outcome in Table 3, patients with isolated thoracic blunt trauma (9 patients) carried a dismal prognosis with zero survivors, this in contrast to penetrating cardiac trauma which in this study carried a 46% survival rate. Of these 9 patients 8 had Stab wounds, and one patient was both shot and stabbed. All the surviving patients with stab wounds, either cardiac or thoracic, had either right-sided atrial or ventricular laceration, or vessel injuries following multiple stab wounds. There were no survivors following stab wounds to the left atrium or ventricle. The difference in survival rate between blunt (0%) and penetrating (46%) cardiac and thoracic trauma is in line with previous studies, where blunt trauma in general, and especially when affecting the heart or the thoracic cage generally fared worse. Blunt trauma requiring ET had a 19% (5/27) survival rate in our study. Examining the data for these 5 surviving patients revealed that out of these survivors 80% had their LOMI extra-thoracic and the ETs were performed as a damage control procedure with cross clamping of the thoracic aorta to control a distal abdominal bleeding. All the surviving patients with blunt trauma had multiple crush injuries, where the injuries to the thoracic organs were of minor

Parameter	All patients (n=45)
Survivors	14 (31%)
Age (years)	36 (26-53)
Gender (male)	37 (82%)
Penetrating trauma	18 (40%)
Blunt trauma	27 (60%)
Injury severity score	48 (33-59)
Ps	6.5 (1.5-19.6)
RTS	3.77 (1.75-5.96)
GCS at Scene of Accident	7 (3-14)
GCS imminent prior to ET	3 (3-7)
BP at Scene of Accident	80 (28-104)
BP ER	40 (0-60)
Pulse ER	96 (11-120)
SOL at injury site	40 (89%)
SOL at ER	33 (73%)
Transport time (minutes)	30 (22-38)
Thoracotomy <60 min	17 (39%)

Data are displayed as medians and interquartile range in parentheses for continuous data. For categorical data numbers and percentage is given.

Table 1: Baseline characteristics for all patients treated with emergency thoracotomy.

pat	Prehospital								in emergency room					
	age	sex	Puls	BP	Pupils	POX	RR	GCS	fluid	BP	POX	RR	GCS	Fluid
1	49	m	105	90	normal	75	X	15	X	85	88	18	X	3500
2	19	f	150	100	dilated	84	15	3	500	116	85	intubated	X	2500
3	22	m	120	80	X	99	25	X	X	80	96	29	X	1750
4	47	m	80	55	normal	90	X	X	1250	80	97	13	X	13000
5	23	m	102	130	normal	94	22	15	0	150	98	X	15	2000
6	55	f	96	110	normal	96	20	13	0	82	99	12	14	1500
7	75	m	X	90	normal	X	30	13	0	100	X	20	14	1000
8	40	f	X	X	X	83	X	X	500	150	X	28	X	1000
9	30	m	X	120	dilated	X	30	15	1000	156	98	15	15	1500
10	33	m	114	184	dilated	X	X	X	X	40	75	intubated	X	1750
11	28	m	80	160	normal	99	23	15	1000	146	98	37	15	1000
12	33	m	113	120	normal	99	X	15	500	130	97	15	15	1000
13	29	m	160	150	normal	98	40	15	0	130	95	X	15	15000
14	58	m	X	90	normal	X	X	X	0	70	X	9	X	2000

Table 2: Data from the 14 survivors X indicates that the figures are missing.

significance, i.e. damage to LIMA/RIMA, and multiple rib fracture with lung parenchymal penetration, compared to the extensive abdominal injuries.

Discussion

Emergency Thoracotomy is a controversial procedure requiring vast recourses with a potential low yield [31]. Some of the controversy originates from slack routines and arbitrary indications. Studies by Rhee and Hunt stipulate firm treatment criteria based on metanalysis of several articles. Most of these articles and included articles originate from major trauma centres with a different panorama of injuries i.e. penetrating trauma is the major mechanism and may thus not be applicable to a Northern European setting. In earlier reports from different trauma centres in Norway and Iceland, blunt trauma has been the dominating mechanism. This is also true for our study, which has 60% blunt trauma, in contrast to the North/South American setting. Stab wounds account for the vast majority of penetrating violence in our study, also this in contrast to the American situation with frequent

GSW and SGW [32]. The relatively long transport time (median 30 min) may also differ between our study and others where the use of extensive pre-hospital services such as helicopters, or short transport time due to dense population figures may affect the final outcome [33].

The very definition of Emergency Thoracotomy differs significantly throughout the literature. In our opinion terms such as immediate and urgent may obscure these studies [34,12]. The operative procedures and clinical outcomes in the studies using this kind of terminology is not applicable to a true emergency setting where an ET is split second decision, and a desperate attempt to save a patient in extremis. In this article we are using the definition stated by Hunt et al. where Emergency Thoracotomy is defined as “occurring either immediately at the site of injury, or in the emergency department or operating room as an integral part of the initial resuscitation process.” No time frame is given in their article, but we find it prudent to only include cases where the time span from accident to thoracotomy is below 2 hours. We are thus excluding all the cases where the patient had extensive workup, such as CT-scans, before the thoracotomy procedure. This article is the first extensive report from Sweden regarding ET at a major Scandinavian trauma hospital. With its different injury pattern, long transport time and the use of ATLS throughout the series, and with the adding on of (S) ACLS the later years, these data add to the previous reports from Northern Europe.

Blunt trauma in our study carries a survival rate of 19% (5 patients). Amongst these survivors, all of them suffered major extra-thoracic injuries, and concurrently all of the survivors in this group had major liver and spleen lacerations and often major pelvic fractures. The thoracotomy procedure thus rather had the character of distal damage control in these cases than primary intervention because of intra-thoracic damages per se. These surviving patients had a mean GCS at 11, Ps 0.34 and ISS 41.

In our study we report a 50% survival rate following penetrating trauma. This exceptionally high survival rate may be attributable to several different factors; Low volume with only 18 cases included. A relatively long transport time, which may contribute to a selection bias when undertaking the decision to perform ET. There are also patients with self-inflicted trauma within this subset of patients, which may affect the extent and severity of damages. The general paucity of gunshot wounds may also explain the high survival rate. It is well documented in previous studies that GSW victims generally fare worse than those with stab wounds [35,36].

Regarding the value of SOL as the determinant for the outcome after a thoracotomy procedure, our data might suggest that it may be enough to record pupillary reaction at the scene of accident, and using this as the strongest predictor for survival. Only 1 patient with an aberrant pupillary reaction on scene survived, and this single patient was at that time fully conscious, and had a previous stroke, which might have affected the neurological assessment. No patients without initial SOL survived. Only one single patient without SOL imminent prior to ET survived. The baseline values grouped by survivors/non survivors are displayed in Table 4. Using logistic regression analysis to predict survivors, revealed GCS and SOL to be the strongest determining factors are displayed in Table 5.

Conclusions

Emergency Thoracotomy has a role in the treatment of trauma patients in Scandinavia/Northern Europe. But with the majority of cases presenting in the ER in this region being blunt trauma, careful guidance and proper selection criteria to perform the procedure

Parameter	Penetrating trauma (n=18)	Blunt trauma (n=27)	p value
Survivors	9 (50%)	5 (19%)	0.025^b
Age (years)	28 (24-34)	49 (29-64)	0.002^a
Gender (male)	17 (94%)	20 (74%)	0.082 ^c
ISS	26 (25-34)	57 (41-66)	<0.001^a
GCS ER	3 (3-13)	3 (3-6)	0.733 ^a
Ps	12.8 (1.7-46.0)	5.1 (1.2-14.2)	0.179 ^a
RTS	3.0 (1.0-4.4)	3.4 (1.8-5.4)	0.683 ^a
SOL at injury site	17 (94%)	23 (85%)	0.634 ^c
Transport time (minutes)	29 (20-36)	32 (27-48)	0.148 ^a
Pulse on Scene of Accident	88 (28-106)	98 (70-120)	0.243 ^a
Respiratory rate	13 (0-22)	15 (0-26)	0.525 ^a

Data are displayed as medians and interquartile range in parentheses for continuous data. For categorical data numbers and percentage is given. ^a Nonparametric test, Mann-Whitney U test, ^b Chi-squared test, ^c Chi-squared test, Fisher's Exact Test, Bold p value indicating statistical significans.

Table 3: Results according to Mechanism of Injury (MOI).

Parameter	Non survivors (n=31)	Survivors (n=14)	p value
Age (years)	38 (26-56)	35 (29-48)	0.668 ^a
Gender (male)	10 (71%)	20 (74%)	0.231 ^c
ISS	50 (34-66)	34 (26-59)	0.033^a
GCS ER	3 (3-4)	13 (3-15)	0.009^a
Ps	0.04 (0.01-0.11)	0.42 (0.11-0.86)	<0.001^a
RTS	2.34 (1.0-3.3)	4.82 (3.4-6.4)	<0.001^a
SOL at Scene of accident (SoA)	26 (83%)	14 (100%)	0.111 ^b
SOL at ER	21 (68%)	12 (86%)	0.305 ^c
BP at ER	65 (0-87)	81(80-87)	0.144 ^a
Pulse at ER	90 (0-120)	94 (103-120)	0.012^a
Abnormal eye movement at SoA	17 (52%)	1 (7%)	0.003^a
Mechanism of injury			
Penetrating trauma	9 (29%)	9 (64%)	0.025^b
Blunt trauma	22 (71%)	5 (36%)	
Transport time (minutes)	30 (22-38)	31 (21-37)	0.844 ^a

Data are displayed as medians and interquartile range in parentheses for continuous data. For categorical data numbers and percentage is given. ^a Nonparametric test, Mann-Whitney U test, ^b Chi-squared test, ^c Chi-squared test, Fisher's Exact Test. Bold p value indicating statistical significans.

Table 4: Patients treated with Emergency Thoracotomy, results grouped by non survivors and survivors.

Univariate analysis					
Predictor	Coefficient (β)	Standard Error	Wald's Chi (df 1)	p value	Odds Ratio (95% CI)
Mechanism of Injury (Penetrating trauma)	1.486	0.68	4.69	0.03	4.40 (1.15-16.81)
RTSSC	0.593	0.2	9.13	0.003	1.81 (1.23-2.66)
Glasgow Coma score (GCS)	0.331	0.1	10.4	0.001	1.40 (1.14-1.70)
Probability of Survival (PS)	0.055	0.02	9.23	0.002	1.61 (1.02-1.09)

Among 45 patients treated with emergency thoracotomy either survived or did not survive, MOI, RTSSC, GCS and PS proved to be significant predictors for survival (Table 5). Those patients with penetrating trauma were 4.4 times as likely to survive than those patients with blunt trauma. 1.81 is the odds ratio for the score RTSSC, indicating that for every additional unit increase in RTSSC (i.e. 3-4), the risk of being a survivor increases by 1.81 times, or by 81%. The 95% confidence interval for the odds ratio indicates that the odds ratio from 95 of 100 similar studies would be expected to fall between 1.23 and 2.66.

Table 5: Logistic regression predicting survivors from Mechanism of Injury (MOI), RTSSC, GCS score and Probability of survive score.

must be utilized. One can expect better outcome in penetrating trauma following ET in this region, due to the relatively low presence of firearms, and the majority being stab wounds that carries a better prognosis. When taking into account LOMI, MOI, as well as SOL, GCS and pupillary reaction recorded at different phases of resuscitation (Scene of accident, Ambulance, ER, and prior to ET), some conclusions might be considered. Only 1 patient out of 18 without initial normal pupillary reaction, survived. Using GCS as a survival predictor revealed that having an initial GCS of 7 or below resulted in 100% mortality in this study. Blunt thoracic injuries had a dismal prognosis, whereas isolated stab wounds to the thorax and right-sided cardiac injuries carries a more promising prognosis. There is also still is a role for ET as a damage control procedure to control abdominal bleeding. With conclusions drawn from the present study, taking in to account the low volume at this single centre, the injury pattern between America and Northern Europe is different, with less gunshot wounds in this study and thus with more promising results in penetrating injuries, but equal results regarding blunt thoracic trauma.

Transport time from injury to the emergency room is of course an important parameter since some of these patients lose the possibility to be saved by ERT during a long transport time. The question of ET, at scene of injury performed by paramedics is a new debate. We suggest more intention to absence of pupillary reaction and low GCS when calculating probability of survival after ERT.

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