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Resuscitative emergency thoracotomy in a Scandinavian trauma hospital—Is it justified?

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Summary

Objective: Resuscitative emergency thoracotomy (ET) is of value in selected (penetrating) trauma patients. Current survival-estimates and recommended guidelines are based on data from the United States. However, reports from European trauma centres are lacking. We report the current experience from a Scandinavian trauma hospital.
Methods: Identification of all consecutive ETs performed during a 5-year period. Data on demographics, and injury severity score (ISS), mechanism and location were recorded. Physiological status on admission (revised trauma score, RTS) and probability of survival (P_s) were calculated. Signs of life (SOL) and need for closed-chest cardiopulmonary resuscitation (CC-CPR) were recorded through the post-injury phase.
Results: Ten patients underwent ET with no survivors. The annual incidence of ET was 0.7 per 100,000 inhabitants during the study period, with an increasing trend during the last years ($r = 0.74$, $p = 0.014$). ETs were performed in 0.7% of all trauma admissions, and in 2.5% of all severely injured patients (ISS $\geq$ 16). Blunt mechanism dominated; only three had penetrating injuries. Most frequent location of major injury was "multiple" ($n = 4$) and "thoracic" ($n = 4$). The male to female ratio was 7:3. Median age was 51 years (range 21—77). Median ISS was 34.5 (range 26—75),

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indicating severely injured patients, with seriously deranged physiology (median RTS of 0.0, range 0—6.1) with poor chance of survival (median P_s of 4.4%, range 0—89.5%). Males had significantly lower RTS and P_s ($p = 0.007$ and 0.03, respectively) than females. Eight patients had signs of life at some time post-injury, but only four in the emergency room. Six patients had both pre- and in-hospital CC-CPR. Four patients had additional surgery to ET. Two possible preventable deaths were identified (P_s of 51 and 89%), one in a third trimester pregnancy.

Conclusion: Emergency thoracotomy is a rarely performed procedure in a rather busy Scandinavian trauma hospital, and outcome is dismal. Reevaluation of our decision-making process concerning the use of emergency thoracotomy is needed. How survival data and clinical experience in Europe compare to current figures from North America deserves further attention.

Introduction

Since the introduction of resuscitative emergency thoracotomy (ET) during the 1960s[8,66] the use of this procedure has ranged from sparing to liberal.[13,38,46,51] Currently, the pendulum has swung towards a more aggressive approach, together with the development and recognition of damage control surgical principles in thoracic trauma.[36,57,64] In many North American urban trauma centres, this procedure has found a niche as part of the resuscitative process because of the great improvements in pre-hospital care systems, allowing an increasing number of patients to arrive in either impending or full cardiopulmonary arrest in the emergency room. As such, resuscitative ET remains a formidable tool within the trauma surgeons' armamentarium. However, its use, indications, and associated risks continue to be debated.[4,26,30,35,36,51,57,58] Of importance, only a few patients survive this heroic effort, with lowest survival in patients with blunt trauma and multiple injuries (Table 1).[52,56]

A striking paucity of studies from Europe is evident when reviewing the literature on ET. A recent review[56] strictly focusing on survival after ET performed in the emergency department included only one UK study[11] (of 24 studies), representing only 18 patients out of the total 4260 under evaluation. Thus, questions arise whether survival rates (Table 1) are generally applicable to the European trauma population. Differences in trauma systems, trauma epidemiology, training and logistics in the North America compared to Europe may ultimately influence the attitude, applicability, and outcome of this specific procedure.

Consequently, due to the lack of reports from low(er)-volume (European) centres with a low(er) incidence of penetrating injuries, we reviewed our recent 5-year experience at a Norwegian university hospital, and discuss the results according to current literature.

Materials and methods

The Stavanger University Hospital serves as primary trauma care hospital for all trauma patients within a mixed urban/rural population of 285,000, with referral function for a broader population of about 360,000. Only patients from the primary catch area of 285,000 were included in this study. The pre-hospital Emergency Medical Service (EMS) system provides paramedic-staffed ground ambulance, as well as anaesthetist-manned rapid-response car and helicopter.[45]

Annually, we receive over 300 patients whose injury severity score (ISS) is >9 and/or whose injury mechanism require trauma team activation by pre-set criteria.[45] Of these, roughly 25% (80—85 patients/year) are severely injured (ISS > 16). Each year 25—30 deaths occur subject to trauma in our region (unpublished data).

Table 1 Estimated survival after emergency department thoracotomy

ET associated feature	Survival (%)
Overall survival	7.4
Penetrating	8.8
Blunt	1.4
Mechanism of injury (MOI)	
Stab wound	16.8
Gunshot wound	4.3
Location of major injury (LOMI)	
Cardiac	19.4
Thoracic	10.7
Abdominal	4.5
Multiple	0.7
Signs of life (SOL)	
Hospital, present	11.5
Hospital, absent	2.6
Transport, present	8.9
Field, absent	1.2

Numbers are based on Refs.[52,56]

The hospital has a designated trauma team, which responds within 5 min of activation, and is usually present in the emergency room when the patient arrives. Briefly, the team consists of a senior surgeon-in-training (Advanced Trauma Life Support, ATLS™ certified) as the trauma-team leader, one orthopaedic surgeon, and one anaesthetist-in-training, as well as specialist nurses, and related specialty services (i.e. attending radiologist). Consultants are present/called in on a rapid response manner (neurosurgery, gynaecology/obstetrics, thoracic/vascular, gastrointestinal surgeons) by priority of the trauma leader.

Resuscitative emergency thoracotomies related to trauma were identified from a prospectively collected trauma registry database and from the electronic hospital files during a 5-year-period (starting 1 January 2001 until 31 December 2005). All ETs related to non-traumatic indications (i.e. ruptured abdominal aortic aneurysm, severe gastrointestinal haemorrhage) were excluded. Procedures performed in the emergency department (ED) as well as the operating room (OR) were included if the ET was the next immediate event indicated for resuscitation. For each case pre-hospital reports, hospital charts, operative descriptions, and autopsy reports were reviewed.

Demographic data were recorded for all patients, as well as mechanism of injury (MOI) and location of major injury (LOMI). Signs of life (SOL) were recorded for the pre-hospital phase, during transport, and upon arrival in the ER. Presence of SOL was defined as one or more of the several following: pupillary response, respiratory effort, or cardiac electrical activity. Injury severity was scored according to the Abbreviated Injury Scale (AIS-90, updated 1998 version) by an AIS/ISS-certified registrar. Injury severity score (ISS),[5] and new injury severity score (NISS)[48] were calculated. Respiratory rate, systolic blood pressure, and Glascow coma score on admission to hospital were used to calculate the revised trauma score (RTS).[17] Probability of survival (P_s) was calculated for each patient using the TRISS-methodology.[14] Statistical analysis was performed with SPSS® Version 11.0 (SPSS, Chicago, IL, USA) using non-parametric tests (Mann–Whitney, Wilcoxon, or Spearman's correlation) when appropriate. Statistical significance was set at $p < 0.05$.

Results

The trauma team in our hospital performed 10 resuscitative ETs for severe trauma during a 5-year-period, with no survivors. With a primary catchment area of 285,000 inhabitants, the annual incidence for ET amounted to 0.7/100,000 inhabitants. Age-adjusted annual incidence of ET for the age-group 20–54 years was 0.7/100,000, and for ages 55–80 years 1.8/100,000. ETs were performed in 0.7% of all annual trauma admissions, and in 2.5% of all severely injured patients (ISS $\geq$ 16).

We noted a significant time trend of ET in our hospital with more ETs performed in the latter years (Spearman's $r = 0.74$, $p = 0.014$). No ETs were performed in the years preceding the study period (1998–2000, unpublished data), only three were performed in the first half (January 2001–June 2003), whereas seven were performed in the latter half (July 2003–December 2005).

The male to female ratio was 7:3. The median age was 51 (range 21–77) years, with five patients >55 years of age. Ethnicity was Caucasian in eight (80%). One third of the patients had positive blood-screen for alcohol or other drugs.

Penetrating injuries accounted for a third of injuries (one suicide; two homicides), whereas blunt injury after motor vehicle collision was the most frequent cause (Table 2). The median values of ISS and NISS were 34.5 (range 25–75) and 57

Table 2 Injury mechanism, location and severity

Case number	MOI	LOMI	ISS	NISS	RTS	P_S (%)
1	Blunt, MVC	Abdominal	26	29	6.376	51.0
2	Blunt, MVC	Multiple	29	66	0.000	5.4
3	Blunt, MVC	Cerebral	35	57	0.000	3.3
4	Blunt/compression	Thoracic	25	57	0.000	1.4
5	Blunt, fall >15 m	Multiple	50	50	4.094	20.2
6	Penetrating, thoracic GSW	Multiple	41	57	0.000	0.2
7	Penetrating, thoracic GSW	Thoracic	75	75	0.000	0.0
8	Penetrating, thoracic SW	Thoracic	29	59	6.613	89.5
9	Blunt, MVC	Multiple	57	75	4.211	14.1
10	Blunt, fall >9 m	Thoracic	34	34	0.000	0.6

MOI: mechanism of injury; LOMI: location of major injury; ISS: injury severity score; NISS: new injury severity score; RTS: revised trauma score; GSW: gunshot wound; SW: stab wound; MVC: motor vehicle crash; P_S: probability of survival.

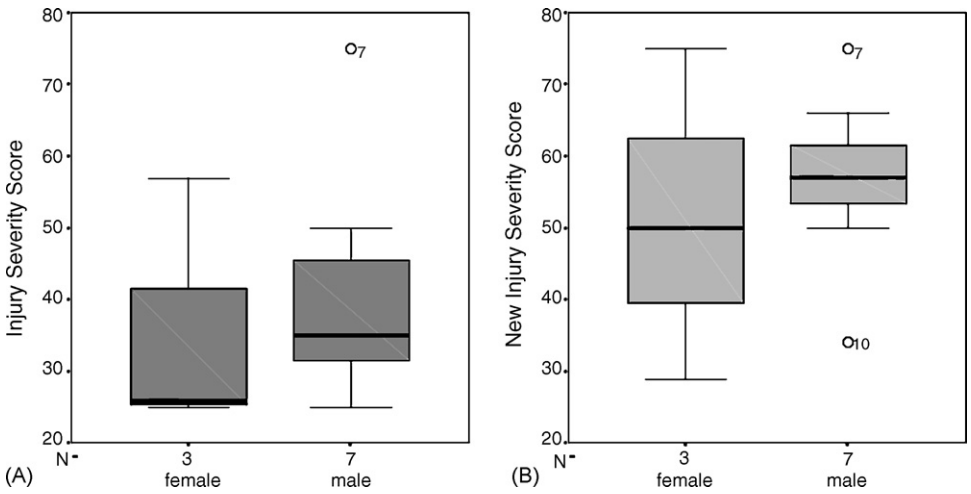

Figure 1 Distribution of ISS and NISS between male and female. Distribution of ISS (A) and NISS (B) did not differ significantly between male and female.

(range 29—75), respectively. The NISS values were significantly higher as compared to ISS ($p = 0.018$). The median P_s was 4.4% (range 0—89.5%). Males and females did not differ significantly with respect to age, ISS, and NISS (Fig. 1), but males had significantly lower RTS ($p = 0.007$) and P_s ($p = 0.03$) when compared to females (Spearman's correlation with regard to female gender: RTS $r = -0.9$, $p < 0.001$; P_s $r = -0.7$, $p = 0.02$) (Fig. 2). The patient (#8) with P_s of 89.5% was a young, third trimester pregnant female who immediately collapsed upon simultaneously performed Caesarean section and ET, with no response to resuscitation and internal heart massage. For patients #6 and #7, considerable pre-hospital time was lost (estimated 20 min) for the police to secure the scene, before the paramedics and the anaesthetist were allowed to enter. Both patients arrived in exanguination in the emergency department and with cardiopulmonary arrest.

Signs of life were present in eight of the ten patients at some time after injury (Table 3; seven on scene, seven during transport), but only four had SOL in the ER. Notably, loss of SOL upon arrival was the indication of ET in these patients. Closed-chest cardiopulmonary resuscitation (CC-CPR) was performed in six patients before arrival in the ER (Table 3). Five resuscitative thoracotomies were emergency procedures, whereas five were urgent (performed in the OR). For most patients, ET was indicated for exanguinating patients arriving in extremies, or with pending cardiopulmonary arrest.

Five of the ETs were performed by the surgeon-on-call alone (all in the ER), whereas the others were performed by, or in assistance with a consultant thoracic surgeon.

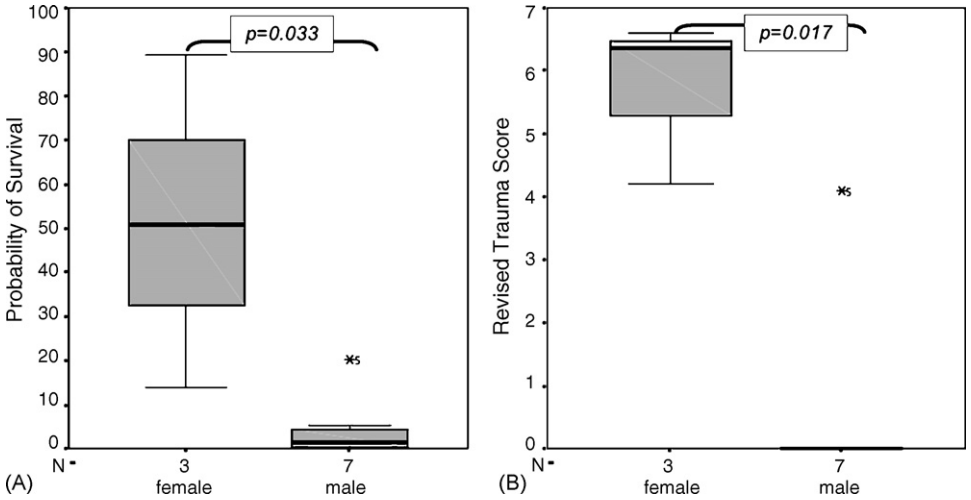

Figure 2 Distribution of P_s and RTS. Males had significantly lower P_s (A) and RTS (B) compared to females. Males were more likely to have no, or greatly deranged, vital signs on admission

Table 3 Resuscitative emergency thoracotomy descriptives

Case number	Clinical indication	CC-CPR			SOL		ET	Outcome
		PH	ER	On-scene	Transport	ER	Location	
1	Exanguination	No	No	Yes	Yes	Yes	OR	Died, OR
2	Suspected pericardial tamponade	Yes	Yes	No	Yes	No	ER	Died, ER
3	Suspected pericardial tamponade	Yes	Yes	Yes	Yes	No	ER	Died, ER
4	Exanguination	Yes	Yes	Yes	No	No	OR	Died, OR
5	Exanguination	No	No	Yes	Yes	Yes	OR	Died, OR
6	Penetrating thoracic trauma, CA	Yes	Yes	No	No	No	ER	Died, ER
7	Penetrating thoracic trauma, CA	Yes	Yes	No	No	No	ER	Died, ER
8	Penetrating thoracic trauma, CA	No	No	Yes	Yes	Yes	OR	Died, OR
9	Exanguination, pending CA	No	No	Yes	Yes	Yes	OR	Died, OR
10	Exanguination, CA	Yes	Yes	Yes	Yes	No	ER	Died, OR

CC-CPR: closed-chest cardiopulmonary resuscitation; CA: cardiac arrest; PH: pre-hospital; ER: emergency room; OR: operating room; SOL: signs of life.

ET was the only procedure performed in six patients (patient #2–7). Additional major surgery performed after, or in conjunction with ET in the OR, included one damage control laparotomy with liver (AIS grade 3 hepatic injury) and pelvic-packing (AIS-grade 5 pelvic injury) with external pelvic fixation for patient #1; one emergency Caesarean-section in the pregnant patient #8 (the child died 2 days later due to severe hypoxic brain injury); and laparotomy with splenectomy (AIS grade 5 injury), a left nephrectomy (AIS grade 5 renal injury), and closure of small bowel perforations and stomach rupture in patient #9; and one exploratory laparotomy in patient #10. One patient had ET and subsequent damage control surgery in the OR, but succumbed to irreversible cardiopulmonary arrest with asystole after leaving the OR (patient #1).

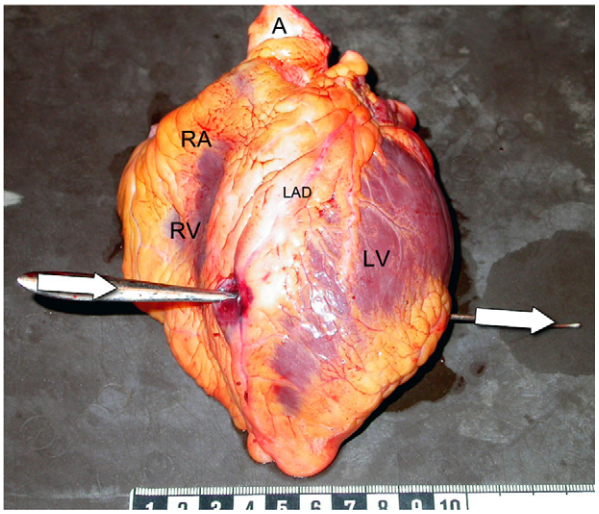

Figure 3 Gunshotwound penetrating the heart. Post-mortem examination of the heart, viewed from front. The bullet transversed (white arrows) the left ventricle (LV) close to the septum, near the left descending coronary artery (LAD). The bullet further penetrated the lower left pulmonary lobe, the diaphragm, the mid-stomach, and transversed the lower splenic pole (pictures not shown). RA: right atrium; RV: right ventricle; A: aorta.

All patients, except one, underwent post-mortem examination in our institution. Autopsy revealed a severely injured population, as indicated by injury severity scores and anatomic location (Table 2). In one patient (#2) who underwent ET on the clinical suspicion of a pericardial tamponade, the autopsy revealed a complex basilar scull (hinge) fracture (AIS grade 4) as the cause of death. ET was, in retrospect, not indicated in this patient. All penetrating trauma deaths had multiple, severe injuries involving vital organs such as heart (Fig. 3), great thoracic arteries, and lungs, and in one patient the bullet had traversed the diaphragm, stomach, and spleen in addition.

Discussion

Resuscitative emergency thoracotomy after trauma is a dramatic event with an overall dismal survival rate.[52,36,56] Since pioneer efforts of the late 19th century[63] surgical intervention in exanguinating trauma has evolved together with improvements in pre-hospital resuscitation,[24,62] trauma triage, and emergency medicine systems.[24,45,57,64] Recently, guidelines for termination of resuscitation in traumatic cardiopulmonary arrest,[49,33,34] and recommended indications for emergency thoracotomy have been published.[52,56] However, the majority of these data are derived from areas with a higher proportion of penetrating trauma, and consequently little is known about its in-hospital use and outcome in Europe.

During a 5-year period no patients survived after ET performed in our hospital. However, we noted a significant time trend of ET in our hospital with an

increase during the latter years. Increased focus on trauma has evolved over the past decades in our hospital with recognised improvements on trauma team function in recent years. For one, the senior surgeon-in-training is required to be familiar with, and preferably certified in ATLS™, and have participated in the national haemostatic life-saving surgery training model.[19] Secondly, criteria for trauma-team activation have been scrutinised. Further, regular team-training performed through a national model, and regularly held trauma-audits have improved the educational impact. Lastly, implementation of a prospective trauma registry, and increased clinical research interest in trauma has evolved. Although data are preliminary, and does not allow for drawing firm conclusions, we speculate if the increasing trend in ETs may be a result of these implementations. However, as evident from the current data, indication for ET appears liberal and is not cost effective for blunt trauma. We need to re-evaluate our decision-making process concerning the use of ET, especially in the blunt trauma patient. For one, data suggest that trauma patients requiring CC-CPR for more than 5—10 min, have extreme poor chances of survival, in particular for blunt trauma.[31,51] The ever-present challenge during initial trauma care, though, is appropriate and timely information to the trauma surgeon who is in charge for making the decision of whether or not performing ET is appropriate. Crucial decisions are sometimes made with only scarce information available. Further, the emotional aspects are not to be disregarded, including the wish to do "everything that could possibly have been done". However, risk of blood born virus transmission should not be neglected, and acknowledging that "everything has been done" (without doing an ET) is sometimes instrumental.[26,61]

The current report on ET from a Norwegian university hospital does not suffice to answer questions at large. However, current guidelines and applicability of ET in trauma lack support of data and validation from the European trauma population. Thus, several issues serve to be addressed.

First, the rarity of this procedure is evident in a rather large Scandinavian trauma centre. This is in accordance with the paucity of reports concerning ET from Europe in general, and Scandinavia in particular. As a result, the current estimated survival rates based on North American data (Table 1)[41] and recommended guidelines[52] for ET may not be generally applicable to the European trauma centres. Several reasons may explain the paucity of European reports; a less aggressive attitude to ET ("no numbers to report"), less favourable outcome ("no survivors to report"), not competitive or comparable to US data ("no need to report" or "do not dare to report"), and less chance to get published in 'high-impact' journals ("nowhere to report"). Furthermore, the much lower frequency of penetrating mechanism in European trauma (about 5%)[36] compared to data from the US (up to 50%),[59] may explain the rarity of European reports and comparable poor results with this procedure, as penetrating trauma patients are those most likely to benefit from ET.[2,3,56]

In a previous Norwegian ET series by Fosse et al.[28] (Ullevaal University Hospital, Oslo) only four of 19 patients survived (three with penetrating injuries) during a 3-years period. With our current estimated incidence rate for ETs, the Norwegian national trauma system (population of 4.8 million) would be exposed to an estimated 30—35 ETs annually, reflecting the rarity of this procedure in Scandinavian trauma. This strengthens the arguments for the current use of compulsory trauma training with the use of animal-models in general surgery in Norway.[29] Two Swedish studies[54,55] include data on ET with eight survivors in nine "emergent and urgent" thoracotomies, however, with focus on isolated penetrating cardiac and lung injuries only. The majority of European studies on ET derive from the UK,[4,11,19,39,53] with several reports on pre-hospital ETs performed by emergency physicians in a helicopter emergency system.[4,19,20,53,67] Of notice, pre-hospital ET is a rarely performed procedure in the US. In contrast, European reports of in-hospital experience with ET are lacking.

Secondly, there is a wide variability in the survival rates after ET as studies vary from 0 to 31%.[30,40,43,51,56] In general, the studies citing higher survival rates include significantly larger proportions of patients merely with severe shock and more recent onset of total cardiopulmonary arrest than those studies reporting lower survival rates. Because the survival rate tends to be poor, the small number of survivors hampers drawing conclusions from any one study. The obvious lack of "negatives" in the literature suggests a publication bias towards series including at least one, or a few survivors, as also noted by the continuous fascination for "successful case reports" (how many thoracotomies were performed with fatal outcome by the same authors/institutions?).[20,25,42,44,67,68] To the authors' knowledge, the literature contains only a few studies with zero survivors.[12,53] Purkiss et al.[53] reported no survivors (n = 16), albeit including only ETs performed on-scene. Initially, this study argued against the use of pre-hospital thoracotomy in trauma, but the results have later been challenged with data in favour of on-scene thoracotomy in select cases.[4,19]

Jahangiri et al.[39] equally reported only 1 survivor out of 16 ETs performed in the emergency room (12 for blunt trauma; no survivors); the 1 survivor suffered bleeding from laceration of intercostal arteries after multiple stab wounds. The Glascow series[11] reported 32% survivors (8 of 25) and represents the most promising European experience overall. However, the population were almost exclusively (24 of 25) penetrating trauma patients. This is in contrast to other European studies in which blunt trauma dominates. The patients in our series were multiple injured with a poor probability of survival in most cases. The one patient with an 89% survival chance was pregnant, an extreme challenge to evaluation and management in trauma.[50] This specific scenario has undergone a retrospective internal audit amongst surgeons, anaesthetists, and obstetricians involved in order to evaluate system efficacy and to detect potential pitfalls for this specific scenario. In retrospect, considerable time was lost in the pre-hospital setting due to the circumstances under which the penetrating trauma took place.

Third, the indications for ET that appear in the literature range from vague to quite specific.[52,1–3,7,10,15,16,18,19,21–23,27,30,32,35,37,41] ET is used in a variety of settings including penetrating thoracic and thoraco-abdominal injuries, and cardiac and exsanguinating abdominal vascular injuries.[65] ET has also been used in exsanguinating peripheral vascular injuries arriving in full cardiopulmonary arrest as well as in paediatric trauma.[9,44,60] Reports also exist on its use in patients presenting in full cardiopulmonary arrest secondary to blunt trauma.

A survey performed among US trauma surgeons[47] found that indications for ET (performed in the emergency department; EDT) were liberal, especially for blunt trauma-related indications, and were determined by clinical parameters, not by physician or institutional factors. Interestingly, there were no significant differences in EDT indications among institutions of differing caseload volume, exposure to penetrating trauma, trauma level designation, American College of Surgeons verification status, or residency program affiliation.[47] Seemingly, performance-criteria for ET are liberal in comparison with established guidelines,[6,30,56] especially for blunt trauma. The presence, or recent loss of SOL influenced responses, but respondents varied greatly in their definition of SOL.[47,56] The results suggest that clinical practice is at variance with ATLS™ guidelines. How these observed attitudes may apply to European and Scandinavian surgeons remains unanswered.

Lastly, definitions remain a problem when dealing with resuscitative ET. Sailing under many names, this procedure is hard to evaluate.[10,15,24,27,29,34,37,42] Close scrutiny reveals several flaws; most series have been retrospective reviews, many from institutions using this technique infrequently. Many institutions report serial and overlapping studies that encompass their experience of many years. A lack of agreement exists regarding the indications for ET in multiple clinical scenarios as well as in defining SOL.

Conclusions

ETs are rare in the Scandinavian trauma scenario and performed in patients presenting in extremies after major trauma, often of blunt aetiology. Our preliminary report over 5 years experienced no survivors in 10 patients, and the dismal outcome may question if this procedure is justified. With a predominating blunt trauma population, this procedure is rarely indicated, and has a poor chance for successful outcome in our institution. According to the current literature, ET may still be indicated in select patients. Training is mandatory for the successful employment of this procedure; indications and outcome need to be addressed, preferably based on European data. As such, European experience with resuscitative ET in trauma needs standardised reporting of important variables for comparison (including SOL, LOMI, and MOI) in addition to standard reporting of injury severity scores and P_s. How survival data and clinical experience in Europe compare to current figures from North America deserves further attention.

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