Simple thoracostomy in prehospital trauma management is safe and effective: a 2-year experience by helicopter emergency medical crews

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Objective To evaluate the effectiveness and potential complications of simple thoracostomy, as first described by Deakin, as a method for prehospital treatment of traumatic pneumothorax.

Methods Prospective observational study of all severe trauma patients rescued by our Regional Helicopter Emergency Medical Service and treated with on-scene simple thoracostomy, over a period of 25 months, from June 1, 2002 to June 30, 2004.

Results Fifty-five consecutive severely injured patients with suspected pneumothorax and an average Revised Trauma Score of 9.6 ± 2.7 underwent field simple thoracostomy. Oxygen saturation significantly improved after the procedure (from 86.4 ± 10.2% to 98.5% ± 4.7%, $P < 0.05$). No difference exists in the severity of thoracic lesions between patients with systolic arterial pressure and oxygen saturation below and above or equal to 90. A pneumothorax or a haemopneumothorax was found in 91.5% of the cases and a haemothorax in 5.1%. No cases of major bleeding, lung laceration or pleural infection were recorded. No cases of recurrent tension pneumothorax were observed. Forty (72.7%) patients survived to hospital discharge.

Conclusions Prehospital treatment of traumatic pneumothorax by simple thoracostomy without chest tube insertion is a safe and effective technique. _European Journal of Emergency Medicine_ 13:276–280 © 2006 Lippincott Williams & Wilkins.

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Introduction

Traumatic pneumothorax (PNX) is a well-known cause of preventable mortality in multiple trauma patients [1,2] and Advanced Trauma Life Support guidelines mandate its immediate treatment by blunt dissection of the chest wall followed by the insertion of a drainage tube (tube thoracostomy) [3]. Many studies demonstrate that prehospital aggressive approach to severe trauma patients with early endotracheal intubation and pleural drainage performed by skilled medical crews leads to an improved survival [4–9]. The previous policy in our Helicopter Emergency Medical Service (HEMS) consisted in the chest decompression by needle thoracostomy (NT) with the introduction of a small-bore catheter (diameter = 2.2 mm), in all patients with signs of PNX associated with severe disturbances of vital parameters, such as oxygen desaturation (< 90%), hypotension [systolic arterial pressure (SAP) < 90 mmHg] and severe dyspnoea; the NT was performed after a positive exploratory puncture. In our experience, the above-mentioned approach was associated with a number of complications, including malpositioning, catheter obstruction and insufficient drainage. Moreover, false-negative exploratory puncture caused missed or delayed diagnoses. This prompted us to a thorough re-evaluation and re-definition of both the indications and the modalities of field treatment of PNX. We performed a comprehensive review of all the available literature [10–21] and analysed all the different techniques for the prehospital treatment of PNX namely NT, with or without small-bore catheter insertion, tube thoracostomy or simple thoracostomy (ST). The latter was first described by Deakin *et al.* [10] who demonstrated its feasibility, safety and effectiveness, but also concluded that its further evaluation was keenly warranted. Then, we adopted ST for the treatment of any PNX in the prehospital setting, extending at the same time the indications of the procedure. The indications for on-scene ST are similar to those described by Schmidt *et al.* [16] and include decreased breath sounds, subcutaneous emphysema, serial rib fractures with chest wall instability, flail chest and penetrating chest wounds. Considering

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flight time, treatment time and the risk of PNX-related cardiorespiratory deterioration during the transport and in the initial phase of the hospital admission, normal physiological variables were not considered a contra-indication for ST in the presence of these clinical signs. In this study, we evaluate this new approach of traumatic PNX as far as safety and effectiveness are concerned.

Methods

The HEMS of the Friuli-Venezia Giulia covers a region of 7.855 km^2, and serves a population of 1 184 000 inhabitants. Roughly 40% of the region is mountainous with a low-density population. The helicopter in use is an Eurocopter EC135 T1, with a flight crew composed of a pilot and a flight technician. The medical flight crew is composed of two registered nurses and one anaesthesiologist, with at least 5 years of experience in the intensive care management of severely traumatized patients. This service is based in one of the two regional level 1 trauma centres, the Udine Hospital. The average number of flight missions is about 800 per year, of which around 700 (88%) are primary missions for trauma patients. Maximum flight time to and from the incident location is approximately 40 min. The time spent on the scene to rescue, extricate if needed, and treat the patient averaged 38 ($\pm$ 10) min.

Before this study, our files show about 15 PNXs per year were recognized and treated in the prehospital phase on the basis of the previously adopted indications. In the present study, all patients with thoracic trauma, who underwent field thoracostomy during the 25 months, from June 1, 2002 to June 30, 2004, were enrolled. Patients found in cardiac arrest were excluded even if successfully resuscitated.

The patients were anaesthetized, tracheally intubated and mechanically ventilated with 100% O_2 before the procedure. As described by Deakin, 'in intubated and paralysed patients, positive pressure ventilation expulses air through the thoracostomy, as the intrapleural pressure rises. Intra pleural pressure in ventilated and paralysed patients never becomes negative, and air is not sucked through the thoracostomy.' This technique cannot be used in spontaneously breathing patients, as they generate negative intrathoracic pressure during inspiration. The most commonly used drugs for induction were ketamine 2–4 mg/kg, intravenously, diazepam 0.3 mg/kg, intravenously, followed by succinylcholine 1 mg/kg, intravenously for muscle relaxation. Vecuronium bromide 0.1 mg/kg, intravenously was administered after the intubation. All patients were monitored with a 3-lead electrocardiogram, pulse oxymetry (SpO_2), capnometry and noninvasive blood arterial pressure measurement. After the skin preparation with a chlorhexidine solution, an incision of approximately 5 cm in length, at the level of the fifth intercostal space between the anterior and the mid-axillary line, was performed with a curved blade scalpel. This was followed by blunt dissection through the intercostal muscles with curved Mayo-Lexer scissors or large artery forceps and the introduction of the gloved finger into the pleural cavity to perform the finger sweep. The surgical incision was covered with a sterile gauze dressing, leaving one side unleashed. Upon arrival at the emergency department (ED), a chest tube was introduced into the pleural space through the ST breach, usually by the attending surgeon. The surgical wound was sutured around the chest tube and connected to a water seal device. Data collected included: indications for chest drainage, Revised Trauma Score, SpO_2 and SAP before and after the procedure, thorax helical computed tomography (CT) findings, Abbreviated Injury Scale (AIS) thorax and Injury Severity Score. For AIS assignation purposes, a PNX was only considered to be tensioning when either obvious escape of air under pressure and/or immediate resolution of derangement of vital parameters following ST were reported. Patients were observed for procedural complications including major bleeding, lung lacerations and pleural infections. This was achieved using the available diagnostic procedures routinely performed in the hospital ED, upon admission and during the intensive care unit (ICU) stay; these included CT-scan, X-rays or both. If the patient underwent an operative surgical procedure, the surgeons records were reviewed. Evaluation of pleural infections was performed by chart review. For some patients who died in hospital, a postmortem examination was performed as described elsewhere in this paper.

The on-scene diagnosis of PNX was confirmed if at least one of the following was recorded: obvious escape of air under pressure upon pleural space opening; bubbling of air into the water seal device; helical CT-scan findings of residual PNX or ipsilateral subcutaneous emphysema in absence of tracheal or main bronchi injuries; pleuro-parenchymal lacerations at autopsy findings. A haemothorax was diagnosed when blood was collected after chest tube placement or visualized by helical CT imaging. Duration in days of mechanical ventilation, chest tube drainage, length of ICU stay and patient outcome was recorded. Numerical data are reported as mean $\pm$ SD, median and range when appropriate. For statistical analysis, a paired t-test was used for comparing means, and the χ^2 test for comparing proportions. Statistical significance for both tests was assumed at $P < 0.05$.

Results

In the study period, 55 patients, 42 (76.3%) male patients, 13 (23.7%) female patients, age 51.6 $\pm$ 19.8 years (range 15–80 years) underwent field ST. Fifty-one were unilateral and four were bilateral, accounting for a total of 59 procedures. The type of trauma was blunt in

Table 1 Clinical indications for on-scene simple thoracostomy (ST)

Indications for ST	No. of patients (%)
Multiple rib fractures – chest wall instability, flail chest	29 (52.7)
Diminished breath sounds	30 (54.6)
Subcutaneous emphysema	15 (27.3)

all patients. The mechanism of injury was motor vehicle accident in 41 cases (74.5%), fall in nine (16.4%), other in five cases (9.1%).

Indications for the ST are reported in Table 1. More than one indication was present in 19 (54.5%) of the patients.

The mean Revised Trauma Score was 9.6 ± 2.7; the mean SpO_2 significantly improved after the ST (from a mean 86.4 ± 10.1% before ST to a mean 98.5% ± 4.7% after ST, $P < 0.05$); 28 patients (50.9%) had an SpO_2 below 90% before chest decompression; this number includes four patients with unobtainable SpO_2 that were considered to have values below 90%, but did record an SpO_2 > 90% after the ST.

Before the ST, 19 (34.5%) patients had an SAP of ≤ 90 mmHg whereas after the procedure only seven (12.7%) patients remained hypotensive ($P < 0.05$).

Thirteen (23.6%) patients had both SBP and SpO_2 below 90 before ST, whereas 21 (38%) patients had SBP and SpO_2 above or equal to 90 on the scene of the accident before ST; mean AIS thorax for these two groups was 4.73 (SD ± 0.65) and 4.29 (SD ± 0.72), respectively; this difference was not statistically significant.

The overall mortality was of 61.6 vs 14.3%, while the overall ICU stay for the survivors was of 20.6 (SD ± 8.6) vs 12.9 (SD ± 19.4) days in the same two groups.

A PNX or a haemopneumothorax was found in 54 (91.5%) of the performed procedures. A PNX was found in 30 (50.8%) cases, a haemopneumothorax in 24 (40.7%) and a haemothorax in three (5.1%). In two cases (3.4%), no pneumothorax or haemothorax was found.

According to the diagnostic methods described previously no cases of major bleeding, lung laceration or pleural infection were recorded.

Thoracic lesions were diagnosed by helical CT-scan in 50 (91.0%) patients, by conventional radiology in one patient (1.8%), by autopsy in one patient (1.8%). Three patients (5.4%) died before any radiological investigation could be undertaken, and autopsy was not performed, owing to legal reasons. A detailed description of lesions was available in 52 patients out of 55 (94.5%). Pulmonary contusions were found in 40 (76.9%) patients, 35 (59.6%) had a unilateral contusion and five (9.6%) had bilateral contusion. Multiple rib fractures or flail chest were found in 28 patients (53.8%), lung lacerations in three (5.8%) diaphragm laceration in three (5.8%), blunt aortic injuries in three (5.8%). Among the 28 patients with multiple rib fractures, 26 (92.8%) had a PNX or a haemopneumothorax, whereas two (7.2%) had a haemothorax.

No case of recurrent tension PNX was observed, according to the absence of recurrent clinical and radiological signs.

In six (11.0%) patients who underwent a unilateral procedure, a PNX on the opposite side was discovered during the helical CT-scan. In four of these patients, it was, however, less than 20 mm thick and in none did it cause respiratory or haemodynamic compromise at the time of the diagnosis. Of the four aforementioned small PNXs, three were not treated and one of them progressed to tension PNX causing sudden cardiac arrest and death of the patient at the end of the operative course.

Mean AIS thorax and Injury Severity Score were 4.5 ± 0.7 and 34.2 ± 11.7, respectively, for 52 patients in whom the description of the lesions was available.

The mean duration of the chest tube drainage and mechanical ventilation was, respectively, 8.3 ± 5.0 days (range 1–26) and 7.5 ± 7.1 days (range 1–27).

Mean length of stay in ICU was 13.1 ± 14.3 days (range 1–82).

Forty (72.7%) patients survived to hospital discharge and 15 (27.3%) died. The cause of death was uncontrolled haemorrhage in seven patients (Table 2), anoxic brain damage in one patient, traumatic brain injury in one patient, multiorgan failure in one patient, undetermined in five patients; among the latter, two patients died in ICU, after 3 and 20 days, respectively, and three patients died in the ED, shortly after arrival.

Discussion

Prehospital chest drainage and endotracheal intubation were demonstrated to improve severe trauma patients survival [4,6–9,11]; Biewener *et al.* [5] recently demonstrated a 19% improvement in survival for severe trauma patients rescued by HEMS crews, who performed chest drainage and endotracheal intubation in 25 and 91% of the patients, respectively, as compared with ground ambulances crews with Basic Trauma Life Support capabilities.

Table 2 Anatomic localization of uncontrolled haemorrhage site in our patients series

Patient	Hemorrhage site
GP	Pelvic ring fracture
GC	Liver laceration
LB	Pelvic ring fracture and lung laceration
LC	Liver and spleen laceration
MD	Pelvic ring fracture, spleen and lung laceration
EL	Pelvic ring disruption
EM	Lung and spleen laceration

The lung lacerations were not attributable to the ST procedures, due to different anatomic lung region involved.

Evaluation of different methods of prehospital treatment of traumatic PNX by literature review is not straightforward, as there are only a few papers that address this specific topic and, to our knowledge, there is only one comparative study [12].

In general, tube thoracostomy with the use of Trocar tubes in the prehospital setting has a reported percentage of complications as lung injuries or severe persistent PNX, and malpositioning rates up to 30 and 60%, respectively [13,14]; high complication rates are reported in the hospital setting as well [15], therefore it seems that it should be avoided, as recommended by many internationally accepted guidelines and courses.

Eckstein and Suyehara [11] analysed 108 needle thoracostomies performed by paramedics before transportation to a large urban level 1 trauma centre and found that only five (5%) of the patients showed objective improvement in field vital signs, whereas Cullinane *et al.* [17] evaluated 25 needle thoracostomies in the prehospital setting and concluded that this procedure was often ineffective.

Schmidt *et al.* [16] evaluated 76 field tube thoracostomies by blunt dissection without the use of Trocar tubes, and found no complications and a negligible malpositioning rate (four cases).

Barton *et al.* [12] compared 169 cases of NT with 106 cases of tube thoracostomy by blunt dissection performed by flight nurses and reported that 19% of patients who underwent NT were pronounced dead on arrival, vs 7% of patients who underwent tube thoracostomy. The authors concluded that this statistically significant difference may suggest a higher survivability during air transport with a chest tube in place. The most frequent procedure-related complications reported in the NT group were malpositioning, malfunctioning and dislodgement.

The technique that was previously in use in our HEMS differed from NT, as it included the introduction of a small-bore catheter through the needle; nevertheless, we encountered the same kind of procedure-related complications as described for NT and in several cases they had potentially lethal consequences.

Simple thoracostomy without chest tube placement is described as a safe and effective technique that has the advantage of being simpler and faster when compared with tube thoracostomy; this technique was previously performed in some cases in our HEMS, but was never evaluated; therefore, after the afore mentioned literature review and some in-depth discussion, we decided to adopt the simple thoracostomy as the standard for the treatment of all PNX in the field.

We have demonstrated ST to be a safe and effective method of chest drainage as we did not record any major complications or infections related to field thoracostomy. Moreover, no recurrent tension PNX occurred in this group. The equipment needed and its relative simplicity make this procedure well suited for Search And Rescue type missions in hostile environments. In our study group, a climber who sustained multiple injuries with a tension PNX was successfully chest drained on a mountain at 2000 m of altitude; he was eventually rescued with the helicopter's winch together with the assisting anaesthesiologist.

Two of the three patients who expired soon after ED arrival without radiological investigation or autopsy had a tension PNX, as confirmed by the field escape of air under pressure and prompt and persistent lung re-expansion, whereas one had a haemothorax, as demonstrated by ED chest tube placement. All three patients underwent a re-exploration with the 'finger-sweep' manoeuvre at the moment of ED admission. Therefore, in those patients, a tension PNX may reasonably be ruled out as the cause of death.

The new indications for field chest drainage were broadened and include all patients with clinical signs of PNX, regardless of the presence of hypotension, severe dyspnoea or oxygen desaturation below 90. After adoption of these treatment indications, a two-fold increase in the number of PNXs treated yearly was observed.

More than 90% of the patients treated had a PNX or a haemopneumothorax, whereas 5% had a haemothorax alone; moreover, there was no significant difference in the severity of thoracic lesions between the two groups of patients who had an SpO_2 and an SBP below and over or equal to 90, as showed by mean AIS values. Not surprisingly mortality and survivors ICU stay was significantly different between these two groups. These data seem to suggest that, as some clinicians [22] and ourselves believe, vital variables are unreliable in determining the severity of thoracic lesions and the presence of a tension PNX.

Endotracheal intubation and positive pressure ventilation followed by simple thoracostomy had an impressive impact on patients with a decreased oxygen saturation as demonstrated by the mean values of 86.3 and 98.5%, respectively, before and after the procedure; it is likely that this positive effect is not due to chest decompression alone, but also due to prompt lung re-expansion and rib cage internal stabilization, accomplished with positive pressure ventilation; this hypothesis is also supported by the fact that 76.9% of patients of this group had unilateral or bilateral pulmonary contusion and 53.8% sustained multiple rib fractures or flail chest, conditions that, in the absence of PNX, probably do not benefit significantly from pleural space drainage.

One of the possible pitfalls of chest thoracostomy is that it is a surgical procedure that requires adequate training and skill to be performed safely. On the other hand, we are convinced that in the prehospital management of severe trauma patients there is little room for medical crews with limited skills and experience: in 1991 Delooz [23] stated that 'if the highest expertise is involved on the scene, prehospital care will not cause delay; on the contrary, it will result in earlier definitive care, limitation of oxygen debt and transfer to the most appropriate trauma care facility'.

Conclusion

Traumatic PNX, including tension PNX are treatable causes of morbidity and mortality in multitrauma patients. Their treatment by simple thoracostomy without chest tube insertion in the early prehospital phase is safe and effective. This procedure has been adopted as our preferred approach in these circumstances.

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