



## Video-tube thoracostomy in trauma resuscitation: A pilot study

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### ABSTRACT

**Background:** Complications related to incorrect positioning of tube thoracostomy (TT) have been reported to be as high as 30%. The aim of this study was to assess the feasibility of flexible videoscope guided placement of a pre-loaded chest tube, permitting direct intrapleural visualization and placement (Video-Tube Thoracostomy [V-TT]).

**Methods:** A prospective, single centre, phase 1 pilot study with a parallel control group was undertaken. The population studied were adult thoracic trauma patients requiring emergency TT who were haemodynamically stable. The intervention performed was V–TT. Patients in the control group underwent conventional TT. The primary outcome was tube position as defined by a consultant radiologist's interpretation of chest x-ray (CXR) or CT. The trial was registered with ANZCTR.org.au (ACTRN: 12,615,000,870,550).

**Results:** There were 37 patients enrolled in the study - 12 patients allocated to the V–TT intervention group and 25 patients allocated to conventional TT. Mean age of participants was 48 years (SD 15) in intervention group and 46 years (SD 15) years in the control group.

In the V–TT group all patients were male; the indications were pneumothorax (83%), haemothorax (8%) and haemopneumothorax (8%). The median injury severity score was 23 (16–28). There were 1 positional and 1 insertional complications. In the control group 72% of patients were male, the indications were pneumothorax (56%), haemothorax (4%) and haemopneumothorax (40%). The median injury severity score was 24 (14–36). There were 8 (32%) positional complications and no insertional complications.

**Conclusion:** V-TT was demonstrated to be a feasible alternative to conventional thoracostomy and merits further investigation.

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### Introduction

Physical injury is responsible for the loss of more economically productive years of life worldwide than heart disease, cancer and HIV combined. Thoracic injuries are responsible for over 35% of trauma deaths [1]. Pneumothorax and haemothorax occur commonly in patients with major trauma. Failure to decompress and drain either is associated with significant mortality and morbidity [2].

Various methods of pleural decompression and drainage with lung re-inflation have been considered since an initial description

of the technique by Hippocrates more than 2000 years ago. An aseptic incision into the chest cavity - followed by sterile gloved finger exploration - is considered current best practice for chest decompression in thoracic trauma [2–4]. This is followed by tube thoracostomy (TT) attached to a closed drainage system to facilitate ongoing drainage.

TT requires surgical placement with an incision between the ribs and into the pleural space, with the tube then fed blindly to a depth of 16–20 cm in adults. The catheters are expected to be placed between the visceral and parietal pleura. However, even with experienced operators, tube malposition occurs up to 20% of the time and tube may become obstructed and not function [5,6]. As a consequence, the catheter may have to be removed and another inserted.

Blind TT may result in extra-pleural placement, intra-fissural placement (Fig. 1a), mediastinal impingement and visceral or

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**Fig. 1.** (a) Possible positions and complications of tube thoracostomy (TT): (A) Trauma to the intercostal neurovascular bundle. (B) Extrapleural placement. (C) Correct position in pleural space. (D) Intrafissural placement. (E) Intrapulmonary placement. (F) Mediastinal impingement or penetration. (G) Trans-diaphragmatic placement. (H) Infection. [3] (b) Intrapulmonary placement of tube thoracostomy. Picture courtesy of Mr Adrian Pick [3].

diaphragmatic penetration (Fig. 1b) - with complication rates of up to 30% described in trauma patients amongst all operators [7].

Recent developments in medical thoracoscopy have raised the possibility that insertion of a video endoscope (videoscope) into the pleural space may allow inspection of pleural anatomy and correct TT placement [8].

The aim of this study was to assess the feasibility of Video-Tube Thoracostomy (V-TT) (Fig. 2a–c) (Vid.1) for correct TT positioning in adult thoracic trauma.

## Methods

### Setting

The study was conducted in The Alfred Hospital, a Level 1 Adult Major Trauma Centre in Melbourne, Australia. Patients requiring TT were identified on arrival to the Emergency & Trauma Centre as part of routine clinical practice. Eligibility requirements were: a diagnosis of pneumothorax or haemothorax; haemodynamic stability; which was defined as SBP > 90 mmHg and 18–75 years of age.

Demographic variables (age, sex and weight,) were collected from patient medical records for all participants. Baseline patient data and pre-hospital procedure data including rates of needle-thoracostomy, intubation and positive-pressure ventilation were extracted from the Alfred Trauma Registry. Case data (Table 1) were retrieved from the data collection forms completed by the researchers.

For this phase 1 feasibility study, the intervention procedure was only performed by the principal and associate researchers involved in the Emergency & Trauma Centre reception where the sterilized videoscope was available. The researchers in the intervention group were required to have completed greater than 20 prior TT's as per the study ethics approval. A concurrent control group was used as a comparator with conventional "blind tube thoracostomy" performed by emergency or surgical consultants and trainees. Eligible patients were assigned to 1 of two groups; V-TT and conventional TT. If the subject met enrolment criteria and a researcher was available, the patient was assigned to the V-TT group. If a researcher was unavailable the patient was assigned to the conventional TT group.



**Fig. 2.** (a–c) V-TT setup.

**Table 1**  
Baseline demographic and clinical characteristics (n = 37).

	Intervention (n = 12)	Control (n = 25)	p-Value
Weight (kg)	84 (40)	76 (13)	0.15
Age- years	48 (15)	46 (15)	0.58
Systolic BP (mmHg)	142 (27)	139 (37)	0.78
ISS	23 (16–28)	24 (14–36)	0.64
Male sex	12 (100%)	18 (72%)	0.07
Blunt Trauma	11 (92%)	24 (96%)	0.99
Intubation + PPV prior to TT	3 (25%)	11 (44%)	0.46
Pre-hospital Needle Thoracostomy	3 (25%)	8 (32%)	0.99
Indication			0.12
PTX	10 (83%)	14 (56%)	
HTX	1 (8%)	1 (4%)	
HPTX	1 (8%)	10 (40%)	
Operator experience (Number of previous TT's)			0.001
<10	0	6 (24%)	
10–20	0	8 (32%)	
>20	12 (100%)	11 (44%)	
Time taken for procedure (Mins)			0.14 <sup>a</sup>
<5	2 (17%)	5 (20%)	
5–10	8 (67%)	7 (28%)	
10–20	0	10 (40%)	
>20	1 (8%)	3 (12%)	
Equipment Failure	1 (8%)	0	

Abbreviations: ISS Injury Severity Score; TT Tube Thoracostomy; PPV Positive Pressure Ventilation; PTX Pneumothorax; HTX Haemothorax; HPTX Haemopneumothorax.

<sup>a</sup> Equipment failure removed from analysis when testing for statistical significance.

#### Intervention: Video Tube Thoracostomy (V-TT) (Vid.1)

Prior to study commencement, physicians who performed V–TT attended a 1-hour practical session covering patient consent procedure, study documentation and filing, physiologic and clinical indications and contraindications, as well as complications of insertion of chest tubes and videoscope equipment set-up. This session included participation in a practical demonstration, where TT insertion into a porcine animal cadaver thorax using V–TT was demonstrated by an experienced physician. After the practical demonstration, each physician performed each step of V–TT on one side of a porcine cadaver thorax. All physicians completed each step successfully in the porcine model. All physicians in the control group attended a 1-day trauma orientation session on the application of basic procedures in trauma including tube thoracostomy before commencement of the study.

For all patients the 4<sup>th</sup>–6<sup>th</sup> intercostal space was chosen as the anatomical “safe-zone” as per the mid-arm point (MAP) method for thoracostomy using anatomical landmarks [9]. The presence of haemodynamic, peri-procedural instability after enrolment was considered a contraindication. However, these patients were included as per an intention-to-treat analysis.

A Karl Storz FIVE 5.5 mm Videoscope was set up alongside the sterile thoracostomy set-up on a separate sterile field (Fig. 2a–c). The videoscope loaded with a 28F flexible intercostal catheter (ICC) and the ICC position secured by a passing the videoscope through a ‘V-shaped’ incision (Fig. 3) in the ICC bulb. Sterile wall-suction tubing was connected and tested, the videoscope monitor connected and the white-balance reset. The thoracostomy was performed as per the conventional technique described.

The Videoscope, preloaded with a 28Fr ICC (V-ICC) was then inserted into the thoracostomy incision and confirmation of access to thoracic cavity assessed on the videoscope monitor. A 2-hand technique was performed with the dominant hand controlling the angulation lever and the non-dominant hand holding the scope and ICC at the insertion site. Once access to the thoracic cavity was confirmed, the V-ICC was advanced into the pleural cavity posterior to the lung with navigational control of the videoscope tip achieved via the angulation lever and scope rotation (Fig. 4a–b). Aspiration of pleural fluid (e.g. haemothorax) was performed at the discretion of the operator via the working channel. Once the



**Fig. 3.** A ‘V-shaped’ incision through the 28 Fr ICC proximal connection bulb secures the endoscope, stopping longitudinal slippage.

desired position was achieved, the videoscope was removed from the ICC by the operator and the ICC secured as per the conventional technique.

In either group, if access to the thoracic cavity was not confirmed, the ICC was withdrawn and access ensured via digital inspection of the pleural space. Asepsis was preserved throughout both techniques and a prophylactic antibiotic was administered in all cases.

Correct tube position (Fig. 5a–b) was defined as pleural (tip or sentinel hole) within the pleural space in the absence of any of the malposition criteria. Tube position was further assessed for apical or basal position as apical (tip or sentinel hole positioned at or above the level of the aortic notch) or basal (tip or sentinel hole positioned 2 cm above the diaphragm or lower).

Tube malposition was defined on CT as presence of any one of the following findings: Extrapleural (tube tip or sentinel hole outside of pleural space); Intrafissural (tube tip or sentinel hole in the interlobar fissure position); Intraparenchymal (tube tip or sentinel hole within lung parenchyma); Mediastinal Impingement/

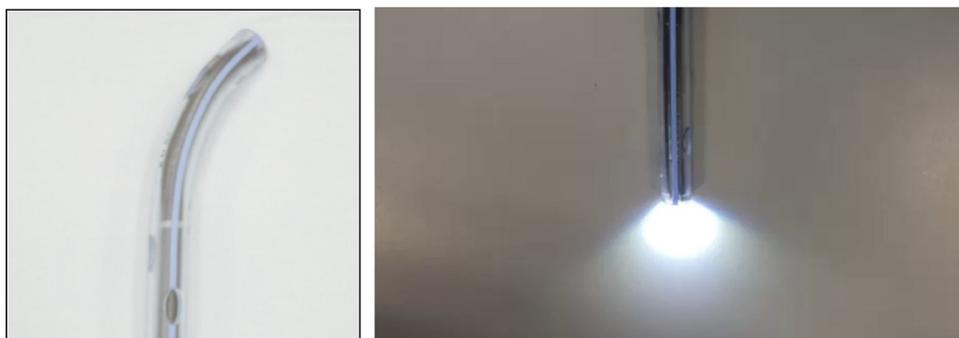


Fig. 4. (a–b) Adjusting the tip direction of the ICC.

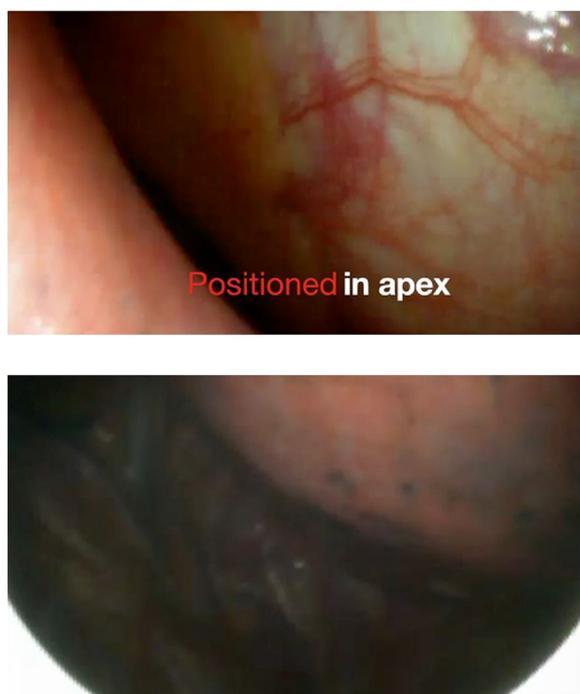


Fig. 5. (a–b) V-TT technique: Apical position with lung edge on view.

Penetration (tube tip or sentinel hole abutting or within mediastinum); Trans-diaphragmic/Intra-abdominal and Tube Folding.

Insertional complications were defined as insertion failure (e.g. equipment malfunction and procedure abortion) or wound site infection. Potential confounding variables including procedural difficulty, procedural time and operator experience were recorded by the operator on the data collection form. Secondary outcomes of duration of tube in situ, duration of hospital stay, need for further intervention (tube thoracostomy and/or need for VATS), infective complications and mortality rates were extracted from The Alfred Trauma Registry database.

Normal or near-normal distributed data were summarized using mean (standard deviation) while skewed and ordinal data were summarized using median (inter-quartile range). Statistical significance was assessed by Student's *t*-test (for difference between means), Wilcoxon Rank Sum test (for difference between medians), Chi-squared test (for difference between proportions) or Fisher's Exact test (for difference between proportions when value in a cell was <5). When using the Fisher's Exact, the *p*-value reported was double of the one-sided exact probability. For assessing the association between the intervention and operator

experience and time of procedure, a nonparametric test for trend across ordered groups was used. A *p*-value of <0.05 was defined to be statistically significant. All analyses were performed using Stata v 11.3 (College Station, Texas, USA).

Ethics approval was obtained from The Alfred Hospital Research & Ethics Committee. The trial was registered with ANZCTR.org.au (ACTRN: 12615000870550).

## Results

Over a 6-month period (December 2015 - July 2016) 37 participants were enrolled. Table 1 summarises the baseline characteristics of both study groups. The clinicians in the intervention group were more experienced and had completed more tube thoracostomies than those in the control group. Time taken to complete V-TT was not different to standard-TT (Table 1).

There were 12 patients who received V-TT and 25 patients received standard TT (Fig. 6). 1 tube (8%) placed using V-TT resulted in tube malposition compared with 8 tubes (32%) placed using conventional TT (*p*=0.22) (Table 2).

The malpositioned tube in the V-TT group was an intraparenchymal placement, which occurred in a patient with dense pleural adhesions on a background of previous thoracic trauma and VATS. Of the 8 malpositioned tubes in the conventional TT group, 5 were placed in a lung fissure; 1 tube was folded onto itself; 1 tube was placed into the pericardial fat-pad resulting in mediastinal impingement and 1 tube placement was intraparenchymal. The 1 tube malposition in the V-TT group required a further TT for a persisting pneumothorax. Of the 8 malpositioned tubes in the TT group, 3 required a further tube insertion and 2 of these required VATS.

One insertional complication occurred in the V-TT group due to equipment failure (suction-cap breakage) resulting in procedure abortion. There were no insertional complications in the control group. There were no cases of empyema in the V-TT group and 1 case of empyema in the control group associated with tube malposition. This patient required VATS for evacuation of the empyema.

One patient in the V-TT group and 2 in the standard-TT group died before hospital discharge. The cause of death in the V-TT group was as a result of a severe traumatic brain injury and occurred 3 days post TT. The 2 deaths in the standard TT group were also unrelated to TT.

## Discussion

This study demonstrated that V-TT was feasible in the trauma centre after staff education. While a positional complication rate using standard TT of 32% was consistent with that reported in the literature, using V-TT resulted in a lower malposition rate of 8%, although this result was not statistically significant in this feasibility trial. V-TT was not associated with any intra-fissural tube placement.

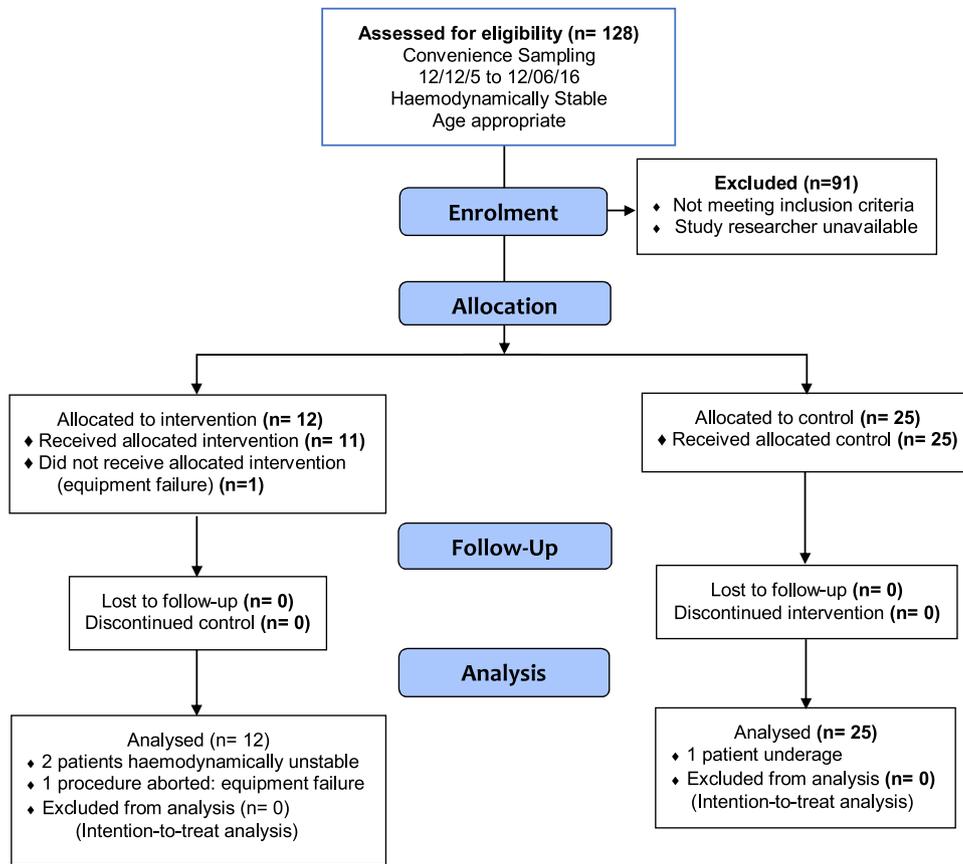


Fig. 6. CONSORT Flow Diagram.

**Table 2**  
Tube Thoracostomy Outcomes (n = 37).

	Intervention (n=12)	Control (n=25)	p-Value
<b>Primary Outcome</b>			0.22
Malposition	1 (8%)	8 (32%)	
Correct position	10 (83%)	17 (68%)	
<b>Secondary Outcomes</b>			
Mortality	1 (8%)	2 (8%)	
Infection	0	1 <sup>b</sup> (4%)	
Persistent Pneumothorax >1 Tube insertion	3 (25%)	9 (36%)	
Insertional Complication	1 <sup>a</sup> (8%)	0	
Duration of Hospital Stay (Days)	9 (7–14)	15 (5–28)	0.38
Tube duration in situ (Days)	4 (3–5)	3 (2–5)	0.11

<sup>a</sup> Equipment failure (suction-cap) and procedure abortion.

<sup>b</sup> Empyema.

This study appears to be the first to trial this technique during trauma resuscitation. The use of a fiberoptic laryngoscope for direct visualization the thoracic space during tube thoracostomy in a cadaver has been previously described [10]. The use of a rigid 32 F thoracic tube as a guide for a semi-flexible fiberoptic thoracoscope rather than using a rigid thoracoscope for the diagnosis, inspection, and management of patients with pleurisy has also been described [11]. Chen et al. observed a variation of direct visualization with the use of an electrical non-fiberoptic endoscope and suggested that visually guided TT may be a safer alternative than non-image guided TT in cases of pleural adhesions [12].

Optimal tube placement for evacuation of a simple pneumothorax has been found to be an apical and anterior position whereas for fluid drainage a dependent tube position at the

posterior base is associated with better success rate in fluid drainage. These placement site choices were reflected in our study with no difference in tube position between cases of simple pneumothorax compared to haemothorax.

Our data demonstrated no additional risk of visceral injury with V–TT in comparison with the gold standard. Parenchymal injury and resulting tube malposition occurred in 1 case in each group. Intraparenchymal TT is more likely to occur with pre-existing pulmonary disease or pleural adhesions [13]. This finding was reflected in the case of tube malposition in the V–TT group where parenchymal injury occurred at thoracostomy in a patient who had undergone previous VATS pleurodesis. Confirmation of access to the pleural cavity by finger sweep and/or visualization of lung parenchyma on V–TT is insufficient. It is the authors'

recommendation that confirmation access to the pleural space is confirmed by presence of intrapleural rib markings on V–TT.

Both cases of intraparenchymal malposition occurred in ventilated patients where intubation and positive pressure ventilation had occurred prior to commencing TT. The literature reports high incidence of lung perforation by surgical instruments in the diseased, hyperventilated lung with a high PEEP where the pleural space may be diminished [14,15]. Consideration of protective ventilation strategies such as reducing PEEP or performing an expiratory hold, to prevent iatrogenic injury during pleural decompression and to assist tube passage and safe placement, warrant further study.

Equipment failure is a potential complication in therapeutic intervention. The case of insertional complication in the V–TT group occurred due to suction cap breakage in this study. The authors recommend that suction equipment is fitted and tested prior to V–TT insertion in the event that aspiration of haemothorax is needed to improve visibility and tube placement. A sterile suction cap replacement should be available in the event of component failure.

### Limitations

This pilot trial with trained and experienced operators limits generalizability to all medical staff. The V–TT required reprocessing and sterilisation between cases. The turnaround time required to sterilize the videoscope device was approximately 4 h and meant that opportunities to enrol patients in the V–TT group were missed. During the latter part of the study disposable videoscopes became available - their use and cost-benefit for V–TT warrants further exploration [16].

As participant enrolment was based on convenience sampling, patients were allocated into the study groups prior to the procedure at the discretion of the operator. There was a greater proportion of patients with simple pneumothorax (83%) in the V–TT group than in the control group (56%). The V–TT group was comprised entirely of male participants compared to 72% of male participants in the control group. Although appropriate for a feasibility study the enrolment methodology was potentially prone to selection bias.

Physicians performing the procedures in the V–TT group had more ICC experience than those that performed the TT in the control group. This may have affected V–TT placement success rate with more highly skilled proceduralists in the V–TT having a lower likelihood of tube malposition.

There was no evidence of a Hawthorne effect in this study with tube malposition rates in the control group at 32% comparable with an historical tube malposition rate as low as 5% in our centre [3].

### Conclusion

This study is the first human study to demonstrate the feasibility of V-TT in the adult trauma resuscitation population. V-TT merits further exploration for technique and design refinement.

### Declarations

The authors of this publication received research support with a 'FIVE' 5.5 mm Videoscope provided by Karl Storz Endoscopy Australia Pty Ltd for the duration of the study. The terms of this arrangement were reviewed and approved by the Alfred Hospital Research & Ethics Committee in accordance with its policy on objectivity in research. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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### Conflict of interest

None.

### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.injury.2018.08.007>.

### References

- [1] Ekpe E.E., Eyo C. Determinants of mortality in chest trauma patients. *Niger J Surg* 2014;20:30–4. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/24665200>.
- [2] Fitzgerald M, Mackenzie C, Marasco S, Hoyle R, Kossmann T. Pleural decompression and drainage during trauma reception and resuscitation. *Injury* 2008;39(1)9–20. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/18164300>.
- [3] Heng K, Bystrzycki A, Fitzgerald M, Gocentas R, Bernard S, Niggemeyer L, et al. Complications of intercostal catheter insertion using EMST techniques for chest trauma. *ANZ J Surg* 2004;74(June (6))420–3. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/15191471>.
- [4] Anderson M, Fitzgerald M, Martin K, Santamaria M, Arendse S, O'Reilly G, et al. A procedural check list for pleural decompression and intercostal catheter insertion for adult major trauma. *Injury* 2015;46(1)42–4. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/24680471>.
- [5] Remerand F, Luce V, Badachi Y, Lu Q, Bouhemad B, Roubey JJ. Incidence of chest tube malposition in the critically ill: a prospective computed tomography study. *Anesthesiology* 2007;106(6)1112–9. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/17525585>.
- [6] Baldt MM, Bankier AA, Germann PS, Pöschl G, Skrbensky GT, Herold CJ. Complications after emergency tube thoracostomy: assessment with CT. *Radiology* 1995;195(2)539–43. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/7724780>.
- [7] Ball CG, Lord J, Laupland KB, Gmora S, Mulloy RH, Ng AK, et al. Chest tube complications: how well are we training our residents? *Can J Surg* 2007;50(6) 450–8. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/18053373>.
- [8] Casos SR, Richardson JD. Role of thoracostomy in acute management of chest injury. *Curr Opin Crit Care* 2006;12(6)584–9. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/17077691>.
- [9] Bing F, Fitzgerald M, Olausson A, Finnegan P, O'Reilly G, Gocentas R, et al. Identifying a safe site for intercostal catheter insertion using the mid-arm point (MAP). Available from: <http://www.qscience.com/doi/pdf/doi:10.5339/jemtac.2017.3>.
- [10] Aho JM, Ruparel RK, Schiller HJ. A technique for visual confirmation of intrathoracic placement of tube thoracostomy using a fiberoptic laryngoscope in a cadaver. *Eur J Trauma Emerg Surg* 2015;41(2)199–202. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/26038265>.
- [11] Yokoyama T, Toda R, Tomioka R, Aizawa H. Medical thoracoscopy performed using a flexible bronchoscope inserted through a chest tube under local anesthesia. *Diagn Ther Endosc* 2009;2009:394817. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/19536345>.
- [12] Chen CH, Chang H, Lee SY, Liu HC, Hung TT, et al. Video-guided tube thoracostomy with use of an electrical nonfiberoptic endoscope. *Ann Thorac Surg* 2013;96(4)1450–4. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/24088456>.
- [13] Fraser R. Lung perforation complicating tube thoracostomy: pathologic description of three cases. *Hum Pathol* 1988;19(5)518–23. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/3371976>.
- [14] Shaikhrezaei K, Zamvar V. Hazards of tube thoracostomy in patients on a ventilator. *J Cardiothorac Surg* 2011;29(March (6))39. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/21447174>.
- [15] Peek GJ, Firmin RK, Arsiwala S. Chest tube insertion in the ventilated patient. *Injury* 1995;26(6)425–6. . Available from: <https://www.ncbi.nlm.nih.gov/pubmed/7558273>.
- [16] Reynolds S, Zurba J, Duggan L. A single-centre case series assessing the Ambu ((R)) a scope 2 for percutaneous tracheostomies: a viable alternative to fiberoptic bronchoscopes. *Can J Respir Ther* 2015;51(2)43–5. . Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4467478/>.