Complications following chest tube insertion pre- and post-implementation of guidelines in patients with chest trauma: A retrospective, observational study

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ABSTRACT

Background: The need to evacuate the chest after a penetrating wound was first recognized in the 18th century. Most thoracic injuries are treated with tube thoracostomy (TT) which refers to the insertion of a TT into the pleural cavity to drain air, blood, pus, or other fluids. However, TT has been challenged in the trauma care due to insertional, positional, or infective complications.

Methods: A retrospective study of all trauma patients who had TT insertion from 2008 to 2014 was conducted based on the trauma registry data to describe patient characteristics, injury characteristics, management, and outcomes. The complication incidences per TT before (2008) and after (2009–2014) the implementation of standard protocol were compared.

Results: During the study period, 804 patients were managed with 1004 TT procedures. The mean age was 34 years, and majority (91%) was males. Motor vehicle crash (43%) was the main mechanism of injury. Mean injury severity score was 22. The rib fractures (68%) were more frequent followed by pneumothorax (49%). Nearly 72% of patients received antibiotic coverage before insertion. The complications developed per TT reduced over the years from 2008 to 2014 (12.6% to 4.4%). The average complication per TT after the protocol implementation (2009–2014) reduced by 7% when compared to the duration before implementation (2008).

Conclusions: The present study shows that standardized management of trauma patients who undergo TT results in a reduction in complications, helps improve patient flow, and ensures the proper management of resources in our high-volume trauma center.

Key Words: Chest tube, thoracic injury, trauma, tube thoracostomy

INTRODUCTION

Trauma is the leading cause of death among individuals under the age of 40 years and accounts for approximately 140,000 deaths per year in the United States.[1] Thoracic trauma is considered a significant injury and is responsible for 25% of these deaths.[2] Mortality was reported to increase in these patients (up to 30%), which underlines the importance of the initial management.[3] Many thoracic injuries may be treated with tube thoracostomy (TT) or thoracocentesis, defined as the insertion of a TT into the...
pleural cavity to drain air, blood, pus, or other fluids.\textsuperscript{[4]} The need to evacuate the chest after a penetrating wound was first recognized by Boerhaave in the early 18\textsuperscript{th} century. He described a blunt-tipped, flexible tube to which suction was applied.\textsuperscript{[5]} These same principles were applied to blunt thoracic trauma by Maloney in 1963.\textsuperscript{[6]} The early diagnosis and advanced treatment of thoracic injuries were seen during the last decade. The insertion of TT is the most commonly used procedure in trauma care; however, it may be left for junior staffs to insert and remove it under insufficient supervision which could increase the rate of complications in some occasions. The use of computed tomography (CT) can reveal overlooked injuries and help in decision-making whether to use TT or perform surgical thoracotomy.\textsuperscript{[7,8]} The management can be divided into three stages: prehospital, emergency department, and surgical. A primary survey can identify life-threatening injuries such as tension pneumothorax, open pneumothorax, and massive hemothorax.\textsuperscript{[9]} Recently, the necessity of chest drain insertion has been challenged due to the high complication rate.\textsuperscript{[10]} These complications are classified as insertional (lung or organ laceration and hemorrhage), positional (extrathoracic placement, persistent hemothorax, or pneumothorax), or infective (wound infection and empyema).\textsuperscript{[11]} Therefore, TT is an essential life-saving skill that must be done safely, effectively, and for the right indications.

Recently, trauma centers started to implement standardized protocols for TT insertion and management, in order to minimize complications and improve the quality of care.\textsuperscript{[12,13]} Earlier in our practice, there were no guidelines for chest tubes. TT was performed by thoracic surgeons before the establishment of the trauma unit in our institution. The trauma center where the study was conducted was started in 2007 as a multidisciplinary level one center, including trauma, orthopedics, neurosurgery, vascular surgery, interventional radiology, and critical care. At the beginning, there was a great variation in the methods of insertion and removal of TT. Insertion site, drain size, and method of securing were very subjective. Most drains were inserted using blunt dissection and connected to underwater seal drainage. A chest X-ray was ordered to evaluate the position. However, in the year 2009, a protocol for TT insertion and care was introduced, to serve as a framework for clinical practice, and to help in minimizing the complications. The objective of this observational study is to assess the implications of implementing TT guidelines at a level one trauma center in patients with chest trauma.

**METHODS**

A retrospective before and after study of all trauma patients who had chest tube insertion from January 2008 to December 2014 was conducted. We compared the outcomes before (2008) and after applying a standard protocol (2009–2014). We investigated the effect of uniform interventions in the management of chest tubes and assessed their outcomes.

Data were obtained from the trauma records, a national registry affiliated with the American College of Surgeons Trauma Quality Improvement Program. The TT protocol was implemented in the year 2009, which includes antimicrobial prophylaxis, TT insertion by trained physicians or under direct supervision, admission in a specialized trauma unit, and daily follow-up. The implementation of the protocol involved all health-care team members. The nurses and respiratory therapists were needed to provide adequate care for patients and promote the guidelines among the trauma surgeons, residents, and interns. Nurses and senior physicians provided supervision to maintain protocol compliance.

During the study period after 2009, patients were managed according to the standardized protocol. Antimicrobial prophylaxis (i.e., cefazolin 1 g) immediately before chest tube insertion was administered. The chest tube was inserted or observed by an experienced surgeon, using open technique. The procedure involved measuring the tube length before insertion, ensuring proper fixation using the purse-string suture and occlusive Vaseline-soaked gauze, monitoring output (<200cc), checking for bubbling or clearance of the color to sero-sanguinous or serous, assessment off suction for 24 h, removal during expiration on earliest opportunity, and a follow-up chest X-ray for lung expansion and to rule out residual collection or pneumothorax. Patients were managed by respiratory therapy, pain medication, follow-up chest X-rays and were seen in the outpatient clinic within 7 days of discharge. The standard protocol of insertion, follow-up, and removal was reinforced with a literature review and explained to all team members in the morning rounds. Postremoval recurrent pneumothorax or hemothorax was used as a key performance indicator. This written protocol was approved by the hospital guidelines committee and reviewed regularly at departmental mortality/morbidity and corporate quality meetings [Supplementary Table 1].

Data collected from the trauma registry included patients demographics, including age and gender; mechanisms of injuries such as motor vehicle crashes (MVCs), falls, and pedestrian hits; chest injuries including rib fractures; injury severity characteristics such as Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS); duration of TT insertion; complications such as pneumothorax, hemothorax and hemopneumothorax, acute respiratory distress syndrome, and pneumonia; antibiotic use before TT insertion; number of tubes used per patient; hospital sites of tube insertion such as trauma room (TRU) or ED, intensive care unit (ICU), and operating room; insertion
problems; tube slippage, bleeding, malposition, and iatrogenic injury; removal complications such as recurrent pneumothorax; and outcomes such as ventilator days, ICU length of stay (LOS), hospital LOS, and in-hospital mortality. The exclusion criteria were death within 48 h from admission. All other trauma patients (males and females above 13 years old) requiring chest tube insertion were included in the study.

Statistical analysis
Data were expressed as proportions, mean ± standard deviation, or medians whenever appropriate. Differences in categorical variables between the groups were analyzed using the Chi-square tests or Fisher exact tests when observed cell values $n < 5$. The continuous variables were analyzed using the student’s t tests, and two-tailed $P < 0.05$ was considered statistically significant. Data analysis was performed using the Statistical Package for the Social Sciences software version 18 (IBM® SPSS Statistics version 18, IBM Corp., Armonk, New York, USA). The Institutional Review Board of the Hamad Medical Corporation, Medical research Center has approved and granted exempt status for this retrospective study (IRB #11151/11 and 15273/15).

RESULTS
A total of 804 patients managed with 1104 TTs were included in the study. The mean age was $33.9 ± 14.9$ years. Most of them were males (91%) The main mechanism of injury was MVC (43%), followed by falls (18%), and pedestrian accidents (17%). The main chest injuries were ribs fractures (68%), pneumothorax (49%), and lung contusion (46%). Hemothorax was seen in 27%, and hemopneumothorax in 22% of cases. The mean chest AIS was three (1–5), and mean ISS was $22.4 ± 10.9$. Approximately three quarters (72%) of patients received antibiotic coverage before insertion. Adherence to antibiotics prescription increased to 76% in 2010 in comparison to 63% and 35% in 2009 and 2008, respectively ($P = 0.001$).

The incidences of major complications such as recurrent pneumothorax, pleural effusion, and hemothorax were reduced over the years. In addition, incidence of insertion problems (tube slippage, bleeding, malposition, and iatrogenic injury) ($P = 0.1$) and removal complications (recurrent hemo-pneumothorax) reduced over the years ($P = 0.01$). Complications developed per TT reduced over the years from 2008 to 2014 (12.6% to 4.4%) [Figures 1 and 2]. Average complication per TT after the protocol implementation (2009–2014) was 5.2% which was 12.6% before the guidelines.

The majority had one TT inserted, and few of cases needed up to five tubes [Table 1]. Most of first and second tubes were inserted in TRU or ED, with additional

| Table 1: Characteristics of patients underwent Tube Thoracostomy in Hamad Trauma Center, Qatar (n = 804) |
|-------------------------------------------------|-------------------------------------------------|
| Variable                                         | Value                                           |
| Age (Mean)                                       | 33.9 ± 14.9                                     |
| Males                                           | 732 (91.2)                                      |
| Mechanism of injury                              |                                                 |
| MVC                                             | 346 (43.1)                                      |
| Fall                                            | 145 (18.0)                                      |
| Pedestrian                                      | 133 (16.8)                                      |
| Hit of heavy objects                             | 36 (5.7)                                        |
| Stabbing                                        | 28 (3.5)                                        |
| ATV                                             | 23 (2.9)                                        |
| Motorcycle                                      | 20 (2.5)                                        |
| others                                          | 62 (7.7)                                        |
| Injuries                                        |                                                 |
| Rib fracture                                    | 546 (68.0)                                      |
| Flail chest                                     | 44 (5.5)                                        |
| Hemothorax                                      | 219 (27.3)                                      |
| Pneumothorax                                    | 390 (48.6)                                      |
| Hemopneumothorax                                | 176 (21.9)                                      |
| Lung contusion                                  | 369 (45.9)                                      |
| Lung laceration                                 | 44 (5.5)                                        |
| sternum fracture                                | 58 (7.2)                                        |
| diaphragmatic injury                            | 30 (3.7)                                        |
| cardiac injury                                  | 6 (0.8)                                         |
| Chest AIS (Median)                              | 11 (1.4)                                        |
| Injury Severity Score (Mean & Median)           | 22.4 ± 10.9 [22 (4-75)]                         |
| Antibiotic Coverage                             | 546 (71.7)                                      |
| Total no. of thoracostomy tube (TT) performed   | 1104                                            |
| 1 TT                                            | 804                                             |
| 2 TT                                            | 233                                             |
| 3 TT                                            | 49                                              |
| 4 TT                                            | 15                                              |
| 5 TT                                            | 3                                               |
| Mechanical Ventilation                          | 409 (50.9)                                      |
| Pneumonia                                       | 186 (23.2)                                      |
| Recurrent pneumothorax                          | 37 (4.6)                                        |
| ARDS                                           | 38 (4.7)                                        |
| Pleural Effusion                                | 56 (7.0)                                        |
| Hemothorax                                      | 26 (3.2)                                        |
| Ventilator days (Median)                        | 7 (1-163)                                       |
| Total LOS (Median)                              | 11 (1-360)                                      |
| Mortality                                       | 108 (13.4)                                      |
The present study found that the implementation of TT placement protocol resulted in a significant improvement in the management of chest trauma. Incidences of major complications, insertion problems, and removal complications reduced following the introduction of the protocol. Major complications were recurrent pneumothorax, pleural effusion, and hemothorax. The main insertion problems were tube slippage, bleeding, malposition, and iatrogenic injury. Removal complications included recurrent hemo-pneumothorax. The majority of patients included in the analysis were young and males with an average age of 34 years which reflects the young healthy expatriate male workers in Qatar. The average ISS and chest AIS revealed the serious nature of chest trauma patients and the severity of injury. However, the complication per procedure reduced to an average of 6% after the protocol was implemented. It can also be a part of the natural learning curve during the establishment of the multidisciplinary approach. As some patients had recurrent pneumothorax, this is an area that merits further study to clarify whether the recurrence was post removal or related to the severity of injury which necessitates insertion of additional tubes. It is a common practice in our institution to employ low pressure suction for pneumothorax that fails to respond to free drainage alone.

Although the use of prophylactic antibiotics is controversial, antimicrobial prophylaxis before TT insertion was administered as per our protocol. Nichols et al. evaluated the safety and efficacy of antibiotics use. They concluded that patients receiving prophylactic antibiotics had a significantly reduced infection rate. In their meta-analysis, Fallon suggested that prophylactic antibiotics reduced the incidence of thoracic empyema after TT. However, Etoch et al. detected no discernible difference in infection rates.

The technique of chest drain removal is still equivocal. Westaby recommended a sustained Valsalva maneuver until the purse string suture is tied. He also emphasizes the importance of meticulously securing the drain in place with a combination of sutures and adherent dressings. Our technique similarly uses Valsalva and Jelonet Paraffin Gauze occlusive dressing to help minimize recurrent pneumothorax.

Another area of potential complication is dislodgment of the drain after insertion. This occurred in approximately 13% of patients admitted. Notably, 51% of patients admitted were mechanically ventilated. The median hospital stay was 11 days (1–360). The overall in-hospital mortality rate was 19.4%. Table 2 shows the frequency of TT procedures performed and complications developed.

**DISCUSSION**

The complications are categorized as positional, insertional, or infective. Our approximate 13% complication rate for TT performed before implementation of guideline in 2008 seems high. Millikan et al. retrospectively analyzed 447 patients between 1974 and 1978. There were technical complications in 4 cases (1%) and 11 cases (2.7%) had empyema. In our series, insertion problems were mainly seen in 2008 and 2009, before implementation of the protocol. Etoch et al. noted a complication rate of 16% per TT. Collop et al. encountered 14 complications in 126 TTs (11% complication rate). Chan et al. encountered 64 complications in 352 TTs (18.2% complication rate) but no insertional complications. Similar complication rate (16% in 2008) in our study (before implementation of a standard protocol) may reflect the complexity of trauma patients and the severity of injury. However, the complication per procedure reduced to an average of 6% after the protocol was implemented. It can also be a part of the natural learning curve during the establishment of the multidisciplinary approach. As some patients had recurrent pneumothorax, this is an area that merits further study to clarify whether the recurrence was post removal or related to the severity of injury which necessitates insertion of additional tubes. It is a common practice in our institution to employ low pressure suction for pneumothorax that fails to respond to free drainage alone.

Figure 2: Complication events associated with tube thoracostomy per patient over the years

| Complication Type          | 2008 Total | 2009 Total | 2010 Total | 2011 Total | 2012 Total | 2013 Total | 2014 Total | Overall Total |
|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-------------|
| Total no. of patients      | 78        | 106       | 108       | 103       | 112       | 144       | 153       | 804         |
| Total complications        | 87        | 130       | 118       | 162       | 168       | 214       | 225       | 1104        |
| Complications developed    | 11        | 10        | 2         | 11        | 14        | 6         | 10        | 64          |
| Complication Rate (per procedure) | 12.6% | 7.7% | 1.2% | 6.8% | 8.3% | 2.8% | 4.4% | 5.8% |

*Table 2: Frequency of insertion & removal complications in TT procedure by year*
1% of our patients and was described by Collop et al.[13]

The policy in our department with regard to drain size is in line with ATLS recommendations: 36–40 French (Fr) drains. Westaby recommended a 26 Fr or larger drain for hemothorax and a 20 Fr or larger for pneumothorax.[20] The use of a large bore (≥36 Fr) drain reduces the complications associated with kinking and clotting. A study by Inaba showed that large bore chest tubes (36–40 Fr) have no advantage compared to smaller tubes (28–32 Fr).[21] Chest tube size did not impact the clinically relevant outcomes. A randomized clinical trial by Kulvatunyoo et al. showed that the use of a 14‑Fr pigtail catheter is associated with reduced pain, with no other clinically important differences compared to larger chest tubes.[22]

Recently, trauma centers have looked at reducing complications by introducing standardized approaches. Anderson et al. implemented a quality control checklist into their trauma service at an adult level one trauma center in Melbourne, Australia.[15] They were able to show a reduction in empyema rates by 2/3 (0.57% vs. 1.44%) over a period of 2 years. Martin et al. developed an algorithm for TT management in all trauma patients at a level one trauma institution in Michigan, USA.[13] Both of these studies support a more standardized approach to TT in trauma, the tube has to be kept on suction until a chest X‑ray is repeated. If the patient requires continuous suction for >3 days, cardiothoracic team is consulted. If output is <200 mL, no air leak, and if the repeated chest X‑ray reveals no pneumothorax, the tube is removed. If there is persistent air leak, recurrent pneumothorax or hemothorax, or continuous drainage, a chest CT scan is done.

Although there is a general agreement for the placement of a TT, there is little consensus on the subsequent management. TT removal increases morbidity if not done at the right time, i.e., stable clinical condition, open lung on X‑ray, and no air leak.[23] While no studies have shown that radiography is necessary after tube removal, it is recommended for patients who are on mechanical ventilation.[24] The proposed time is at least 3 h after removal. This is in accordance with our practice which is 4 h postremoval.

The retrospective design of the study is a major limitation. The number of patients included in the study before implementation of the guidelines is somehow limited. The trauma center was established in 2007, and the guideline was implemented in 2008.

CONCLUSIONS

The study shows that standardized management of trauma patients who undergo TT results in a reduction in complications, helps improve patient flow, and ensures the proper management of resources in our high-volume trauma center. Although there are areas need further investigation, this study reveals that a standard and systematized approach improves the patient outcomes. A protocol was established and constantly reviewed in our institution which helped to standardize the practice and contributed in reducing the morbidity. Further improvements require a systems-based approach, focusing on training and team work as part of quality improvement strategies.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Ethical conduct of research

This study was approved by the Institutional Review Board / Ethics Committee at Hamad Medical Corporation, Medical research Center (IRB #11151/11 and 15273/15). The authors followed applicable EQUATOR Network (http://www.equator-network.org/) guidelines, during the conduct of this research project.

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Supplementary Table 1: Guidelines for chest tube insertion and removal at trauma surgery section (Hamad General Hospital)

Antimicrobial prophylaxis should be administered immediately before chest tube insertion

Chest tube should be inserted or supervised by an experienced surgeon

Open technique method should be used to avoid using trocar

Chest tube length should be measured from the site of insertion to the apex of the corresponding lung before insertion

Ensure proper fixation using stay suture or purse string suture and occlusive Vaseline-soaked gauze

Keep chest tube on low-grade suction for 24 h

Monitor the output, check for stopping of bubbling, or clearance of the color to sero-sanguinous or serous

Remove the chest tube if the output <100 cc

Remove during expiration on earliest opportunity

Follow-up chest X-ray after 4 h for lung expansion and to rule out residual collection or pneumothorax

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