ORIGINAL ARTICLE

Closed Tube Thoracostomy Morbidity Rate in a Philippine Tertiary Government Hospital: 6-Year Review

Richard C. Briones, MD,[1] Marla Vina A. Briones, MSc Epidemiology (Public Health),[2] Kathleen S. Cruz, MD[3] and Realyb B. Dongaban, MD[1]

[1]*Bicol Medical Center, Naga City, Camarines Sur, Philippines*
[2]*Naga City, Camarines Sur, Philippines*
[3]*Bicol Surgical Health Hub, Naga City, Camarines Sur, Philippines*

ABSTRACT

Background and Objective. Closed tube thoracostomy is one of the most common hospital procedures known for its effectivity and safety; however, complications may occur, leading to poor patient outcomes. To date, the burden of morbidity among patients who underwent closed tube thoracostomy in the Philippines remains unknown. Therefore, this study aims to determine the in-hospital morbidity rate among patients who underwent closed tube thoracostomy in a tertiary government hospital.

Methods. This is a descriptive cross-sectional study of admitted patients who underwent closed tube thoracostomy at Bicol Medical Center from 2015 to 2020. Data were collected by reviewing medical charts.

Results. A total of 376 patients were included in the study. Morbidity rate was 15.16% (95% CI: 11.69-19.19%), and majority were due to improper chest tube placement. Compared to those without complications, a higher proportion of patients with complications had pleural effusion and had chest tube failure (both $p \leq 0.05$). The median operative time was also significantly longer in patients with complications compared to those without complications ($p=0.0012$). Mortality was significantly lower in patients with complications than those without complications. Total and postoperative length of stay were significantly longer in patients with complications than those without complications ($p<0.00001$).

Conclusion. Complications after closed tube thoracostomy are common. Across all variables analyzed, only indication of chest tube insertion, operative time, and occurrence of chest tube failure were found to differ between patients with and without complications. Moreover, patients with complications had longer length of stay than those without. Reducing positional tube complications may help decrease in-hospital morbidity.

Keywords: chest tube, tube thoracostomy, morbidity, complications

INTRODUCTION

Closed tube thoracostomy (CTT) is one of the most common procedures performed in hospitals, especially among trauma patients.[1,2] However, despite its effectivity and safety, several studies now emphasize the high complication rate associated with chest tube insertion and removal.[3–5] Based on previously published international studies, 16-20% of CTT patients experience morbidity.[5–7] This often leads to additional patient burden.[7] CTT complications tend to increase patient hospitalization costs due to operative and/or radiologic intervention.[7–9] The limited evidence-based guidelines on chest tube management can potentially affect patient clinical outcomes.

Corresponding author: Richard C. Briones, MD
Surgery Department
Bicol Medical Center
Naga City, Camarines Sur, Philippines
Email: chardbriones@yahoo.com

Using the standardized format suggested by Aho et al., CTT complications can be classified into insertional, positional, removal, infectious/immunologic, and instructional/educational/equipment.[10] Using this classification, the authors established a standard definition, allowing comparability between studies. Positional complications are more common, especially among low-resource hospitals that are not using imaging techniques.[7] Therefore, the difficulty in managing this complication requires early recognition and intervention.[5]

CTT is still widely performed in low-resource hospitals such as Bicol Medical Center (BMC). The burden of CTT complications in the local setting remains unknown. In addition, only a few studies have been published using the standard format of classifying CTT complications.[10] This study, therefore, aims to determine the in-hospital morbidity rate of CTT in a tertiary government hospital in the Philippines. The study also aims to compare the characteristics and outcomes of patients who developed and did not develop CTT-related complications.

MATERIALS AND METHODS

The researchers utilized a descriptive cross-sectional study design. All admitted patients, regardless of age, who underwent CTT at BMC from January 2015 to December 2020 were included in this study. Both service and private patients that were admitted for at least 24 hours with any indication for initial chest tube insertion were included. Patients who had previous CTT, required bilateral CTT, underwent other thoracic procedures other than CTT during the same admission, and who had unsuccessful insertion were excluded.

At BMC, CTT is performed in the operating theatre by general surgical residents. Unstable patients, however, undergo chest tube insertion in the emergency room. Chest X-ray is obtained in most patients before CTT to confirm the diagnosis of thoracic pathology. When indicated, patients undergo CTT via a blunt dissection technique under local anesthesia.

The minimum sample size requirement was computed using OpenEpi. Setting the prevalence of CTT complication at 19%, a maximum tolerable error at 5%, and a 95% confidence level, a minimum of 236 CTT patients are required.[5] However, to capture the data of all CTT patients, the researcher utilized a total enumeration technique wherein all eligible patients were included in the study.

The study was approved by the Bicol Regional Training and Teaching Hospital-Institutional Review Board (BRTTH-IRB Protocol No. 2021-020). Since no direct patient contact was involved, informed consent was waived for this study. The following data were collected via a retrospective review of medical charts from September to December 2021. Age, sex, patient classification, comorbidities, injury type, time to CTT (i.e., number of hours from injury or referral to CTT), hemodynamic instability (i.e., at least one abnormality on vital signs: blood pressure, heart rate, respiratory rate, and oxygen saturation), the urgency of CTT, CTT setting, imaging technique during insertion, endotracheal intubation, chest tube indication, surgeon expertise, advanced training program, chest tube size, rib insertion interspace, use of suction, use of antibiotic prophylaxis, operative time, anesthesia type, chest tube duration, mechanical ventilation, re-intervention after chest tube failure (i.e., unexpanded lung), result of chest tube failure, respiratory therapy, mortality, total length of stay, and postoperative length of stay were recorded. Appendix A presents the operational definition of variables collected.

The type of in-hospital morbidity experienced by patients was assessed by two independent reviewers, and any discrepancy was resolved through discussion. Complications were classified based on Aho et al.'s standardized format for reporting complications.[10] Only complications arising from the index CTT were analyzed. Complications resulting from re-CTT procedures were not included in the analysis.

Stata MP version 17 was used for data processing and analysis. Continuous variables were presented as median/interquartile range (IQR) due to the non-normal distribution based on Shapiro-Wilk's test. Categorical variables were expressed as frequency and percentages. Mann-Whitney U test was used to compare continuous data. The Chi-square and Fisher's exact tests were used to analyze categorical data. P-values ≤0.05 were considered statistically significant.

RESULTS

A total of 425 patients underwent CTT at BMC from 2015 to 2020, of which 376 patients were eligible and were included in the analysis (Appendix C).. Fifty-seven (57) developed in-hospital morbidity. CTT morbidity prevalence was 15.16% (95% CI: 11.69-19.19%). Specific CTT complications are summarized in Table 1. Only five patients developed two simultaneous complications. The most common complication was positional (57.89%, Figure 1), wherein the chest tube was found to be kinked or obstructed (Table 1).

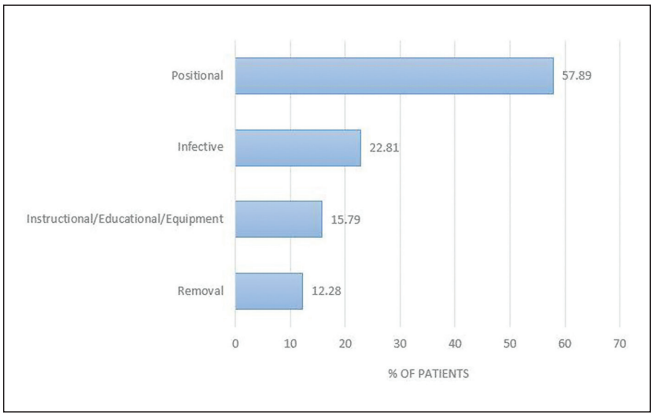


Figure 1. Classification of CTT complications (n=376).

Table 1. Specific CTT Complications (n=376)

Complication	n (%)
Insertional (n=0)	
Intra-thoracic injury to structure w/in 24h	0
Extra-thoracic injury to structure w/in 24h	0
Others	0
Positional (n=33)	
Intra-thoracic	
Kinked/obstructed	33 (100)
Erosion into structures 24h after placement	0
Compression of structures 24h after placement	0
Extra-thoracic	0
Subcutaneous injury	0
Abdominal injury w/o organ injury	0
Abdominal organ erosion 24h after placement	0
Others	0
Removal (n=7)	
Post-removal pneumothorax requiring intervention	1 (14)
Post-removal bleeding	1 (14)
Spontaneous dislodgment	5 (71)
Retained foreign object	0
Others	0
Infective/immunologic (n=13)	
Minor site infection	0
Major empyema	13 (100)
Necrotizing fasciitis	0
Scalded skin syndrome	0
Pyoderma gangrenosum	0
Others	0
Instructional/educational/equipment (n=9)	
Malfunction of equipment	0
Patient care education	0
Improper equipment setup	0
Improper securement not resulting in dislodgement requiring intervention	9
Others	0

Table 2 presents the demographic and clinical profile of CTT patients. Comparative analysis by presence of complications was performed. The median age was 47 (range: 1 to 86 years old), and most were between 18 and 60 years old. The majority were males and were admitted as service patients. The most common comorbidity was pulmonary tuberculosis, which affected 41% of patients. Injury types at the thoracic cavity were predominantly non-trauma related. Hemodynamic instability was recorded in only 13% of patients. Only 5% had endotracheal intubation at the time of CTT. More than half of the patients underwent CTT due to pneumothorax (51%), while 40% were due to pleural effusion.

There was no significant difference observed between patients with and without complications in terms of age, sex, patient classification, comorbidities, injury type, and prior endotracheal intubation. The indication for CTT placement was the only one found to be significantly different. Specifically, patients with complications had more incidence of pleural effusion than those without complications (67% vs. 35%, p<0.0001) Pneumothorax was less in patients with complications than those without complications (30% vs. 55%, p<0.0001).

The intervention performed on patients with and without complications are compared in Table 3. The median time from injury/referral to CTT was 1.1 hours. More than half (55%) of the patients underwent CTT in the ER setting, and only 3% underwent image-guided insertion using ultrasound. None of the patients underwent computed tomography (CT)-guided CTT. More than half (55%) of CTTs were performed by junior residents, and only 9% were performed by consultants. Fifty-nine percent (59%) of patients were inserted with a 32 Fr chest tube and 45% were placed in the 5th mid-axillary line (MAL) while 37% were at the 6th MAL. Only a few (2%) patients underwent suction during drainage. One percent underwent antibiotic prophylaxis before chest tube insertion. Most patients underwent local anesthesia without sedation (79%).

None of the patients received respiratory therapy after CTT. Only 240 patients had their chest tubes removed before discharge. These patients' median chest tube duration was 9.1 days (range: 0.7-45.9 days). Chest tube failure, primarily due to unexpanded lungs, was recorded in 18% of patients. Among the 69 patients with chest tube failure, 36% were shifted to a modified Heimlich valve, 32% underwent another CTT, 17% had thoracoscopy, 7% had thoracotomy, and 7% received no additional procedure.

Only operative time and chest tube failure were found to be significantly different by the presence of CTT complications. The median operative time of patients who developed complications was significantly higher than those who did not develop complications (p=0.0012). Furthermore, a higher proportion of patients who developed complications had chest tube failure than those who did not develop complications (70% vs. 9%, p<0.0001).

Table 4 presents the clinical outcomes of CTT patients. Sixty-nine CTT patients died during hospital stay, with an incidence of 18% (95% CI: 14.57-22.64%). Among the patients who died, the median time from admission to death was 12 days [IQR: 5-22], while the median time from CTT to death was seven days [IQR: 1-14; Range: 0-37 days]. Among survivors, the median total length of hospital stay was 16 days (range: 4-53 days), and the median post-operative length of stay was 14 days (range: 0-47 days).

A significantly lower proportion of patients with complications died than those without complications (p=0.016). In addition, patients with complications had significantly longer total length of stay (p<0.00001) and postoperative stay (p<0.00001).

DISCUSSION

In recent years, studies on CTT morbidity have been gaining popularity worldwide. However, to the best of the

Table 2. Demographic and Clinical Profile of Patients by Presence of Complication (N=376)

Characteristics	All patients (n=376), n (%)	With complication (n=57), n (%)	Without complication (n=319), n (%)	*P* value
Age (in years), median	47 [IQR: 25-60]	40 [IQR: 23-55]	47 [IQR: 25-61]	0.1509
<18 years old	37 (10)	9 (16)	28 (9)	0.221
18 to 60 years old	242 (64)	36 (63)	206 (65)	
>60 years old	97 (26)	12 (21)	85 (27)	
Sex				
Female	100 (27)	12 (21)	88 (28)	0.304
Male	276 (73)	45 (79)	231 (72)	
Patient classification				
Pay	24 (6)	3 (5)	21 (7)	1.000
Service	352 (94)	54 (95)	298 (93)	
Comorbidities, %yes				
Hypertension	42 (11)	4 (7)	38 (12)	0.280
Diabetes mellitus	18 (5)	3 (5)	15 (5)	0.743
Malignancy	26 (7)	6 (11)	20 (6)	0.256
Infection	1 (1)	0	1 (1)	1.000
Renal failure	5 (1)	1 (2)	4 (1)	0.563
Pulmonary Tuberculosis	154 (41)	28 (49)	126 (40)	0.174
COPD	37 (10)	4 (7)	33 (10)	0.437
Pneumonia	31 (8)	2 (4)	29 (9)	0.197
Others	33 (9)	5 (9)	28 (9)	0.999
Injury type				
Non-trauma	256 (68)	42 (74)	214 (67)	0.229
Trauma, blunt	74 (20)	9 (16)	65 (20)	
Trauma, penetrating	41 (11)	4 (7)	37 (12)	
Trauma, both blunt and penetrating	5 (1)	2 (4)	3 (1)	
Hemodynamic stability				
Stable	328 (87)	48 (84)	280 (88)	0.458
Unstable	48 (13)	9 (16)	39 (12)	
Endotracheal intubation				
With	19 (5)	1 (2)	18 (6)	0.330
Without	357 (95)	56 (98)	301 (94)	
Chest tube indication, %yes				
Pneumothorax	192 (51)	17 (30)	175 (55)	<0.0001*
Hemothorax	68 (18)	13 (23)	55 (17)	0.315
Pleural effusion	151 (40)	38 (67)	113 (35)	<0.0001*
Pleurodesis	1 (1)	0	1 (1)	1.000
Postop care	1 (1)	0	1 (1)	1.000

Table 3. Management of Patients by Presence of Complication (n=376)

	All patients (n=376), n (%)	With complication (n=57), n (%)	Without complication (n=319), n (%)	*P* value
Time to CTT (in hours), median	1.1 [IQR: 0.3-5.8]	2 [IQR: 0.3-12.3]	1 [IQR: 0.3-5.3]	0.2375
Urgency				
Elective	1 (0.3)	0	1 (1)	1.000
Emergency	375 (99.7)	57 (100)	318 (99)	
CTT setting				
ER	208 (55)	32 (56)	176 (55)	1.000
OR	164 (44)	25 (44)	139 (44)	
ICU	4 (1)	0	4 (1)	
Imaging technique—insertion				
Yes, ultrasound	11 (3)	1 (2)	10 (3)	1.000
No	365 (97)	56 (98)	309 (97)	

Table 3. Management of Patients by Presence of Complication (n=376) *(continued)*

	All patients (n=376), n (%)	With complication (n=57), n (%)	Without complication (n=319), n (%)	*P* value
Surgeon level of expertise				
Consultant	34 (9)	6 (11)	28 (9)	0.318
Senior resident	136 (36)	25 (44)	111 (35)	
Junior resident	206 (55)	26 (46)	180 (56)	
Advanced training program				
Yes	35 (9)	3 (5)	32 (10)	0.254
No	341 (91)	54 (95)	287 (90)	
Chest tube size				
14Fr	22 (6)	4 (7)	18 (6)	0.140
24Fr	31 (8)	2 (4)	29 (9)	
28Fr	76 (20)	7 (12)	69 (22)	
32Fr	222 (59)	42 (74)	180 (56)	
36Fr	14 (4)	2 (4)	12 (4)	
Others	11 (3)	0	11 (3)	
Rib insertion space, %yes				
5th AAL	18 (5)	1 (2)	17 (5)	0.762
6th AAL	24 (6)	3 (5)	21 (7)	
5th MAL	170 (45)	29 (51)	141 (44)	
6th MAL	139 (37)	23 (40)	116 (36)	
7th MAL	19 (5)	1 (2)	18 (6)	
8th MAL	4 (1)	0	4 (1)	
6th PAL	2 (1)	0	2 (1)	
Suction				
Yes	6 (2)	0	6 (2)	0.597
No	370 (98)	57 (100)	313 (98)	
Antibiotic prophylaxis				
Yes	4 (1)	0	4 (1)	1.000
No	372 (99)	57 (100)	315 (99)	
Operative time (in minutes), median	15 [IQR: 15-20]	20 [IQR:15-25]	15 [IQR: 15-20]	0.0012*
Anesthesia used				
Local with sedation	76 (21)	9 (16)	67 (21)	0.433
Local without sedation	296 (79)	47 (82)	249 (78)	
General	4 (1)	1 (2)	3 (1)	
Respiratory therapy				
Yes	0	0	0	-
No	376 (100)	57 (100)	319 (100)	
Chest tube duration (in days), median [n=240]	9.1 [IQR: 5.2-14.7]	10.6 [IQR: 5-16.8]	9 [IQR: 5.2-14.7]	0.5028
Mechanical ventilation				
Yes	7 (2)	1 (2)	6 (2)	1.000
No	369 (98)	56 (98)	313 (98)	
Chest tube failure				
Yes	69 (18)	40 (70)	29 (9)	<0.0001*
No	307 (82)	17 (30)	290 (91)	

Table 4. Clinical Outcomes by Presence of Complication (n=376)

	All patients (n=376), n (%)	With complication (n=57), n (%)	Without complication (n=319), n (%)	*P* value
In-hospital mortality				
Yes	69 (18)	4 (7)	65 (20)	0.016*
No	307 (82)	53 (93)	254 (80)	
Total length of stay (in days) of survivors, median [n=307]	16 [IQR: 11-26]	24 [IQR: 17-33]	15 [IQR: 10-23]	<0.00001*
Postop length of stay (in days) of survivors, median [n=307]	14 [IQR: 9-21]	20 [IQR: 13-29]	13 [IQR: 8-19]	<0.00001*

researcher's knowledge, this is the first study done in the Philippines that explores the burden of morbidity among patients who underwent CTT. Although the present study only included patients from one institution, the results may serve as baseline information for future local studies.

Overall CTT morbidity in this study was 15.16%. This is close to the estimates of previous studies which utilized Aho et al. definition and classification of CTT morbidity ranging from 16-20%.[5–7,9,10] Among those who developed CTT morbidity, 57.89% were classified as positional, wherein chest tubes were found to be kinked or obstructed. This finding was similar to a study done in South Africa where most complications were also classified as positional.[7] A study done in Finland and the US also reported that most (69-97%) complications were positional.[8,9]

The study by Sritharen et al. showed that insertional complications (38%) are the second leading cause of CTT morbidity.[7] In contrast, the present study recorded no insertional complication among CTT patients. The composition of the patient population may explain the difference in rates. In the study by Sritharen et al., chest tube insertion was challenging probably due to a high proportion of blunt trauma patients.[7] In contrast, the population in this study is primarily non-trauma patients.

Although imaging techniques are widely available to minimize positional and insertional complications, in low-resource settings like BMC, radiographic imaging is not routinely performed.[5,11] Only 3% of patients in this study underwent ultrasound-guided CTT, and none utilized a CT scan. Positional-related morbidities require complex intervention and may result in worse patient outcomes if not addressed promptly. Therefore, early recognition of this complication is important. The lack of guidelines on image-guided CTT should also be reviewed to prevent these types of complications.

In this study, the second leading complication was infective, specifically empyema. This affected 13 of the 376 CTT patients (3.46%) which was within the range reported by previous studies.[4,7,12–15] Prophylactic antibiotic administration lowers the risk of empyema; however, only 1% of patients in the study received this intervention. In a study by de Abreu et al., infections may also be reduced by performing the CTT in the OR.[16] In this study, however, 55% of the procedures were performed in the emergency room.

This study observed that the indication for CTT was significantly different between patients with and without complications. A higher proportion of patients with complications underwent CTT due to pleural effusion compared to those without complications, similar to the findings of a published study.[9] Pleural effusion is one of the leading causes of morbidity; similar to the result of this study. Unfortunately, published studies did not explore this finding; hence, no comparison can be made. Patients with prolonged operative time may have complex thoracic pathology, thus, increasing the likelihood of postoperative complications.

Chest tube failure, defined as having unexpanded lung in this study, was also higher in patients who developed complications than those who did not develop complications. Given that most complications were positional, chest tubes were likely to be non-functional; hence, the possible reason why chest tube failure was higher in these patients. A similar result was observed in a study in Brazil wherein a higher proportion of patients with complications required chest tube re-insertion due to non-functioning drains.[14]

Overall in-hospital mortality was 18% close to that estimated by a study done in Brazil.[14] Mortality was much lower in patients who developed complications than those who did not. This finding can be explained by the fact that mortality was defined as death due to any cause during their hospital stay, not just because of CTT. The current study design inhibits further assessment of CTT-related death since the researchers only rely on what was written in medical charts. Similar to previous studies, patients with complications had significantly increased length of hospital stay.[9,15]

This study has several limitations. First, only one institution was included. The results may, therefore, have limited generalizability since the characteristics of the patients may be different compared to those admitted in other institutions, specifically, private hospitals. Second, BMC is a training institution, hence, general surgery residents-in-training were primarily performing the CTT. The skill level of the trainee was not available and has not been accounted for during the review of the records. However, patient outcome could have been affected by the difference in skill level and experience. Third, only specific complications are provided in the medical charts. In order to minimize misclassification bias, two independent researchers determined the presence/absence of complications as well as the category of classification. Fourth, the study mainly aims to assess the burden of CTT morbidity in the chosen study setting to serve as baseline data for future local studies. The descriptive design of this research was limited to the comparison of patient characteristics and outcomes; and examination of relationship of morbidity with other variables was not yet considered. Last, the data were collected via a retrospective review of medical charts. This limits the researcher from collecting more information about patient's cause of death (i.e., whether related to CTT or not). In addition, the researchers can only assume the completeness and accuracy of the data from patient charts. Quality control was performed during data processing by performing consistency checks. The primary investigator verified inconsistent encoded data from the medical charts.

The large sample size and inclusion of all CTT patients for six years is one of the study's strengths. After an extensive literature search, all possible variables in the medical charts that may influence morbidity rates have been explored. The present research highlights that CTT morbidity is common in BMC, the chosen study setting. Therefore, interventions and strategies that are known to minimize positional

complications should be implemented to ensure better patient outcomes. The feasibility and cost-effectiveness of image-guided CTT in BMC should be explored. The CTT complications and outcomes of trauma versus non-trauma patients should be further examined by future researchers. The association of CTT morbidity with patient outcomes such as mortality and prolonged length of stay warrants further analysis. Moreover, predictors of mortality among CTT patients should also be explored.

CONCLUSION

Complications after closed tube thoracostomy are common. Across all variables analyzed, only indication of chest tube insertion, operative time, and occurrence of chest tube failure were found to differ between patients with and without complications. Moreover, patients with complications had longer length of stay than those without. Reducing positional tube complications may help decrease in-hospital morbidity.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

None.

REFERENCES

1. Ahmad R, Bhatti DS, Bokhari MHT, Asad A. A university hospital based study on thoracic trauma: life threatening event, its etiology, presentation, and management. Cureus. 2019 Dec 6;11(12):e6306. doi:10.7759/cureus.6306. PMID: 31938598; PMCID: PMC6944145.
2. Narayanan R, Kumar S, Gupta A, Bansal VK, Sagar S, Singhal M, et al. An analysis of presentation, pattern and outcome of chest trauma patients at an urban level 1 trauma center. Indian J Surg. 2018 Feb;80(1):36-41. doi: 10.1007/s12262-016-1554-2. PMID: 29581683; PMCID: PMC5866799.
3. Graham DS, Livingston EH. Chest Tubes. JAMA. 2019 Aug 27;322(8):792. doi: 10.1001/jama.2019.8842. PMID: 31454047.
4. Kashani P, Harati S, Shirafkan A, Amirbeigi A, Hatamabadi HR. Comparing the quality and complications of tube thoracostomy by emergency medicine and surgery residents: a cohort study. Emerg (Tehran). 2017;5(1):e33. PMID: 28286840; PMCID: PMC5325903.
5. Hernandez MC, El Khatib M, Prokop L, Zielinski MD, Aho JM. Complications in tube thoracostomy: Systematic review and meta-analysis. J Trauma Acute Care Surg. 2018 Aug;85(2):410-6. doi: 10.1097/TA.0000000000001840. PMID: 29443856; PMCID: PMC6081248.
6. Struck MF, Fakler JKM, Bernhard M, Busch T, Stumpp P, Hempel G, et al. Mechanical complications and outcomes following invasive emergency procedures in severely injured trauma patients. Sci Rep. 2018 Mar 5;8(1):3976. doi: 10.1038/s41598-018-22457-9. PMID: 29507415; PMCID: PMC5838247.
7. Sritharen Y, Hernandez MC, Haddad NN, Kong V, Clarke D, Zielinski MD, et al. External validation of a tube thoracostomy complication classification system. World J Surg. 2018 Mar;42(3):736-41. doi: 10.1007/s00268-017-4260-8. PMID: 28932968.
8. Hernandez MC, Zeb MH, Heller SF, Zielinski MD, Aho JM. Tube thoracostomy complications increase cost. World J Surg. 2017 Jun;41(6):1482-7. doi: 10.1007/s00268-017-3897-7. PMID: 28120094.
9. Vilkki VA, Gunn JM. Complications related to tube thoracostomy in Southwest Finland hospital district between 2004 and 2014. Scand J Surg. 2020 Dec;109(4):314-9. doi:10.1177/1457496919857262. PMID: 31232199.
10. Aho JM, Ruparel RK, Rowse PG, Brahmbhatt RD, Jenkins D, Rivera M. Tube thoracostomy: a structured review of case reports and a standardized format for reporting complications. World J Surg. 2015 Nov;39(11):2691-706. doi: 10.1007/s00268-015-3158-6. PMID: 26159120.
11. Menegozzo CAM, Artifon ELA, Meyer-Pflug AR, Rocha MC, Utiyama EM. Can ultrasound be used as an adjunct for tube thoracostomy? A systematic review of potential application to reduce procedure-related complications. Int J Surg. 2019 Aug;68:85-90. doi:10.1016/j.ijsu.2019.06.012. PMID: 31229699.
12. Kong VY, Sartorius B, Oosthuizen G V, Clarke DL. Prophylactic antibiotics for tube thoracostomy may not be appropriate in the developing world setting. Injury. 2015 May;46(5):814-6. doi: 10.1016/j.injury.2015.01.030. PMID: 25669963.
13. Reinersman JM, Allen MS, Blackmon SH, Cassivi SD, Nichols FC, Wigle DA, et al. Analysis of patients discharged from the hospital with a chest tube in place. Ann Thorac Surg. 2018 Apr;105(4):1038-43. doi:10.1016/j.athoracsur.2017.10.042. PMID: 29397929.
14. Nascimento IK Do, Morad HM, Perlingeiro JAG, Parreira JG, Assef JC. Predictors of pleural complications in trauma patients undergoing tube thoracostomy: a prospective observational study. Rev Col Bras Cir. 2022 Aug 22;49:e20223300. doi:10.1590/0100-6991e-20223300-en. PMID: 36000682; PMCID: PMC10578792.
15. Platnick C, Witt CE, Pieracci FM, Robinson CK, Lawless R, Burlew CC, et al. Beyond the tube: Can we reduce chest tube complications in trauma patients? Am J Surg. 2021 Nov;222(5):1023-8. doi:10.1016/j.amjsurg.2021.04.008. PMID: 33941358.
16. de Abreu EMS, Machado CJ, Neto MP, de Rezende Neto JB, Sanches MD. The impact of a chest tube management protocol on the outcome of trauma patients with tube thoracostomy. Rev Col Bras Cir. 2015 Jul-Aug;42(4):231-7. doi: 10.1590/0100-69912015004007. PMID: 26517798.

APPENDICES

Appendix A. Operational definition of variables

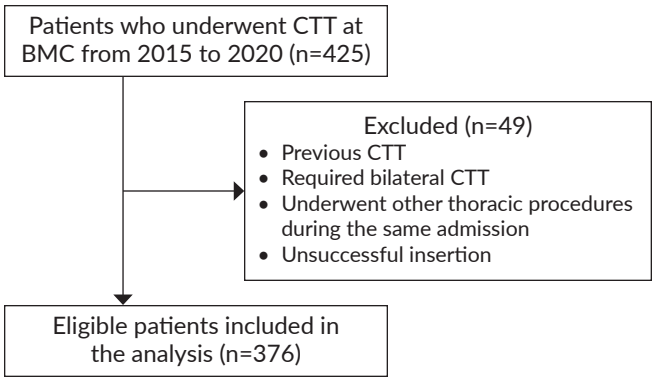
1. Morbidity type is the type of in-hospital morbidity experienced by patient as assessed by two independent reviewers. Classified based on the standardized format for reporting complications by Aho et al. (Appendix B).[10] Categorized as insertional, positional, removal, infective/ immunologic, instructional/educational/equipment.
2. Mortality is defined as patient death during hospital stay based on medical records. Categorized as yes or no.
3. Year variable refers to the year of patient admission from 2015 to 2020.
4. Age variable is the patient age in years at the time of chest tube insertion based on medical records. Categorized as <18 years old, 18 to 60 years old, ≥60 years old.
5. Sex refers to the patient sex based on medical records. Categorized as male or female.
6. Patient classification refers to the admitting classification of patient. Categorized as pay or service.
7. Comorbidities refer to the presence of any of the following comorbidities at the time of CTT based on medical records: hypertension, diabetes mellitus, malignancy, infection, renal failure, COPD, COVID-19, others.
8. Injury type at the thoracic cavity based on medical records. Categorized as non-trauma, blunt trauma, penetrating trauma, both blunt and penetrating trauma.
9. Hemodynamic stability is the patient stability based on vital signs at the time of chest tube insertion: BP, RR, HR, and O_2 saturation. Normal values for each parameter are: SBP: 90-140 mmHg, DBP: 60-90 mmHg, RR: 9-20 cpm, HR: 50-100 bpm, O_2 saturation: 95-100%. Stable patients have normal values on all parameters above. Unstable patients have at least one abnormal value on any of the parameters.
10. ET intubation at the time of chest tube insertion. Categorized as yes or no.
11. CTT indication is the primary indication for CTT based on medical records. Categorized as pneumothorax (primary spontaneous, secondary spontaneous, acquired), hemothorax, pleural effusion: simple fluid, pleural effusion: empyema, pleural effusion: chylothorax, pleurodesis, postoperative care, others.
12. Time to CTT is the number of hours from injury/referral to CTT based on medical records. Computed from date/ time of CTT referral to date/time of chest tube insertion.
13. Urgency of CTT based on medical records. Categorized as elective or emergency.
14. CTT setting is the hospital location where CTT was performed. Categorized as emergency room, operating room, intensive care unit, others.
15. Imaging technique-insertion refers to the use of CT scan or ultrasound during insertion. Categorized as yes CT scan, yes ultrasound, no.
16. Surgeon level of expertise is the current level of expertise of the operating surgeon at the time of CTT based on medical records. Categorized as junior residents (PGY 1-2), senior residents (PGY 3-5), and consultant.
17. Advanced training program demonstrates if the surgeon who performed CTT underwent ATLS/ TCVS/trauma training based on medical records. Categorized as yes or no.
18. Chest tube size successfully inserted to patient based on medical records.
19. Rib insertion interspace is where the chest tube was inserted based on medical records
20. Angle of insertion of the chest tube based on medical records.
21. Suction determines if the surgeon performed suction during CT drainage based on medical records. Categorized as yes or no.
22. Antibiotic prophylaxis determines if patient was given prophylaxis before chest tube insertion based on medical records. Categorized as yes or no.
23. Operative time is the number of minutes from start to end of CTT.
24. Anesthesia is the type of anesthesia used during CTT. Categorized as local with sedation, local without sedation, general, others.
25. Timing of chest xray (CXR) is the number of hours from chest tube removal to chest radiograph based on medical records. Computed from date/time of CT insertion to date/time of chest xray.
26. Chest tube duration is the number of days from chest tube insertion to removal. Computed from date/time of chest tube insertion to date/time of chest tube removal.
27. Mechanical ventilation variable determines if the patient was in mechanical ventilation at the time of chest tube removal based on medical records. Categorized as yes or no.
28. Intervention after chest tube failure determines the type of surgical intervention/s performed after chest tube failure based on medical records. Categorized as thoracotomy, thoracostomy, re-CTT (i.e., tube reinsertion or insertion of second tube).
29. Respiratory therapy determines if patient underwent respiratory therapy after CTT. Categorized as yes (including number of sessions) or no.
30. Result of chest tube failure is categorized as retained hemothorax or loculated pleural effusion.
31. Total length of stay is the number of days from the time of admission to discharge or death.
31. Postop length of stay is the number of days from the time of initial CTT to discharge or death. Computed from date/time of chest tube insertion to date/time of discharge or death.

Appendix B. Definition of CTT morbidities by Aho et al.[10]

Table 2. Complications Related to Thoracostomy Placement

Complication category	Examples of complication (references)	Specific injuries documented
Insertional Intrathoracic		(*n* = 65)
	Injury to structure upon placement, within 24 h (7–52)	Injury to all heart chambers and pulmonary structures, except trachea
	Immediate myocardial infarction (53, 54)	Main pulmonary artery injury
	Immediate arrhythmia, within 24 h (55–58)	Perforated esophagus
		Cardiac tamponade
		Tension pneumothorax after injury to lung parenchyma
		Contralateral pneumothorax from tube thoracostomy crossing mediastinum
		Contralateral hemothorax from chest tube
		Immediate diaphragmatic paralysis
		Perforation of abdominal organs, which have herniated through either diaphragmatic ruptures or previous diaphragmatic hernias
		New diaphragmatic hernia
		Horner syndrome from either traction on or trauma to the sympathetic chain
		Systemic air embolism
		Cerebral air embolism
		Rupture of angiomatoid lesions
		Atrial fibrillation from cardiac irritation
		Bradycardia resulting in death due to vagal hematoma
Extrathoracic[a]	Injury to structure upon placement, within 24 h (52, 59-71)	Abdominal placement
		Extrathoracic subclavian arterial compression
		Cerebral herniation due to negative pressure on cerebral spinal fluid leak after spinal trauma
		Intercostal nerve laceration and compression
		Intercostal arterial injury resulting in hemorrhage
		Brachial plexus injury
		Ulnar neuropathy
		Rupture of breast implants leading to silicone thorax
		Hepatic placement, both asymptomatic and leading to life-threatening hemorrhage
		Lacerated and ruptured inferior vena cava, right ventricle, and hepatic vein[b]
Positional Intrathoracic		(*n* = 36)
	Kinked/obstructed (72)	Delayed erosion into right atrium
	Erosion into structures >24 h after placement (73–97)	Late diaphragmatic paralysis
	Compression of structures >24 h after placement (98, 99)	Tension pneumothorax due to kinking or obstruction
	Arrhythmia without ischemia >24 h after placement	Horner syndrome after gradual contact and erosion into the sympathetic chain
		Pulmonary artery arteriovenous fistula
		Pulmonary artery pseudoaneurysm
		Delayed pulmonary artery perforation
		Aortic rupture from chest tube compression
		Pressure necrosis of esophagus
		Pressure necrosis of intrathoracic stomach
		Esophageal compression with dysphagia
		Bronchocutaneous fistula
		Esophagopleural fistula
		Chylothoraces from erosion into thoracic duct
		Lymphocele
		Contralateral diaphragmatic paralysis
		Erosion into intrathoracic stomach from diaphragmatic hernia
Extrathoracic	Subcutaneous injury (100, 101)	Subcutaneous placement
	Abdominal injury without organ injury	Delayed erosion and migration of silicone from breast implant through thoracostomy tract
	Abdominal solid organ erosion into structures >24 h after placement	Intercostal arteriovenous fistula
	Abdominal hollow organ erosion into structures >24 h after placement	Scapular winging due to pressure on long thoracic nerve
	Retroperitoneal injury	Epigastric artery pseudoaneurysm
	Erosion into structures >24 h after placement (102–107)	Injury and erosion into spinal canal with spinal air
Removal		(*n* = 11)
	Postremoval pneumothorax	Pulmonary tissue herniation
	Postremoval bleeding	Subcutaneous emphysema resulting in acute scrotum
	Spontaneous dislodgement	Subcutaneous emphysema resulting in vertebral artery dissection
	Retained foreign object (108)	Subcutaneous emphysema resulting in abdominal compartment syndrome
	Spontaneous retraction (109)	Upper airway obstruction from subcutaneous emphysema
	Subcutaneous emphysema (110–114)	Retained portion of chest tube
	Pulmonary tissue herniation (115–118)	Spontaneous retraction of thoracostomy tube into thoracic cavity
Infective and immunologic		(*n* = 7)
Minor	Site infection (119)	Site infection
Major	Empyema (120)	Empyema
	Necrotizing fasciitis (121–124)	Scalded skin syndrome
	Scalded skin syndrome	Empyema from *Clostridium difficile*
		Necrotizing fasciitis of chest wall
Immunologic	Pyoderma gangrenosum (125)	Pyoderma gangrenosum of thoracic wall
Instructional/educational/ equipment		(*n* = 5)
	Malfunction of equipment	Not correctly connecting thoracostomy to atrium
	Patient care education (126)	Suture chest tube to thoracic wall
	Improper equipment setup (127-129)	Improper set up of Heimlich valve
	Improper securement not resulting indislodgement, requiring intervention (130)	Reversal of Heimlich valve by patient
		Incorrectly dressing thoracostomy site

[a] *Cases of splenic laceration or colonic injury outside of the thorax have been reported in case series, but not in case reports found during the literature review described in this study*
[b] *Case met multiple groups of our criteria*



Appendix C. Study flow diagram.