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Pigtail Drainage of Iatrogenic Pneumothorax or Hemothorax: Is a Sufficient Procedure?

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Abstract

Background: Pigtail catheters, originally used by cardiologists to drain chronic pericardial effusions, have been adapted for pleural drainage. This study aimed to evaluate the effectiveness of pigtail catheterization as an alternative to chest tube in the management of iatrogenic pneumothorax and hemothorax.

Methods This prospective interventional study included 50 adult patients (>18 years) diagnosed with iatrogenic pneumothorax (Group A, n=25) or iatrogenic hemothorax (Group B, n=25).). All patients underwent clinical evaluation, including history taking, clinical examination, imaging procedures [chest CT and chest x-ray], and laboratory investigations.

Results: Group A had a significantly shorter hospital stay than Group B ($P < 0.001$). Regarding catheter-related complications, Group B had a significantly higher failure rate ($P < 0.001$). Univariate analysis revealed that hemothorax, chronic liver disease, central venous line insertion, and true cut biopsy from a central mass were significant risk factors for failure of the pigtail catheter.

Conclusions: Pigtail catheter is more efficient in the management of iatrogenic pneumothorax than hemothorax. It is preferred to initially apply conventional chest tube in the latter to avoid the high failure rate of these small catheters.

KEYWORDS
Thoracic Catheters; Iatrogenic Disease; Pneumothorax; Hemothorax; Chest Tube

Introduction

Iatrogenic hemothorax and pneumothorax are recognized complications that may arise from various medical procedures [1,2]. Iatrogenic hemothorax may occur as a complication of procedures such as central venous catheter placement, thoracentesis, lung biopsy, or chest tube insertion. Vascular injury during these procedures can lead to bleeding into the pleural space [3]. Similarly, iatrogenic pneumothorax involves the presence of air in the pleural space due to procedural trauma, typically during thoracentesis, central line insertion, chest tube placement, or mechanical ventilation. Accidental puncture of the lung or escape of air can lead to partial or complete lung collapse, resulting in respiratory compromise [4-6]. Although chest tube remains a standard approach for managing both conditions, it carries risks such as tube malfunction, malposition, or injury to adjacent structures like the liver or diaphragm. Traditional chest tubes are typically large-bore (32–40 Fr) and require surgical cut-down for insertion, which can be traumatic and associated with significant pain

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and discomfort [7]. Pigtail catheters, initially used by cardiologists for draining chronic pericardial effusions, have since been adapted for pleural drainage [8,9]. These 14 Fr small-caliber catheters can be inserted percutaneously at the bedside [10]. Several studies have demonstrated that pigtail catheters are as effective as conventional chest tubes for treating pleural effusions and pneumothorax [11,12], with the added benefits of reduced insertion trauma and patient discomfort [13–15]. Despite growing evidence supporting their use in pneumothorax and pleural effusions, there is limited research evaluating the efficacy of pigtail catheters for iatrogenic hemothorax, particularly in the Egyptian context. This knowledge gap provided the rationale for conducting the present study. The aim of this study was to evaluate the effectiveness of pigtail catheterization as an alternative to traditional chest tube in the management of iatrogenic pneumothorax and hemothorax.

Patients and Methods

Fifty individuals of both sexes who met the clinical criteria for either iatrogenic hemothorax or pneumothorax and were older than 18 years were included in this prospective interventional trial.

The patient or their family members gave their signed, informed consent. During January 2023–January 2024, the study was conducted with permission from the faculty of medicine of Cardiothoracic Department, Faculty of Medicine Assiut University Hospitals Ethical Committee and Institutional Review Board (approval code: 17101911).

Refusing to participate in the study and being younger than 18 were the exclusion criteria. Patients were classified into Group A (pneumothorax) and Group B (hemothorax) based on clinical and radiological diagnosis."

Every patient had their personal history taken, including their name, age, gender, residence, marital status, and special habits; their current complaint; an analysis of each complaint's onset, course, duration, what increases, what decreases, and any associations; and any prior medical or surgical procedures that may have been implicated in pneumothorax/hemothorax like central venous catheter (CVC) insertion, previous thoracic surgery, pleural biopsy, lung biopsy, and thoracocentesis, evaluation of different body systems, existing medical conditions, as well as any prior surgery history], Clinical examination [local chest examination (inspection, palpation, percussion, and auscultation) and general examination (patient appearance, physique, complexion, body mass index, neck examination, and vital sign evaluation)]" radiological tests [In certain patients with uncertain diagnoses, a chest CT scan and x-ray were done to try to identify the cause, particularly in hemothorax patients], and Complete blood count, coagulation profile (including bleeding, coagulation time, and international normalized ratio), and arterial blood gases in patients experiencing acute respiratory distress are examples of laboratory tests.

Pigtail tube insertion:

The ipsilateral arm was placed under the patient's head while they were in a supine position during the surgery. If at all feasible, the head was raised 30 to 60 degrees to reduce the diaphragm's position and lower the danger of iatrogenic harm.

A solution of 2% chlorhexidine in alcohol was used to prepare the skin. Towels were used to cover the field. The distance between the pectoralis major and latissimus dorsi was defined at the anterior axillary line, and the fourth or fifth intercostal gap was located.

After locating intercostal space, local anesthesia (5 mL of 1–2% lidocaine with epinephrine) was infiltrated into the skin raising the cutaneous wheel at incision site and subcutaneous tissue. To prevent harm to the intercostal neurovascular bundle, the anesthesia was extended to the rib and the pleural space along the superior portion of the rib. A 10-milliliter syringe was fitted with an 18-gauge needle, which was then inserted across the superior portion of the rib along the previously anesthetized tract while it was being drawn back. Pneumothorax patients showed aspirating bubbles upon entering the pleural space, whereas hemothorax patients showed blood or bloody fluid. The syringe was removed, and the guide wire was inserted into the

Table 1: Basic demographic data, pathology-related data, procedure time, pigtail output, duration of drainage, and success rate of the studied patients (n = 50). Data are displayed as frequency (%) or median (IQR).

		Group A (n = 25)	Group B (n = 25)	P value
Demographic data				
Age (years)		39 (28 – 51)	40 (28 – 52)	0.683
Sex	**Male**	14 (56%)	13 (52%)	0.777
	Female	11 (44%)	12 (48%)	
Medical comorbidities	**DM**	4 (16%)	5 (20%)	0.713
	HTN	6 (24%)	5 (20%)	0.733
	Chronic liver disease	3 (12%)	5 (20%)	0.440
	Smoking	7 (28%)	9 (36%)	0.544
Pathology-related data				
Side	**Right**	12 (48%)	14 (56%)	0.571
	Left	13 (52%)	11 (44%)	
Cause of injury	**Central venous line**	9 (36%)	5 (20%)	0.208
	True cut from a central mass	6 (24%)	11 (44%)	0.136
	Needle aspiration	5 (20%)	5 (20%)	1
	Dialysis catheter	0 (0%)	4 (16%)	**0.037***
	Mechanical ventilation	3 (12%)	0 (0%)	0.074
	Liver abscess drainage	2 (8%)	0 (0%)	0.149
Procedure time (minutes)		10 (8 – 15)	12 (8 - 14)	0.409
Total output (ml)		---	700 (300 – 1000)	---
Days of drainage		3 (2 – 5)	2 (2 – 7)	**0.001***
Success		19 (76%)	5 (20%)	**< 0.001***

DM: diabetes mellites, HTN: hypertension.
*: significant as P value < 0.05.

needle. Pigtail catheter insertion followed the Seldinger technique under sterile conditions, using 10–12 Fr catheters and ultrasound or clinical landmark guidance

Postprocedural care:

Postprocedural pain was assessed via the visual analogue score (VAS) It uses an eleven-point rating system, with 0 denoting no pain and 10 denoting the greatest agony ever experienced. [17, 18]. It was assessed on the day of pigtail catheter insertion (day 0) and the following two days (postprocedural days 1 and 2). A chest x ray was taken after 12, 24, and 48 hours to assess the position of the catheter and to confirm lung expansion. If lung expansion was not obtained or incomplete resolution of pneumothorax/ hemothorax was detected, a conventional wide bore chest tube was inserted. Once the chest x ray showed that the lung had reached full expansion, the catheter was removed at the surgeon's discretion. The patient was discharged 24 hours after removal of the tube.

The success rate was the main result. Postprocedural pain scores, the number of tube days, the frequency of tube-related problems, the length of hospital stay, and the risk variables for pigtail failure were the secondary outcomes.

Sample Size Calculation:

The G Power software version 3.1.3 was used to determine the sample size. The paired t test was used to compare the mean of the measured effusion between the two dependent means (before and after catheter application). The effect size was assumed to be 0.5, the alpha error prob was 0.05, and the power (1-beta error prob) was 0.80. A minimum of 27 patients was needed for the sample. In order to boost the research's power, we recruited all 50 patients who met our eligibility requirements during the study period.

Statistical analysis

SPSS v27 was used for statistical analysis (IBM©, Armonk, NY, USA). Histograms and the Shapiro-Wilks test were employed to assess the data distribution's normality. The unpaired student t-test was used to analyse quantitative parametric data, which were shown as mean and standard deviation (SD). The Mann Whitney test was used to evaluate quantitative non-parametric data, which were shown as the median and interquartile range (IQR). The Chi-square test or Fisher's exact test, as applicable, was used to examine the qualitative variables, which were shown as frequency and percentage (%).

Results

The duration of catheter drainage decreased significantly in Group B (two vs. three days in Group A – p = 0.001). Success rate showed a significant increase for the management of pneumothorax (P < 0.001). Failed cases were successfully managed by conventional chest tube with no need for surgical exploration. Regarding age, sex, medical comorbidities (diabetes mellitus, hypertension, chronic liver disease, and smoking), procedure time, and all causes of damage, with the exception of dialysis catheter, which was significantly related with group B (P=0.037), there were no significant differences between the two groups. Table 1

Group A experienced a considerably shorter hospital stay than Group B (P < 0.001). Regarding catheter-related complications, failure rate was significantly higher in Group B (P < 0.001). No significant differences were observed regarding VAS score. Re-expansion pulmonary oedema happened in Group A in only two patients (8%), and both patients were successfully managed by IV furosemide and steroid administration. No patients developed that complication in Group B. Additionally, no patients developed infection or catheter slippage in both groups. Table 2

Univariate analysis revealed that hemothorax, chronic liver disease, central venous line insertion, and Tru-cut biopsy from a central mass were significant risk factors for failure of the pigtail catheter. Table 3

Discussion

The main findings of this study were to evaluate the efficacy of pigtail catheter in two Illnesses that might develop as unanticipated side effects of different medical procedures are iatrogenic hemothorax and pneumothorax. The most frequent cause of iatrogenic hemothorax in our analysis was true cut central mass biopsy, while the most frequent cause of iatrogenic pneumothorax was CVC insertion.

Table 2: Pain assessment (VAS score), duration of hospitalization, and tube related complications of the studied patients (n = 50). The frequency (%) or median (IQR) are used to display the data

		Group A (n = 25)	Group B (n = 25)	P value
VAS score	**Pain at 0 day**	2 (1 – 4)	3 (1 – 4)	0.396
	Pain at first day	3 (1 – 4)	3 (2 – 4)	0.441
	Pain at second day	2 (1 – 4)	2 (1 – 4)	0.791
Duration of hospitalization (days)		4 (4 – 6)	5 (5 – 8)	**< 0.001***
Tube related complications	**Failure rate**	6 (24%)	20 (80%)	**< 0.001***
	Re-expansion pulmonary edema	2 (8%)	0 (0%)	0.149

VAS: Visual analogue score.
*: significant as P value < 0.05.

Table 3: Pain assessment (VAS score), duration of hospitalization, and tube related complications of the studied patients (n = 50)

Predictors	Univariate regression			
	P value	OR	95% C.I. for odds ratio	
			Lower	Upper
Pneumothorax	R			
Hemothorax	**< 0.001***	**2.153**	**1.694**	**3.160**
Age	0.867	0.994	0.922	1.071
Male gender	R			
Female gender	0.555	0.714	0.234	2.184
DM	0.814	0.840	0.197	3.582
HTN	0.624	1.400	0.365	5.365
Chronic liver disease	**0.048***	**1.118**	**1.013**	**1.346**
Smoking	0.311	0.533	0.158	1.799
Right side	R			
Left side	0.768	0.846	0.278	2.572
Central venous line	**0.045***	**3.929**	**1.029**	**14.992**
True cut from a central mass	**0.001***	**0.067**	**0.013**	**0.345**
Needle aspiration	0.400	1.833	.448	7.511
Dialysis catheter	0.357	0.333	0.032	3.446
Mechanical ventilation	0.458	1.588	0.468	5.387
Liver abscess drainage	0.189	0.925	0.824	1.039
Procedure time	0.313	1.164	.867	1.561

CI: confidence interval; OR: odds ratio; DM: Diabetes mellitus; HTN: hypertension

In a previous study which included patients with iatrogenic hemothorax, the etiologies were as follows; chest tube insertion (40%), percutaneous liver biopsy (20%), thoracocentesis (14%), central venous line insertion (10%), diaphragmatic resection (3%), percutaneous transhepatic cholangiography (3%), while the remaining 10% had unidentified etiology [3].

Differences between studies regarding the etiology of the studied entities could be explained by different sample size, rates of different medical and surgical procedures, and the experience of the staff performing them.

The pneumothorax group in the current study had a considerably greater success rate than the hemothorax group (76% vs. 20%, respectively; P < 0.001). Patients who experienced failure were managed by conventional wide thoracostomy tubes. The failure rate of a pigtail catheter in draining hemothorax compared to pneumothorax can be attributed to several factors [13]: 1.Blood Clot Formation: In hemothorax, the presence of blood can lead to the formation of clots within the catheter or its drainage channels, 2. Viscosity of Fluid: Blood is more viscous than air, which can further impede the flow of blood through the narrow lumen of a pigtail catheter. The higher viscosity of blood makes it more challenging for the catheter to adequately drain hemothorax compared to the relatively less viscous air in pneumothorax, 3. continuous Bleeding: Hemothorax may involve ongoing bleeding from injured blood vessels, resulting in a continuous influx of blood into the pleural cavity,4. Catheter size and configuration: The size and configuration of a pigtail catheter may not be optimized for draining hemothorax compared to traditional thoracostomy tubes. Conventional thoracostomy tubes typically have a larger diameter and multiple side holes, allowing for better drainage which against some paper that said size does not matter [31].

According to our results, Mortman et al. [22] reported that although pigtail catheters are believed to cause less pain and tissue trauma, they do not necessarily drain the pleural space as well as the conventional thoracostomy tubes.

On the other hand, another study conducted in swine models having acute hemothorax proved the equal efficacy of pigtail versus conventional chest tubes in achieving drainage of the hemothorax. In that study, According to Russo et al. [23], blood drained from the chest tube more quickly than from the pigtail catheter during the first three minutes (348 ± 109 mL/min vs. 176 ± 53 mL/min), although this difference was not statistically significant ($p = 0.19$). After that, there was little difference in the two tubes' drainage rates. Although the overall percentage of blood drained from the chest by the chest tube was greater (87.3% vs. 70.3%), the difference was not statistically significant ($P = 0.21$).

Our findings revealed that during the zero day and the subsequent two days following catheter insertion, the measured pain scores did not exceed a value of 4, indicating that the procedure was associated with mild to moderate pain.

Pigtail catheters are associated with less pain intensity compared to conventional wide chest tubes for several reasons [23-25]: 1. Smaller Size: Pigtail catheters have a smaller diameter compared to wide chest tubes, 2. reduced Discomfort: Pigtail catheters are often more flexible and have a coiled or curled design, allowing them to conform to the contours of the pleural space, 3. Reduced Nerve Irritation: Wide chest tubes may be more likely to come into contact with and irritate nerves within the pleural space, leading to increased pain intensity, and 4.faster recovery: Due to their smaller size and reduced tissue trauma, pigtail catheters may promote faster healing and recovery compared to wide chest tubes.

According to Weiss et al. [26], which supports our findings, pain scores were significantly decreased when the pigtail catheter was used, and that was reflected on the analgesic demands, which was significantly lower compared to the conventional chest tube group (1 vs. 3+ days, median, $p < 0.05$).

In the current study, total drain output ranged between 300 and 1000 ml in the hemothorax group. Another study that included patients with traumatic hemothorax managed by pigtail catheters reported that initial catheter output was 650 ml, while 24-, 48-, and 72-hour outputs were 980, 300, and 50 ml, respectively [27].

Difference in outputs among studies could be explained by difference in the severity of hemothorax (or effusion), and the diameter of the catheter used for drainage.

Our findings showed that the duration of catheter drainage decreased significantly in Group B (two vs. three days in Group A – $P = 0.001$). That could be explained the higher failure rate in the hemothorax group which necessitated removal of the blocked or non-functioning pigtail catheter to be replaced with the conventional chest tube after 48 hours. Therefore, there was an apparent decrease in the pigtail duration in the hemothorax group.

Another study reported that it needed a mean of 5 ± 0.8 days for the pigtail catheter to be removed in patients with traumatic hemothorax [12]. Bauman et al. [27] described median drainage duration of four days in their cases with traumatic hemothorax. Kulvatunyou et al. [7] reported a lower catheter days for their pneumothorax cases which had a median value of two days (range, 2 – 3).

In the current study, the duration of hospitalization decreased significantly in Group A compared to Group B (median = four vs. five days, respectively – $p < 0.001$). It is reasonable to encounter more hospitalization periods in the hemothorax group, as blood needs more time to be drained than air. Additionally, there was an initially higher failure rate in the hemothorax group.

According to the research done by Kulvatunyou and colleagues, [12] the duration of hospitalization ranged between 6 and 12 days for traumatic hemothorax patients who underwent pigtail catheter insertion. Another study reported that the median hospitalization period for patients with traumatic hemothorax managed by pigtail catheter was 6.5 days [27].

The length of hospitalization may vary from study to study, which may be explained by variations in patient and illness criteria, length of stay till resolution, and discharge facility procedures. In the current study, re-expansion pulmonary edema was encountered in 8% of patients in the pneumothorax group. That is in accordance with the normal reported range for the same complicated which ranges between 0.9% and 29.8% in the literature [28-30].

There is a paucity of trials handling the previous prediction, which is another advantage in favor of our study. The first parameters are well explained previously in the discussion. Regarding the second one (true cut biopsy), we think that the procedure might have yielded major bronchovascular injury that led to significant air or blood leak that was not sufficiently drained by the pigtail catheter.

As far as we are aware, there is a paucity of trial evaluating the efficacy of pigtail catheters in patients with iatrogenic pneumothorax/hemothorax, which was a good motive for us to conduct this study that intended to evaluate the efficacy of the pigtail catheter as an alternative to chest tube for iatrogenic pneumothorax /hemothorax. Although minimally invasive, pigtail catheter use requires caution in certain pathologies such as hemothorax and post-biopsy injuries due to higher failure risk [31].

To the best of our knowledge, no previous studies have addressed the same perspective of ours, which constitutes a major advantage in favor of our research.

We suggested that future research should be expanded to include additional patients from various cardiothoracic facilities, pigtail catheters should be applied in patients with pneumothorax because of its advantages over the chest tube (less pain and effective drainage), and patients with hemothorax should be initially managed with the conventional thoracostomy tube, when drainage is indicated, as it is more likely to encounter failure when the pigtail catheters are applied.

Limitations

The relatively small sample size that was collected from a single center data and selection bias is the main drawback. Also, we should have compared pigtail catheters with conventional thoracostomy tubes to elucidate which has the higher efficacy and success rate. The upcoming studies should address the previous drawbacks.

Conclusion

Pigtail catheters are more effective at managing iatrogenic pneumothorax than hemothorax. It is preferred to initially apply conventional chest tube in the latter to avoid the high failure rate of these small catheters.

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References

1. Smith RS, Vanzant E, Catena F. Pneumothorax and Hemothorax. In: Galante JM, Coimbra R, editors. Thoracic Surgery for the Acute Care Surgeon. Cham: Springer International Publishing; 2021: 159-68.
2. Perkins A. Trouble with the lungs: Pneumothorax and hemothorax. Nursing made Incredibly Easy. 2022;20:12-22.
3. Panaro F, Al Taweel B, Leon P, et al. Morbidity and mortality of iatrogenic hemothorax occurring in a cohort of liver transplantation recipients: a multicenter observational study. Updates in Surgery. 2021;73:1727-34.
4. Celik B, Sahin E, Nadir A, Kaptanoglu M. Iatrogenic pneumothorax: etiology, incidence and risk factors. The Thoracic and cardiovascular surgeon. 2009;57:286-90.
5. Loiselle A, Parish JM, Wilkens JA, Jaroszewski DE. Managing iatrogenic pneumothorax and chest tubes. Journal of hospital medicine. 2013;8:402-8.
6. Hsu C-W, Sun S-F. Iatrogenic pneumothorax related to mechanical ventilation. World journal of critical care medicine. 2014;3:8.
7. Kulvatunyou N, Erickson L, Vijayasekaran A, et al. Randomized clinical trial of pigtail catheter

versus chest tube in injured patients with uncomplicated traumatic pneumothorax. Journal of British Surgery. 2014;101:17-22.
8. Lock JE, Bass JL, Kulik TJ, Fuhrman BP. Chronic percutaneous pericardial drainage with modified pigtail catheters in children. The American journal of cardiology. 1984;53:1179-82.
9. Fuhrman BP, Landrum BG, Ferrara TB, et al. Pleural drainage using modified pigtail catheters. Critical care medicine. 1986;14:575-6.
10. Bauman ZM, Kulvatunyou N, Joseph B, et al. A prospective study of 7-year experience using percutaneous 14-French pigtail catheters for traumatic hemothorax/hemopneumothorax at a level-1 trauma center: size still does not matter. World Journal of Surgery. 2018;42:107-13.
11. Kulvatunyou N, Vijayasekaran A, Hansen A, et al. Two-year experience of using pigtail catheters to treat traumatic pneumothorax: a changing trend. Journal of Trauma and Acute Care Surgery. 2011;71:1104-7.
12. Kulvatunyou N, Joseph B, Friese RS, et al. 14 French pigtail catheters placed by surgeons to drain blood on trauma patients: is 14-Fr too small? Journal of Trauma and Acute Care Surgery. 2012;73:1423-7.
13. Browning RF, Mullenix P, Middendorf M, McKay S, Turner JJF. Pneumothorax: Large-Bore Tubes Vs. Pigtail Catheter. In: Turner JJF, Jain P, Yasufuku K, Mehta AC, editors. From Thoracic Surgery to Interventional Pulmonology: A Clinical Guide. Cham: Springer International Publishing; 2021: 259-72.
14. Aziz F, Penupolu S, Flores D. Efficacy of percutaneous pigtail catheters for thoracostomy at bedside. Journal of Thoracic Disease. 2012;4:292.
15. Liu Y-H, Lin Y-C, Liang S-J, et al. Ultrasound-guided pigtail catheters for drainage of various pleural diseases. The American journal of emergency medicine. 2010;28:915-21.
16. Chang S-H, Kang Y-N, Chiu H-Y, Chiu Y-H. A systematic review and meta-analysis comparing pigtail catheter and chest tube as the initial treatment for pneumothorax. Chest. 2018;153:1201-12.
17. Heller GZ, Manuguerra M, Chow R. How to analyze the Visual Analogue Scale: Myths, truths and clinical relevance. Scandinavian journal of pain. 2016;13:67-75.
18. Ghaderi F, Banakar S, Rostami S. Effect of pre-cooling injection site on pain perception in pediatric dentistry: "A randomized clinical trial". Dental research journal. 2013;10:790.
19. Zeiler J, Idell S, Norwood S, Cook A. Hemothorax: a review of the literature. Clinical pulmonary medicine. 2020;27:1.
20. Ishak M, Chakraborty D, Kassirian S, Dhaliwal I, Mitchell MA. Risk of iatrogenic pneumothorax based on location of transbronchial biopsy: a retrospective cohort study. BMC Research Notes. 2023;16:1-5.
21. Huan N-C, Sidhu C, Thomas R. Pneumothorax: classification and etiology. Clinics in chest medicine. 2021;42:711-27.
22. Mortman KD, Tanenbaum MT, Cavallo KM, et al. Reintervention Rate After Pigtail Catheter Insertion Compared to Surgical Chest Tubes. The American Surgeon. 2023: 89(12): 5487 - 5491.
23. Russo RM, Zakaluzny SA, Neff LP, et al. A pilot study of chest tube versus pigtail catheter drainage of acute hemothorax in swine. Journal of Trauma and Acute Care Surgery. 2015;79:1038-43.
24. Viftrup A, Laustsen S. Pain during and after insertion of chest drains. Nordisk sygeplejeforskning. 2020;10:127-38.
25. Beeton G, Ngatuvai M, Breeding T, et al. Outcomes of Pigtail Catheter Placement versus Chest Tube Placement in Adult Thoracic Trauma Patients: A Systematic Review and Meta-Analysis. The American Surgeon. 2023:89(16): 2743 - 2754.
26. Weiss T, Dreznik Y, Kravarusic D. Pigtail Catheter versus Large Bore Chest Tube for the Management of Spontaneous Pneumothorax in Children: A Retrospective Study. European Journal of Pediatric Surgery. 2023: 34 (4): 346 - 350.
27. Bauman ZM, Kulvatunyou N, Joseph B, et al. Randomized clinical trial of 14-French (14F) pigtail catheters versus 28–32F chest tubes in the management of patients with traumatic hemothorax and hemopneumothorax. World Journal of Surgery. 2021;45:880-6.

28. Sakuraba M, Mishina T, Tanaka A. Re-expansion Pulmonary Edema after Chest Drainage for Pneumothorax; Evaluation of Risk Factors in 630 Episodes. ARC Journal of Sugery. 2021;7(1):9-12.
29. Rozenman J, Yellin A, Simansky DA, Shiner RJ. Re-expansion pulmonary oedema following spontaneous pneumothorax. Respiratory medicine. 1996;90:235-8.
30. Kim YK, Kim H, Lee CC, et al. New classification and clinical characteristics of reexpansion pulmonary edema after treatment of spontaneous pneumothorax. The American journal of emergency medicine. 2009;27:961-7.
31. Lin HL, Chou YP. 14-French Pigtail Catheters for Traumatic Hemothorax/Hemopneumothorax: Size Does Not Matter. World J Surg. 2018; 42(8):2686.