QMJ
A peer reviewed journal
QATAR MEDICAL JOURNAL

RESEARCH ARTICLE

Occult Pneumothorax in Patients Presenting with Blunt Chest Trauma: An Observational Analysis

Ismail Mahmood[1], Basil Younis[1], Khalid Ahmed[1], Fuad Mustafa[1], Ayman El-Menyar[2,3], Mohammad Alabdallat[1], Ashok Parchani[1], Ruben Peralta[1], Syed Nabir[4], Nadeem Ahmed[4], Hassan Al-Thani[1]

Address for Correspondence:
Ayman El-Menyar
[1]Department of Surgery, Trauma Surgery Section, Hamad Medical Corporation, Doha, Qatar
[2]Clinical Research, Trauma & Vascular Surgery Section, Hamad Medical Corporation, Doha, Qatar
[3]Clinical Medicine, Weill Cornell Medical College, Doha, Qatar
[4]Department of Radiology, Hamad General Hospital, Doha, Qatar
Email: aymanco65@yahoo.com

http://dx.doi.org/10.5339/qmj.2020.10
Submitted: 15 September 2019
Accepted: 21 November 2019

Cite this article as: Mahmood I, Younis B, Ahmed K, Mustafa F, El-Menyar A, Alabdallat M, Parchani A, Peralta R, Nabir S, Ahmed N, Al-Thani H. Occult Pneumothorax in Patients Presenting with Blunt Chest Trauma: An Observational Analysis, Qatar Medical Journal 2020:10 http://dx.doi.org/10.5339/qmj.2020.10

كيوسايتس
QSCIENCE
دار جامعة حمد بن خليفة للنشر
HAMAD BIN KHALIFA UNIVERSITY PRESS

ABSTRACT

Background: We aimed to assess the management and outcome of occult pneumothorax and to determine the factors associated with failure of observational management in patients with blunt chest trauma (BCT).
Methods: Patients with BCT were retrospectively identified from the trauma database over 4 years. Data were analyzed and compared on the basis of initial management (conservative vs. tube thoracostomy).
Results: Across the study period, 1928 patients were admitted with BCT, of which 150 (7.8%) patients were found to have occult pneumothorax. The mean patient age was 32.8 ± 13.7 years, and the majority were male (86.7%). Positive-pressure ventilation (PPV) was required in 32 patients, and bilateral occult pneumothorax was seen in 25 patients. In 85.3% (n = 128) of cases, occult pneumothorax was managed conservatively, whereas 14.7% (n = 22) underwent tube thoracostomy. Five patients had failed observational treatment requiring delayed tube thoracostomy. Pneumonia was reported in 12.8% of cases. Compared with those who were treated conservatively, patients who underwent tube thoracostomy had thicker pneumothoraxes and a higher rate of lung contusion, rib fracture, pneumonia, prolonged ventilatory days, and prolonged hospital length of stay. Overall mortality was 4.0%. The deceased had more polytrauma and were treated conservatively without a chest tube. Patients who failed conservative management had a higher frequency of lung contusion, greater pneumothorax thickness, higher Injury Severity Scores (ISS), and required more PPV.

Conclusions: Occult pneumothorax is not uncommon in BCT and can be successfully managed conservatively with a close clinical follow-up. Intervention should be limited to patients who have an increase in size of the pneumothorax on follow-up or become symptomatic under observation. Patients who fail conservative management may have a greater pneumothorax thickness and higher ISS. However, large prospective studies are warranted to support these findings and to establish the institutional guidelines for the management of occult pneumothorax.

Keywords: chest trauma, occult pneumothorax, chest CT scan, ventilation

INTRODUCTION

In BCT, the presence of air in the pleural space is referred to as pneumothorax, which has been reported in up to 55% of cases.[1] However, the primary diagnostic modality for screening pneumothorax in the emergency setting is chest radiography; it has lower sensitivity, which increases the chances of misdiagnosis (30% – 40%).[2 – 4] The most accurate diagnostic tool to detect blood or air in the pleura in the initial trauma setting is the thoracic computed tomography (CT) scan, which has > 95% sensitivity and is the gold standard tool for detecting thoracic lesions.[5] In addition, the CT scan is the modality of choice for diagnosing occult pneumothorax in trauma patients that remain undetected by normal supine chest X-rays.[6] It may be challenging to observe occult pneumothorax in severely injured patients. In such patients, the clinical concern is the risk of progression to life-threatening tension pneumothorax, particularly if the patient is undergoing positive-pressure ventilation (PPV).[7]

Moreover, emergency physicians often encounter difficulty in choosing the appropriate treatment strategy for occult pneumothorax. The selection of chest tube insertion over conservative management remains controversial due to the association of more complications from tube thoracostomy than from the pneumothorax itself.[8] An earlier management strategy supported the placement of a chest tube for all clinically or radiographically diagnosed pneumothoraxes after trauma.[9] However, this practice has been changed due to the reported risk of major complications (22%) secondary to intercostal tube placement.[9]

To date, we do not have an institutional guideline for the indications to opt for the initial insertion of chest tube in occult pneumothorax patients. Therefore, the important issue is to distinguish the pneumothoraxes that can be treated conservatively from those which require chest drainage. According to the Eastern Association for the Surgery of Trauma practice management guidelines, occult pneumothorax can be observed in a stable patient regardless of PPV.[10] In contrast, Advanced Trauma Life Support guidelines recommend that traumatic pneumothorax is best treated with a chest tube, especially in those requiring general anesthesia or PPV.[11] However, there is increasing evidence in the adult[12,13] and pediatric literature suggesting that occult pneumothoraxes may be safely observed even while under PPV[14,15]; however, occult pneumothorax progression and respiratory distress are independently associated with the need for tube thoracostomy insertion.[12]

In this study we sought to analyze the clinical presentations, management, and outcomes of trauma patients who presented with occult pneumothorax and to determine which clinical factors were associated with failure of initial conservative management in our Level I trauma center.

METHODS

Study participants and setting

This is a retrospective chart review of all admitted BCT patients who were diagnosed with pneumothorax on chest CT scan that was not evident on initial supine chest X-ray. We reviewed the trauma registry database at Hamad General Hospital, the only Level I trauma center in the state of Qatar, from November 2010 to November 2014.

As per the standard of care, we also retrieved data on the in-hospital clinical follow-up, to review the erect P-A view chest X-rays (or, if this was not possible, supine films) to assess the progression of pneumothorax during the hospital course.

Our inclusion criteria included all blunt thoracic trauma patients with occult pneumothorax which was diagnosed and measured by CT scan to quantify the highest perpendicular distance in millimeters from the chest wall of the largest air pocket as described by De Moya et al.[16] The exclusion criteria were all patients who had concurrent occult hemothorax on chest CT scan and those who were aged < 14 years.

Data collection

Patient demographics (age and sex), mechanism of injury, presence of lung contusions, rib fracture, chest CT scan findings (pneumothorax thickness, bilateral pneumothorax), intubation, ventilation mode, chest Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), management for pneumothorax, failure of conservative management, length of hospital and intensive care unit stay, ventilatory days, and mortality were examined. Outcomes such as chest tube complications (pneumonia, empyema, and tension pneumothorax) were also recorded. Clinical follow-up was carried out to determine when the chest tube was placed as part of management and for other indications in each case with an occult pneumothorax.

A CT scan was performed using 120 ml of Omnipaque injected at 3 ml/s and with a Siemens Medical Systems 64-slice scanner. Images were rebuilt with slice thicknesses of 1.2, 2.5, or 5 mm, reviewed, and analyzed by a trauma consultant radiologist.

In our trauma center, there are on an average, 2500 trauma activations per year, of which approximately 1600 – 1800 patients require hospital admission. Roughly 80% of patients with significant injuries underwent a pan CT scan (Head, Neck, Chest & Abdomen), and the rest underwent region specific CT scan based on the anatomical region, mechanism of injury, and at the discretion of the treating physician.

Occult pneumothorax referred to the findings of a normal initial chest radiograph of the trauma patient, which was later detected as a pneumothorax on a subsequent thoracic CT scan.

Pneumonia: Centers for Disease Control and Prevention in Atlanta, GA, USA (CDC) criteria (purulent sputum, leukocytosis, positive culture of endotracheal secretion, infiltrate on chest radiograph, and fever) were used to make a diagnosis of pneumonia.[17]

Hamad General Hospital provides trauma services to the whole population of Qatar, and it successfully achieved Trauma Distinction Accreditation offered by Accreditation Canada International. The Qatar National Trauma Registry is a database that participates in both the National Trauma Data Bank and the Trauma Quality Improvement Program of the American College of Surgeons-Committee on Trauma (ACS-COT). The Medical Research Center (IRB# 14513/14) at Hamad Medical Corporation, Doha, Qatar, has approved the study.

Statistical analysis

Data were presented as mean ± standard deviation, medians (range), and proportions, as appropriate. We categorized and compared the management of pneumothorax in two groups as conservative versus chest tube insertion. Differences in categorical and continuous variables were analyzed using the χ^2 test and Student's t-test, as appropriate. Yates' corrected chi-square was used for categorical variables, if the expected cell frequencies were below 5. A significant difference was considered when the two-tailed p value was <0.05. Statistical Package for the Social Sciences version 18 (SPSS, Inc., Chicago, IL USA) was used for the data analysis.

RESULTS

Across the study period, 1928 patients were admitted with BCT; of them, 150 (7.8%) patients were found to have occult pneumothorax. The mean patient age was 32.8 ± 13.7 years, and the majority of them were male (86.7%). The most frequent mechanism of injury was motor vehicle crash (50%) followed by pedestrian struck by a car (18.7%), and fall from a height (11.3%) (Table 1).

Lung contusion (72%) characterized the most frequent chest injury, and 78 (52%) patients had rib fractures with a median of 3.5 ribs (range 1 – 12). On CT scan evaluation, the median pneumothorax thickness was 8.5 (range: 2 – 173) mm. Half of patients had occult pneumothorax thickness in the range of 1 – 9.9 mm (50.3%) followed by 10 – 19.9 mm (22.8%). Only 16.8% of patients had occult pneumothorax thickness of ≥30 mm (Figure 1). Bilateral occult pneumothorax was seen in 25 (16.7%) patients.

Endotracheal intubation and PPV were needed in 32 (22%) patients secondary to severe head injury (Glasgow Coma Scale (GCS) < 8). Seven patients on PPV received a prophylactic chest tube as per the discretion of the treating physician and one patient developed respiratory distress with radiographic evidence of pneumothorax progression.

Figure 2 shows examples of pneumothorax in two cases.

Eight (5.3%) patients required general anesthesia for surgical intervention involving maxillofacial, neurosurgical, or orthopedic procedures.

Figure 3 shows a flow chart for management of patients with occult pneumothorax. Conservative

Table 1. Demographics, clinical presentation, and outcome of patients with occult pneumothorax based on management approach.

	Total (n = 150)	Conservative (n = 128)	Tube thoracostomy (n = 22)	P
Age (mean ± SD)	32.8 ± 13.7	31.2 ± 13	36.7 ± 16.6	0.08
Males	130 (86.7%)	109 (85.2%)	21 (95.5%)	0.18
Mechanism of injury				
Motor vehicle crash	75 (50.0%)	68 (53.1%)	7 (31.8%)	0.03 for all
Pedestrian	28 (18.7%)	25 (19.5%)	3 (13.6%)	
Fall from height	17 (11.3%)	11 (8.6%)	6 (27.3%)	
Others	30 (20.0%)	24 (18.8%)	6 (27.3%)	
Pneumothorax thickness (mm)	8.5 (2 – 173)	8 (2 – 173)	13 (2 – 50)	0.36
Bilateral pneumothorax	25 (16.7%)	20 (15.6%)	5 (22.7%)	0.60
Lung contusion	108 (72.0%)	89 (69.5%)	19 (86.4%)	0.10
Rib fracture	78 (52.0%)	64 (50.0%)	14 (63.6%)	0.23
Number of fractured ribs	3.5 (1 – 12)	3 (1 – 12)	5.5 (1 – 9)	0.09
Injury severity score	16.4 ± 9.4	16.3 ± 9.7	17 ± 7.6	0.74
Chest AIS *median (range)*	3 (2 – 5)	3 (2 – 5)	3 (2 – 4)	0.01
mean ± SD		2.52 ± 0.55	2.82 ± 0.50	
Surgical intervention	8 (5.3%)	7 (5.5%)	1 (4.5%)	0.73
Mechanical ventilation	32 (21.3%)	25 (19.5%)	7 (31.8%)	0.19
Ventilatory days	10 (1 – 25)	10 (1 – 25)	12 (1 – 18)	0.68
ICU length of stay	8.5 (1 – 82)	7 (1 – 82)	9 (2 – 32)	0.40
Hospital length of stay	7 (1 – 139)	7 (1 – 139)	8.5 (2 – 117)	0.05
Pneumonia	19 (12.8%)	15 (11.9%)	4 (18.2%)	0.41
Mortality	6 (4.0%)	6 (4.7%)	0 (0.0%)	0.65

AIS: Abbreviated injury score; ICU: Intensive care unit.

management of occult pneumothorax was effectively attained in 128 (85.3%) cases initially, and the remaining 22 (14.7%) cases underwent tube thoracostomy. Of the 22 patients who required chest tube insertion, 17 patients were managed with immediate tube thoracostomy, whereas five patients failed conservative management and required delayed chest tube insertion (2 patients had a progression of the occult pneumothorax on follow-up chest radiographs, two developed pleural effusion, and one had increased respiratory distress with oxygen desaturation while on PPV).

The mean ISS was 16.4 ± 9.4 and the median chest AIS was 3 (range 2 – 5). The median duration of PPV was 10 (range: 1 – 25) days, and hospital length of stay was 7 (range: 1 – 139) days. Pneumonia was the commonest in-hospital complication, observed in 12.8% of cases.

Table 1 reveals a comparison between tube thoracostomy and conservatively treated patients groups. As compared with those who were treated conservatively, patients who underwent tube thoracostomy had higher mean chest AIS (2.8 ± 0.5 vs. 2.5 ± 0.5; $p = 0.01$) and were more likely to have prolonged length of hospital stay [8.5 days (2 – 117) vs. 7 (1 – 139); $p = 0.05$]. On the other hand, conservatively treated patients were more likely to be involved in motor vehicle crashes and pedestrian injuries ($p = 0.03$ for all).

The overall mortality was 4.0%, and all deaths occurred during the index admission in patients who sustained polytrauma (ISS ≥ 29) and head injury and were treated without a chest tube. Table 2 shows the characteristics of patients who required delayed tube thoracostomy. Although it was statistically not significant, patients who failed conservative management were more likely to have frequent lung contusion, had greater pneumothorax thickness, required PPV, and were severely injured with greater ISS as compared with those who were successfully treated conservatively.

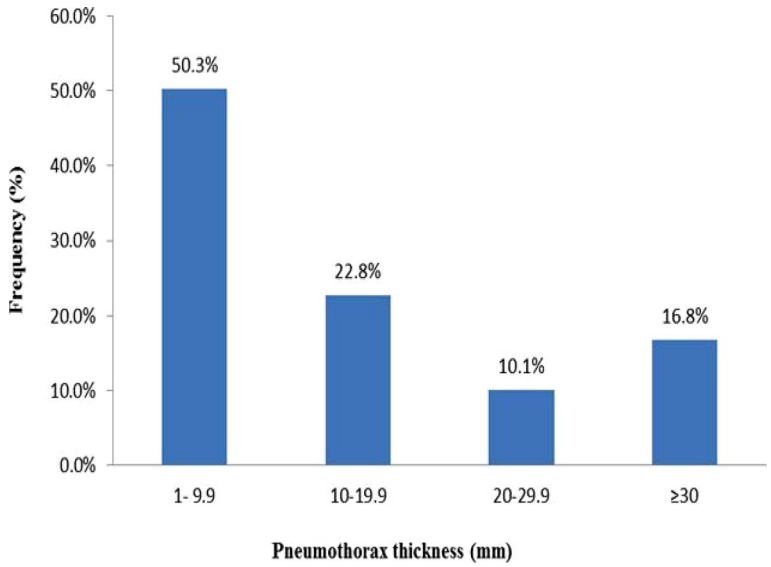

Figure 1. Computed tomography scan findings of occult pneumothorax thickness in millimeters.

DISCUSSION

Occult pneumothorax is a relatively infrequent manifestation of blunt chest injuries that varies in frequency from 1.8% to 6%.[6] In our center, around 7.8% of BCT patients were found to have occult pneumothorax. The present study, utilizing nationally representative data, assessed the clinical presentation, management, and outcomes of thorax trauma patients found to have occult pneumothorax on CT scan. There are several key findings of this study. First,

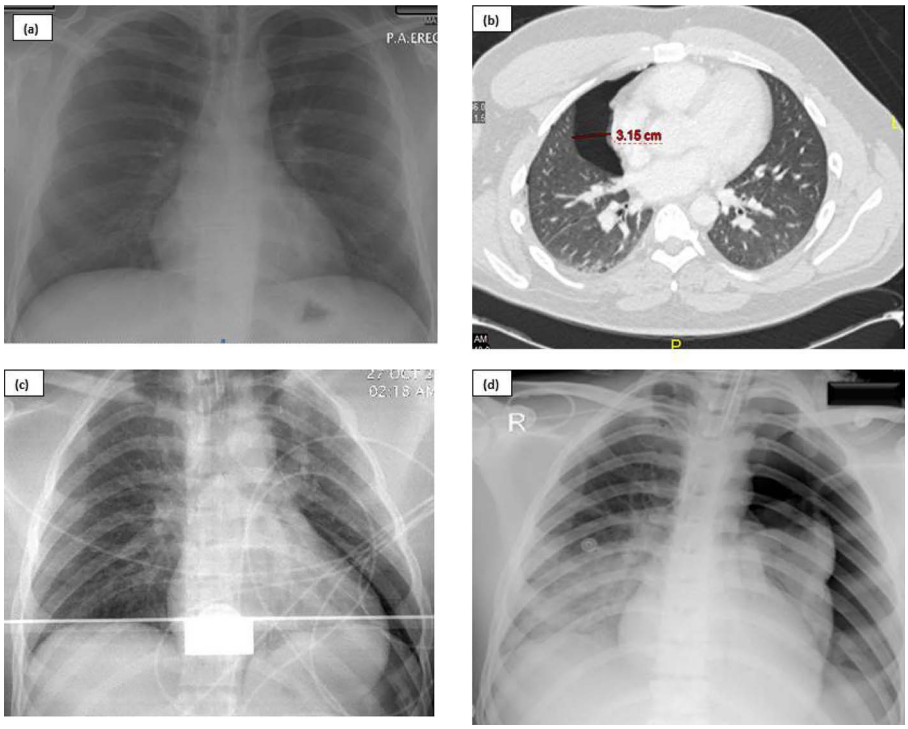

Figure 2. Case 1 (a) Chest radiograph and (b) corresponding computed tomography scan of a patient with a 31.5 mm pneumothorax on the left side not identified on chest X-ray. Case 2: (c) Chest radiograph with evidence of pneumothorax progression and (d) chest radiograph on admission.

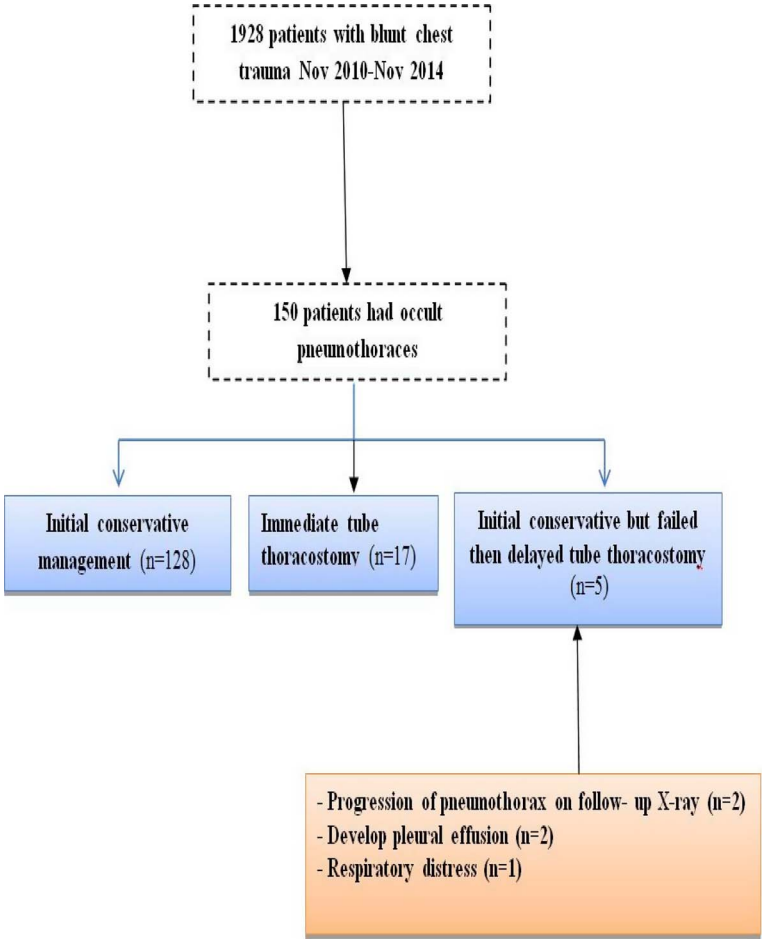

Figure 3. Management of patients with occult pneumothorax in the current study.

the majority (85%) of patients who were diagnosed with occult pneumothorax could be successfully treated conservatively. Second, the leading mechanism of injury was MVC and pedestrian trauma. Third, the failure rate of conservative management was low and was more likely to be associated with lung contusion, greater pneumothorax thickness, the need for PPV, and greater injury severity.

Historically, tube thoracostomy was the preferred treatment approach for pneumothorax, hemothorax, empyema, and hemopneumothorax, and at the time of the Vietnam War, it was considered as the standard of care.[18] However, placement of a thoracostomy tube is not without risk, and in some cases there may be a chance of incomplete drainage. The major complication rate for tube thoracostomy is nearly 22%, including pneumothorax after tube removal, infections (empyema or wound infection), and insertional (intercostal artery or intraparenchymal lung injuries) technical error.[19]

Occult pneumothoraxes are relatively recent radiological phenomena that appeared with the upsurge of thoracic CT scans as the initial screening modalities for investigation of BCT.[6,20] Several researchers suggest that close observation for occult pneumothorax is safer and feasible if there is no respiratory distress or progression in the size of pneumothorax on the radiographic follow-up.[21–23] This is in agreement with our findings of a 96% success rate of expectant management in occult pneumothorax patients.

Approximately 15% of patients in this series required chest tube placement. Of them, 17 patients were managed with immediate tube thoracostomy based on the attending physician's discretion, and five patients who failed observation underwent delayed tube thoracostomy. Our incidence is slightly lower than that reported by the American Association for the surgery of trauma (AAST) multicenter study and may be due to the absence of concurrent occult hemothorax, which was not regarded as an exclusion

Table 2. Demographics, clinical presentation and outcome of patients with failed conservative management.

Variables	Value
Age (mean ± SD) yrs	25.0 ± 9.3
Males	4 (80.0%)
Lung contusion	5 (100%)
Rib fracture	3 (60.0%)
Number of fractured ribs	2 (1 – 7)
Pneumothorax thickness (mm) median, range	15 (3 – 46)
Bilateral pneumothorax	1 (20.0%)
Intubation	2 (40.0%)
Mechanical ventilation	2 (40.0%)
Chest abbreviated injury score	2 (2 – 3)
Injury severity score	21.8 ± 2.9
Surgical intervention	0 (0.0%)
Pneumonia	1 (20.0%)
Ventilatory days	11 (5 – 17)
ICU length of stay	11.5 (5 – 21)
Hospital length of stay	16 (9 – 21)
Mortality	0 (0.0%)

ICU: Intensive care unit.

criterion in that study.[24] Moreover, none of our patients developed complications related to delayed tube thoracostomy. Given the 10-fold increase that has occurred in the use of chest CT for trauma evaluation, Plurad et al.[25] studied 1,873 chest CT results after negative chest X-rays. They concluded that the number of patients who needed treatment was small in spite of the increase in occult findings.

Enderson et al.[26] evaluated the efficacy of tube thoracostomy in trauma patients with occult pneumothorax in a randomized prospective study. The authors reported that the size of initial occult pneumothorax could not predict the formation or progression of a tension pneumothorax. Patient with occult pneumothorax that requires mechanical ventilation should undergo chest tube insertion.[26] Other investigators also recommended chest tube insertion in occult pneumothorax patients subjected to PPV due to the associated risk of developing tension pneumothorax.[7,27,28]

The current strategies for mechanical ventilation have been improved because of evidence-based medicine. Pinhu et al.[29] recommended adjustment of few parameters including an increase in tidal volumes from 8 to 10 mL/kg, peak inspiratory pressure limits of 40 – 50 cm H_2O, and limited positive end-expiratory pressure. Standard practice for the management of critically ill patients is based on decreased airway pressures and tidal volumes. The management guidelines for mechanical ventilation focused on controlling mean and peak airway pressures and very low pressures.[30] The lower tidal volumes (5 – 7 mL/kg) and average peak inspiratory pressure (18.7) were used in the current study. In our cohort, 32 patients required PPV, 26 (78.8%) were treated conservatively, and seven (21.2%) patients required tube thoracostomy; of them, two failed expectant management and later on underwent tube thoracostomy.

Similar to our findings, Barrios et al.[31] reported an 80% success rate for observational management in patients with occult pneumothorax (80%) who required mechanical ventilation with PPV. An earlier study showed successful conservative management in 53% of occult pneumothorax patients requiring PPV.[26]

It has been suggested that a conservative management approach can be considered in patients with mild injuries who are hemodynamically stable. Therefore, tube thoracostomy in chest trauma patients is not an essential part of the management strategy.[32] Moreover, a prior study showed that observation is at least as safe and effective as tube thoracostomy in patients with

occult pneumothorax.[33] A recent study by Zhang et al.[34] also supported conservative management in occult pneumothorax due to the lower rate of complications compared with chest tube insertion; these observations corroborate well with our findings.[35–37]

Limitations

The major limitation of the study is the single center and small sample size of patients who underwent tube thoracostomy. As this is a retrospective study, management decisions, with the placement of prophylactic tube thoracostomy on admission, especially for patients who required PPV, were not dictated by the study protocol but represented a lack of consensus in the current practice. The lack of understanding of why 17 patients underwent immediate chest tube placement could be in part explained by the physician's discretion in the lack of consensus and institutional protocols. In addition, multivariate analysis to identify the clinical predictors of failure of conservative management was impractical due to the small numbers of outcomes (five patients who underwent delayed tube thoracostomy after failed observation). The incidence of occult pneumothorax in our database may have been underestimated as we did not have an institutional protocol to follow during that era.

CONCLUSIONS

Patients with occult pneumothorax can be successfully managed conservatively with clinical follow-up as the treatment of choice. Intervention should be limited to those patients who have a pneumothorax of increasing size on follow-up radiographs or become symptomatic under observation. The initial size of the occult pneumothorax did not seem to be signi□cant in determining the need for tube thoracostomy. Patients who fail conservative management may have a greater pneumothorax thickness and higher ISS. However, large prospective studies are warranted to support these results and to establish institutional guidelines for the management of occult pneumothorax.

ACKNOWLEDGEMENT

We thank the registry database team in the Trauma Surgery Section, Hamad General Hospital, Qatar.

Ethics Approval

The study obtained ethical approval from Research Ethics Committee, at Medical Research Center, Hamad Medical Corporation, Doha, Qatar (IRB#14513/14). A waiver of consent was granted as no direct contact with patients and data were anonymous.

Data Availability

Data will be available upon request after approval and signing agreement with the Medical Research Center (research@hmc.org.qa)

Funding

This research did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector.

Competing Interests

The authors have no conflict of interest, no financial issues to disclose and no funding was received for this study.
This study was presented in part at the 18th European Congress for Trauma and Emergency Surgery (ECTES 2017), May 7-9, 2017, in Bucharest, Romania.

REFERENCES

1. Ball CG, Kirkpatrick AW, Laupland KB, Fox DI, Nicolaou S, Anderson IB, et al. Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. *J Trauma*. 2005;59(4):917-24; discussion: 924–925.
2. Chiles C, Ravin CE. Radiographic recognition of pneumothorax in the intensive care unit. *Crit Care Med*. 1986;14:677–680.
3. Tocino IM, Miller MH, Fairfax WR. Distribution of pneumothorax in the supine and semirecumbent critically ill adult. *Am J Roentgenol*. 1985;144:901–905.
4. Kurdziel JC, Dondelinger RF, Hemmer M. Radiological management of blunt polytrauma with CT and angiography: an integrated approach. *Ann Radiol*. 1987;30:121–124.
5. Chen L, Zhang Z. Bedside ultrasonography for diagnosis of pneumothorax. *Quant Imaging Med Surg*. 2015;5(4):618–623.

6. Ball CG, Kirkpatrick AW, Feliciano DV. The occult pneumothorax: what have we learned? *Can J Surg*. 2009;52(5):E173 – E179.
7. Ball CG, Hameed SM, Evans D, Kortbeek JB, Kirkpatrick AW. Canadian Trauma Trials Collaborative. Occult pneumothorax in the mechanically ventilated trauma patient. *Can J Surg*. 2003;46(5): 373 – 379.
8. Omar HR, Abdelmalak H, Mangar D, Rashad R, Helal E, Camporesi EM. Occult pneumothorax, revisited. *J Trauma Manag Outcomes*. 2010 Oct;4:12.
9. Ball CG, Lord J, Laupland KB, Gmora S, Mulloy RH, Ng AK, et al. Chest tube complications: how well are we training our residents? *Can J Surg*. 2007;50(6): 450 – 458.
10. Mowery NT, Gunter OL, Collier BR, Diaz JJ, Jr, Haut E, Hildreth A, et al. Practice management guidelines for management of hemothorax and occult pneumothorax. *J Trauma*. 2011;70(2):510 – 518.
11. American College of Surgeons Committee. *Advanced trauma life support program for doctors*. 9th ed. Chicago: American College of Surgeons; 2013.
12. Michaeli P, Munnangi S, Digiacomo JC, Gonzalez E, Catherine AMK. Factors associated with chest tube placement in blunt trauma patients with an occult pneumothorax. *Crit Care Res Pract*. 2019;2019.
13. Hefny AF, Kunhivalappil FT, Matev N, Avila NA, Bashir MO, Abu-Zidan FM. Management of computed tomography-detected pneumothorax in patients with blunt trauma: experience from a community-based hospital. *Singapore Med J*. 2018;59(3):150 – 154.
14. Fulton C, Bratu I. Occult pneumothoraces in ventilated pediatric trauma patients: a review. *Can J Surg*. 2015;58(3):177 – 180.
15. Kirkpatrick AW, Rizoli S, Ouellet JF, Roberts DJ, Sirois M, Ball CG, et al. Canadian Trauma Trials Collaborative and the Research Committee of the Trauma Association of Canada. Occult pneumothoraces in critical care: a prospective multicenter randomized controlled trial of pleural drainage for mechanically ventilated trauma patients with occult pneumothoraces. *J Trauma Acute Care Surg*. 2013;74(3):747 – 54, discussion 754-5.
16. De Moya MA, Seaver C, Spaniolas K, Inaba K, Nguyen M, Veltman Y, et al. Occult pneumothorax in trauma patients: development of an objective scoring system. *J Trauma*. 2007;63:13 – 17.
17. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections. *Am J Infect Control*. 1988;16:128 – 140.
18. Monaghan SF, Swan KG. Tube thoracostomy: the struggle to the standard of care. *Ann Thorac Surg*. 2008;86(6):2019 – 2022.
19. Deneuville M. Morbidity of percutaneous tube thoracostomy in trauma patients. *Eur J Cardiothorac Surg*. 2002;22:673 – 678.
20. Guerrero-López F, Vazquez-Mata G, Alcazar-Romero PP, Fernández-Mondéjar E, Aguayo-Hoyos E, Linde-Valverde CM. Evaluation of the utility of computed tomography in the initial assessment of the critical care patient with chest trauma. *Crit Care Med*. 2000;28:1370 – 1375.
21. Brasel KJ, Stafford RE, Weigelt JA, Tenquist JE, Borgstrom DC. Treatment of occult pneumothoraces from blunt trauma. *J Trauma*. 1999;46:987 – 991.
22. Hill SL, Edmisten T, Holtzman G, Wright A. The occult pneumothorax: an increasing entity in trauma. *Am Surg*. 1999;65:254 – 258.
23. Collins JC, Levine G, Waxman K. Occult traumatic pneumothorax: immediate tube thoracostomy versus expectant management. *Am Surg*. 1992;58: 743 – 746.
24. Moore FO, Goslar PW, Coimbra R, Velmahos G, Brown CV, Coopwood TB Jr, et al. Blunt traumatic occult pneumothorax: is observation safe?-results of a prospective, AAST multicenter study. *J Trauma*. 2011;70(5):1019 – 1023, discussion 1023-5.
25. Plurad D, Green D, Demetriades D, Rhee P. The increasing use of chest computed tomography for trauma: is it being over utilized? *J Trauma*. 2007;62:631 – 635.
26. Enderson BL, Abdalla R, Frame SB, Casey MT, Gould H, Maull KI. Tube thoracostomy for occult pneumothorax: a prospective randomized study of its use. *J Trauma*. 1993;35(5):726 – 729, discussion 729-30.
27. Bridges KG, Welch G, Silver M, Schinco MA, Esposito B. CT detection of occult pneumothorax in multiple trauma patients. *J Emerg Med*. 1993;11(2): 179 – 186.
28. Omert L, Yeaney WW, Protech J. Efficacy of thoracic computerized tomography in blunt chest trauma. *Am Surg*. 2001;67:660 – 667.
29. Pinhu L, Whitehead T, Evans T, Griffiths M. Ventilator-associated lung injury. *Lancet*. 2003;361(9354): 332 – 340.
30. Pham T, Brochard LJ, Slutsky AS. Mechanical Ventilation: State of the Art. *Mayo Clin Proc*. 2017;92(9):1382 – 1400.
31. Barrios C, Tran T, Malinoski D, Lekawa M, Dolich M, Lush S, et al. Successful management of occult pneumothorax without tube thorocostomy despite positive pressure ventilation. *Am Surg*. 2008;74(10): 958 – 961.

32. Pramod T, Shashirekha CA, Chandan KR, Harsha R. Role of conservative management of traumatic chest injuries: a retrospective study & review of literature. *Int J Sci Stud.* 2015;3(8): 147 – 150.

33. Yadav K, Jalili M, Zehtabchi S. Management of traumatic occult pneumothorax. *Resuscitation.* 2010;81(9):1063 – 1068.

34. Zhang M, Teo LT, Goh MH, Leow J, Go KT. Occult pneumothorax in blunt trauma: is there a need for tube thoracostomy? *Eur J Trauma Emerg Surg.* 2016; 42(6):785 – 790.

35. Lee KL, Graham CA, Yeung JHH, Ahuja AT, Rainer TH. Occult pneumothorax in Chinese patients with significant blunt chest trauma: incidence and management. *Injury.* 2010;41: 492 – 494.

36. Wilson H, Ellsmere J, Tallon J, Kirkpatrick A. Occult pneumothorax in the blunt trauma patient: tube thoracostomy or observation? *Injury.* 2009;40(9): 928 – 931.

37. Mahmood I, Tawfeek Z, El-Menyar A, Zarour A, Afifi I, Kumar S, et al. Outcome of concurrent occult hemothorax and pneumothorax in trauma patients who required assisted ventilation. *Emerg Med Int*. 2015;2015.