[Original Research]

≋CHEST®

Conservative Management in Traumatic Pneumothoraces
An Observational Study

Steven P. Walker, MBChB; Shaney L. Barratt, BMBS, PhD; Julian Thompson, MD(Res); and Nick A. Maskell, DM, FCCP

BACKGROUND: Traumatic pneumothoraces are a common consequence of major trauma. Despite this, there is a paucity of literature regarding their optimal management, including the role of conservative treatment. The aim of this study was to assess the treatment, complications, and outcomes of traumatic pneumothoraces in patients presenting to a major trauma center.

METHODS: The prospectively collected Trauma Audit and Research Network (TARN) database was used to identify all patients presenting with traumatic pneumothoraces to a UK major trauma center from April 2012 to December 2016. Demographics, mechanism of injury, injury severity score (ISS), management, and outcomes were analyzed.

RESULTS: Six hundred two patients were included during the study period. Mean age was 48 years (SD, 22 years), and 73% were men. Mean ISS was 26 and inpatient mortality was 9%. Of the 602 traumatic pneumothoraces, 277 of 602 (46%) were initially treated conservatively. Two hundred fifty-two of 277 patients in this cohort (90%) did not require subsequent chest tube insertion, including the majority of patients (56 of 62 [90%]) who were receiving positive pressure ventilation (PPV) on admission. The hazard ratio (HR) for failure of conservative management showed no difference between the ventilated and nonventilated patients (HR, 1.1; P = .84). Only the presence of a large hemothorax was associated with an increased likelihood of failure of conservative management.

CONCLUSIONS: In the largest observational study of traumatic pneumothoraces published to date, > 90% of patients whose pneumothorax was managed conservatively never required subsequent tube drainage. Importantly, this also applies to patients requiring PPV, with no significant increased risk of failure of expectant management. These data support a role for conservative management in traumatic pneumothoraces. CHEST 2017; ■(■):■-■

KEY WORDS: pneumothorax; trauma; ventilation

Traumatic pneumothoraces are present in one-fifth of patients who have undergone multiple trauma[1] and is the most common potentially life-threatening injury in blunt chest trauma.[2] Thoracic trauma occurs in nearly two-thirds of multiple trauma cases and represents the primary cause of death in 25% of trauma patients.[3] Trauma as a whole is a major public health problem, with > 150,000 deaths and > 3 million nonfatal injuries per year in the United States,[4] representing the leading cause of death for individuals younger than 45 years of age.[5]

Although uncomplicated traumatic pneumothoraces may be well tolerated, the risk of tension and resultant cardiorespiratory compromise makes identification important, particularly since the basic procedure of tube thoracostomy insertion can potentially avert significant morbidity and mortality.[6] Current guidance by the American College of Surgeons Advanced Trauma Life Support[7] advises chest tube placement for any traumatic pneumothorax, although it suggests that asymptomatic pneumothoraces can be managed with observation and aspiration at the treating physician's discretion. It does, however, state that a chest drain is required in patients receiving either general anesthesia or positive pressure ventilation (PPV) to avoid a life-threatening pneumothorax.[7]

This concept has been challenged, principally with the increased use of CT imaging in trauma that has identified small subcentimeter-sized pneumothoraces. This has raised the question of whether these small "occult" pneumothoraces, which can make up to 76% of all traumatic pneumothoraces,[8] can be left untreated, particularly when positive pressure is required. Despite an early study indicating a high rate of tension in conservatively management patients receiving PPV,[9] studies[6,8,10-12] suggest that occult pneumothoraces can be managed expectantly, including in patients receiving PPV.

Whether these results can translate to all traumatic pneumothoraces is unclear and needs clarification. CT scanning is now almost ubiquitous in patients with multiple trauma, and the distinction between occult and overt pneumothoraces may become antiquated. Case studies have also suggested that it is possible to treat larger pneumothoraces with observation.[2,13]

The aim of our study was to use a large trauma patient cohort to create a profile of consecutive patients presenting with traumatic pneumothoraces to examine the outcomes of conservatively managed patients and determine whether there are factors that can help predict whether a chest tube is required.

Methods

From April 2012 to November 2016, patients were identified as part of the Trauma Audit and Research Network (TARN) of patients presenting to the ED at Southmead Hospital, a regional UK adult major trauma center (MTC). It covers a population of 2.3 million, is supported by six other trauma unit hospitals, and admits > 1,000 major trauma patients per year. The TARN registry is a prospective observational registry of hospitalized patients who have undergone major trauma in England and Wales. TARN has given ethical approval (Section 251) for research on the anonymized data submitted by member hospitals. The TARN database includes all trauma patients irrespective of age who have a direct admission or are transferred to a member hospital and whose length of stay is 3 days or more, as well as those admitted to a high-dependency area regardless of length of stay. It also includes deaths of trauma patients occurring in the hospital, including the ED, and those transferred to other hospitals for specialist care or for an ICU/HDU bed. Certain specific injuries were excluded, including isolated neck of femur fractures or intertrochanteric/greater trochanteric fractures in persons > 65 years.

International Classification of Diseases, tenth revision, codes included were S270 (traumatic pneumothorax), S270 (traumatic pneumothorax closed), S2701 (traumatic pneumothorax open), S271 (traumatic hemothorax), S2710 (traumatic hemothorax closed), S2711 (traumatic hemothorax open), S272 (traumatic hemopneumothorax), S2720 (traumatic hemopneumothorax closed), and S2721 (traumatic hemopneumothorax open).

Information was collected on demographics, injury (mechanism of injury, description of injuries, Injury Severity Score [ISS]), management (type, size of drain, length of drain placement), and pneumothorax characteristics (laterality, size, and accompanying hemothorax). Airway support was characterized as either requiring PPV before hospital admission or in the ED (initial PPV) or requiring PPV subsequently due to general anesthesia administration or clinical deterioration (subsequent PPV). The size of the pneumothorax was obtained from chest radiographs at the hilum and apex, and on CT imaging, the largest collection was measured along a line perpendicular from the chest wall to the lungs or mediastinum. Clinical parameters were obtained from initial observations on attendance in the ED. Respiratory distress was determined if respiratory rate was either ≥ 30 or < 8, if supplementary oxygen or mechanical or manual ventilation was used, if the oxygen saturation was $\leq 90\%$, or if the patient was in respiratory arrest. Hemodynamic instability was determined if the systolic BP was < 90 mm Hg or the heart rate was ≥ 100 bpm. Conscious-level impairment was determined if the Glasgow Coma Scale (GCS) score was < 15 or the patient was ventilated at arrival.

Statistical analysis

Descriptive statistics were used to summarize patient characteristics and clinical data. Means ($\pm$ SD) were calculated for parametric data, and medians (interquartile range [IQR]) were calculated for nonparametric data. Several checks for normality, including Kolmogorov-Smirnov, Shapiro-Wilk, kurtosis, and skewness calculations, were performed. Continuous parametric variables were analyzed using independent t tests, and continuous nonparametric variables were analyzed using the Mann-Whitney test. Categorical data were analyzed using the χ^2 test. $P < .05$ was considered statistically significant.

Univariate proportional hazard ratios (HRs) were calculated using Cox regression analysis for factors associated with failure of conservative treatment, for example, size of pneumothorax, mechanism of injury, ISS, presence of rib fractures, clinical features (respiratory, hemodynamic, GCS score), presence of hemothorax, bilateral vs unilateral pneumothorax, use of PPV, and surgical procedures. Further multivariable Cox regression analysis was performed to determine which factors (age, size of pneumothorax, ISS, presence of rib fractures, clinical conditions [respiratory, hemodynamic, GCS score], presence of hemothorax, bilateral vs unilateral pneumothorax, and use of PPV) were independently predictive of failure of conservative management. These factors were decided in an a priori statistical analysis plan. All statistical analysis was performed using SPSS, version 23.0 (SPSS, Inc.).

Results

Demographics

Three thousand seven hundred seventy-one trauma patients presenting to this MTC were registered in the TARN database from April 2012 to December 2016. Seven hundred sixty-five patients were identified using the search criteria. Six hundred thirty-six patients with pneumothoraces were identified, with 602 patients included for analysis (Fig 1). Table 1 summarizes patient demographics, mechanism of injuries, ISS, pneumothorax characteristics, management, and outcomes for patients managed nonconservatively and those managed conservatively. Table 2 summarizes the characteristics and outcomes for successful and failed observational management.

Traumatic pneumothoraces were present in 636 of 3,771 trauma patients (17%) during the study period.

The mean age was 48 years (SD, 22 years), 438 of 602 patients (73%) were men, and 330 of 602 patients (55%) received their injuries as a result of road traffic accidents. The mean ISS score (26) represented very severe injuries, 189 of 602 patients (31%) required immediate invasive ventilation, and 56 of 602 patients (9%) died during admission. Three hundred twenty-five of 602 patients (54%) had an intervention performed before hospital admission or on admission, which included needle decompression, chest tube insertion, or chest surgery. In the remaining 277 of 602 patients (46%), the pneumothoraces were initially treated conservatively. The patients who were managed conservatively had significantly smaller pneumothoraces compared with the patients managed with immediate interventions (median, 5.5 mm vs 22 mm), with the majority of lesions < 10 mm (Fig 2).
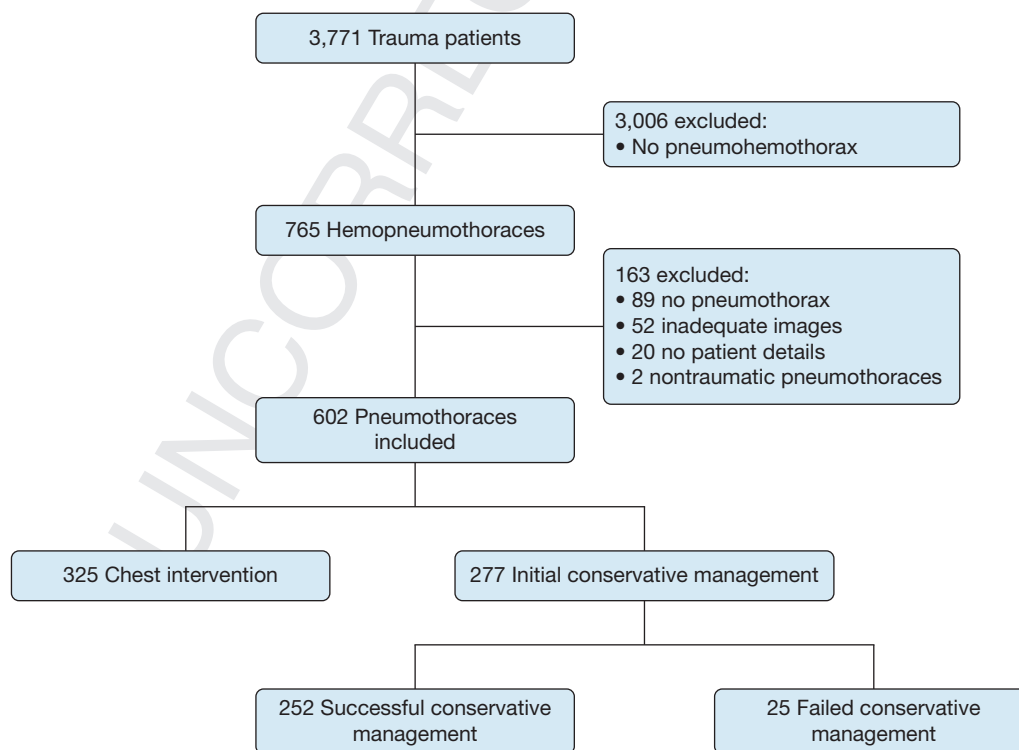

Figure 1 – Cohort diagram. Demonstration of the numbers of patients included in the study, providing reasons for noninclusion where necessary.

print & web 4C/FPO

TABLE 1] Characteristics and Outcomes in Patients Receiving Nonconservative vs Conservative Management

Variable	Initial Nonconservative Management (n = 325)	Conservative Management (n = 277)	P Value
Age, SD, y	48.8 (21.5)	47.1 (21.9)	.36
Male sex, %	252 (77.5)	186 (67.1)	.04
Mechanism of injury, %			.04
Vehicle collision	175 (53.8)	155 (56)	
Fall < 2 m	58 (17.8)	55 (19.9)	
Fall > 2 m	52 (16)	48 (17.3)	
Stabbings	25 (7.7)	5 (1.8)	
Crush injuries	7 (2.2)	8 (2.9)	
Blows	8 (2.5)	6 (2.2)	
Mean ISS, SD	26.9 (14.7)	25.0 (12.3)	.08
Median pneumothorax size, mm, IQR	22 (35.9)	5.5 (8.8)	< .001
Significant (> 2 cm) hemothorax, %	58 (17.8)	17 (6.1)	< .001
Initial positive pressure ventilation, %	127 (39.1)	62 (22.4)	< .001
Subsequent positive pressure ventilation, %	159 (48.9)	139 (50.2)	.12
Presence of respiratory distress, %	199 (61.2)	138 (49.8)	.06
Presence of hemodynamic compromise, %	132 (40.6)	71 (25.6)	< .001
Presence of decreased GCS score, %	135 (41.5)	90 (32.5)	.03
Median hospital length of stay, IQR, d	10 (17)	10 (13.5)	.35
Median ICU length of stay, IQR, d	2 (9.5)	0 (5)	< .001
Mortality, %	11.1%	7.2%	.1

GCS = Glasgow Coma Scale; IQR = interquartile range.

Patients who were managed with immediate interventions also had a higher incidence of respiratory, hemodynamic, and neurologic compromise and a higher proportion of significant hemothoraces than did those managed conservatively. Both groups had comparable ages, ISS data, mortality rates, and total length of stay.

Of the 277 of 602 patients (46%) managed conservatively, 252 of 277 (90%) did not require subsequent thoracic intervention. This included the majority of patients (56 of 62 [90%]) requiring immediate PPV who were treated conservatively. There was no significant difference in the failure rate between the patients receiving PPV (6 of 62 [9.7%]) and those not requiring PPV (19 of 215 [8.8%]) in the conservative arm.

Using univariate analysis, the size of the pneumothorax, mechanism of injury, presence of rib fractures, clinical condition, surgery, and ISS were not significantly associated with failure of conservative management (Table 3). The median size of the pneumothorax (5.3 mm vs 8.2 mm; P = .13) was comparable between groups and did not increase the likelihood of progression requiring chest tube insertion, with HRs of

1.61 (P = .08) and 2.84 (P = .07) on univariate and multivariable analyses, respectively.

Univariate and multivariable analyses also confirmed that acute PPV does not appear to confer an additional risk of failure of conservative management (HR, 1.1; P = .8 and HR, 1.5; P = .96, respectively). Additionally, requiring subsequent PPV during an inpatient stay due to clinical deterioration or for general anesthesia did not represent an increased risk of failure of conservative management. In contrast, the presence of a hemothorax was associated with an increased likelihood of failure of expectant management (HR, 4.08; P < .01), which was confirmed by multivariable Cox regression analysis (Table 4).

Of the 25 of 252 patients in whom observational management failed, 23 had a large chest drain inserted and two went on to have thoracic surgery (rib fixation with hemothorax evacuation). The main indication for chest tube insertion was increasing pneumothorax (19 of 23 cases) and enlarging hemopneumothorax (4 of 23 cases). The mean duration prior to chest tube insertion was 2.96 days (SD, 4.03 days). Requiring subsequent chest tube insertion in the conservative arm led to a

TABLE 2] Characteristics and Outcomes of Conservatively Managed Patients

Variable	Conservative Management (Successful) (n = 252)	Conservative Management (Failed) (n = 25)	P Value
Age, SD, y	46.7 (22.4)	51.2 (16.2)	.33
Male sex, %	169 (67.1)	17 (68)	.92
Mechanism of injury, %			.72
Vehicle collision	142 (56.3)	13 (53)	
Fall < 2 m	49 (19.4)	6 (24)	
Fall > 2 m	42 (16.7)	6 (24)	
Stabbings	5 (2)	0	
Crush injuries	8 (3.2)	0	
Blows	6 (2.4)	0	
Mean ISS, SD	24.9 (12.5)	25.0 (11.0)	.97
Median pneumothorax size, IQR, mm	5.3 (8.6)	8.2 (16.5)	.13
Significant (> 2 cm) hemothorax, %	12 (4.9)	5 (20)	< .01
Initial positive pressure ventilation, %	56 (22.2)	6 (24)	.84
Subsequent positive pressure ventilation, %	123 (49)	16 (64)	.15
Presence of Respiratory distress, %	124 (50.2)	14 (60.9)	.33
Presence of hemodynamic compromise, %	67 (27.2)	4 (18.2)	.36
Presence of decreased GCS, %	80 (32.3)	10 (40)	.43
Median hospital length of stay, IQR, d	10 (13.8)	11 (14.5)	.66
Median ICU length of stay, IQR, d	0 (4)	3 (12.0)	.15
Mortality, %	7.1	8	.88

ISS = Injury Severity Score. See Table 1 legend for expansion of other abbreviations.

nonsignificant increased length of stay (11 vs 10 days; $P = .597$). The two patients with mortalities in this group had an ISS score of 40 (> 25 represents severe or critical injuries) with intracranial hemorrhage, and it is unlikely that the pneumothorax contributed to the overall outcome. The rate of cardiothoracic surgery was higher in the intervention cohort, with 18 of 325 patients requiring surgery.

Table 5 shows the characteristics of patients with a pneumothorax visible on chest radiography (overt pneumothorax) and of patients with a pneumothorax not visible on chest radiography (occult pneumothorax). One hundred seventy-seven patients had chest radiography as their initial chest imaging. One hundred thirty-seven of these patients proceeded to chest CT imaging. Of these 137 patients, 11 had a chest drain in situ at the time of chest radiography. Of the remaining 126 patients, 61 of 126 (48%) had no visible pneumothorax. Occult pneumothoraces were generally smaller than the overt pneumothoraces, with a respective median size of 7.26 mm vs 25.07 mm ($P < .001$).

The majority, 470 of 603 study patients (78%), had evidence of rib fractures, with 361 of 470 patients and 143 of 470 patients having more than three and five rib fractures, respectively. Four hundred twenty-seven of 470 of the fractures were unilateral, and 167 of 470 were reported as flail chest, with 12 of 470 reported as
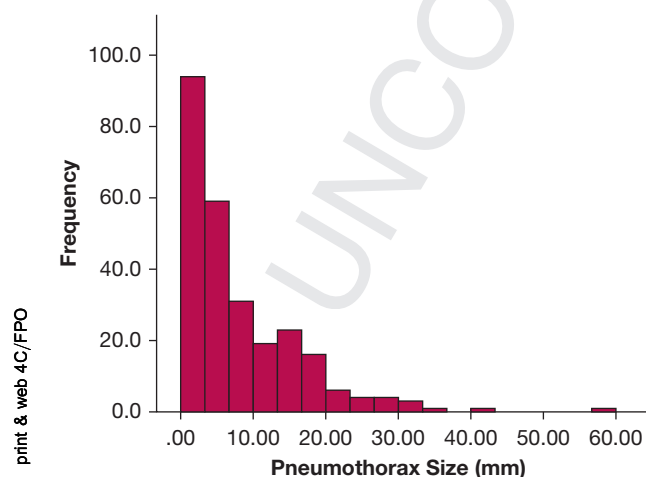

Figure 2 – Pneumothorax size in conservatively managed patients.

print & web 4C/FPO

TABLE 3] Hazard Ratios for Failed Conservative Management

Variable	Hazard Ratio	P Value	95% CI
Male sex	1.05	.92	0.45-2.2
Size of pneumothorax ($\geq$ 2 cm vs < 2 cm)	1.61	.08	0.94-2.76
Bilateral vs unilateral pneumothorax	1.34	.25	0.83-2.12
ISS score (very severe vs severe and moderate severe)	1.17	.69	0.54-2.58
Presence of rib fractures	1.15	.57	0.71-1.88
Hemothorax (> 2 cm)	4.08	< .01	1.53-10.88
Received initial positive pressure ventilation	1.1	.84	0.44-2.76
Received subsequent positive pressure ventilation	2.10	.08	0.91-4.87
Presence of respiratory distress	1.23	.33	0.810-1.87
Presence of hemodynamic compromise	0.78	.37	0.45-1.34
Presence of decreased GCS score	1.17	.45	0.78-1.74

See Table 1 and 2 legends for expansion of abbreviations.

bilateral flail chest. There was no statistically significant association between the presence of rib fractures and significant hemothorax ($\chi^2 = 0.946$; $P = .331$).

There was a 10% complication rate associated with chest tube insertion. Fifteen patients (4.4%) required their drains to be resited, four patients (1.2%) had their drains dislodged, five patients (1.5%) had intraparenchymal drains on CT imaging, two patients (0.6%) experienced empyema, and one patient (0.3%) had a guidewire left in the pleural cavity. Eight patients (2.4%) required a subsequent drain after initial removal due to reaccumulation of air or fluid.

Discussion

Chest drain insertion is not without risk of complications, with documented complication rates ranging from 15% to 30%.[12,14-16] Current guidelines recommend chest tube placement for traumatic pneumothorax, particularly in patients receiving PPV,[7] with a caveat that asymptomatic nonventilated patients can be managed with observation or aspiration at the treating clinician's discretion. Existing literature has examined whether occult pneumothoraces can be managed conservatively.[6,12] Scoring systems to determine whether chest tube intervention is required for occult pneumothoraces are in their infancy and have

TABLE 4] Multivariable Cox Regression Analysis for Failure of Conservative Management

Variable	Hazard Ratio	P Value	95% CI
Hemothorax > 2 cm	5.29	< .01	1.78-15.79

not been prospectively validated.[17] We sought to determine whether traumatic pneumothoraces can be treated conservatively and examined factors that safely identify patients who could avoid chest tube insertion. In this paper, we show that the majority of patients managed conservatively, including patients receiving PPV, did not require further invasive ventilation.

Studies have focused on whether there is a role for conservative management for occult pneumothoraces that are not initially visible on chest radiography.[6,12] The resultant positive findings, including in patients receiving PPV, have been incorporated into clinical guidelines.[18] Although these studies have been useful in establishing management pathways for traumatic pneumothoraces, they do have limitations. It is difficult to translate their findings into clinical practice in which CT is becoming the first-line investigation, with the majority of patients (70%) in our study having had a CT scan as their initial imaging and > 90% undergoing CT imaging during the inpatient stay. Furthermore, the distinction between overt and occult can be misleading.

TABLE 5] Overt and Occult Pneumothoraces Characteristics

Variable	Occult Pneumothoraces (n = 61)	Overt Pneumothoraces (n = 65)
Age, SD, y	52.04 (23.80)	56.30 (20.45)
Male sex, %	48 (78.7)	47 (72.3)
Median size of pneumothorax on CT, IQR, mm	7.26 (12.39)	25.07 (37.46)
Median ISS, IQR	20.00 (9.50)	16.00 (11)

See Table 2 legend for expansion of abbreviations.

Whether a pneumothorax is seen on a chest radiograph is not solely related to its size and can be influenced by other factors, for example, the use of supine chest radiography has decreased sensitivity,[8] with occult pneumothoraces in our study reaching > 80 mm in size.

With this is mind, we proposed to look at the outcomes for traumatic pneumothoraces as a whole. Nearly half of the patients (46%) included were managed conservatively, with the majority of them (252 of 277 [90%]) not requiring subsequent invasive treatment for their pneumothoraces. This included 56 of 62 patients (90%) who received immediate PPV. Multivariable analysis supported the finding that immediate or subsequent PPV did not confer an additional risk of failure of conservative management. This is consistent with the most current study on occult pneumothoraces, with Moore et al[12] demonstrating a failure rate of 14% in patients receiving PPV managed with observation. Although this was higher than their 4.5% failure rate for those not receiving PPV, the latter was not identified as an independent predictor of failed management on multivariate analysis, and no patient experienced tension pneumothorax related to delayed tube insertion. Smaller earlier studies found conflicting results. Brasel et al[11] and Enderson et al[9] demonstrated a 22% and 53% failure rate, respectively, for patients with occult pneumothoraces who were receiving PPV and were managed with observation. Brasel et al's[11] paper concluded that observation was safe in these patients, whereas Enderson et al[9] recommended tube thoracostomy for all patients requiring PPV. This has led to an ongoing debate regarding the management of occult pneumothorax in patients receiving PPV. The East Practice Management Guidelines (2011) on occult pneumothoraces[18] recommend that occult pneumothoraces may be observed in stable patients regardless of PPV. The currently recruiting Management of Occult Pneumothoraces in Mechanically Ventilated Patients (OPTICC) trial (ClinicalTrials.gov: NCT00530725), which is randomizing occult pneumothoraces in patients receiving PPV between chest tube insertion and observation, should contribute to this evidence base.

The size of the pneumothorax was not a predictor of failed observation in our study on univariate and multivariate analyses, with nonsignificant differences in the size of pneumothoraces between the successful and failed observed groups. Pneumothorax size had previously been thought to be a predictor of progression,[19] with De Moya et al[17] proposing a scoring system using the size of the occult pneumothorax and its relationship to the hilum to guide management. However, this has not been successfully validated,[12] with Moore et al[12] demonstrating that pneumothorax size was not an independent predictor of failed observation.

The presence of a hemothorax appears to be predictive of failure of conservative management in both overt and occult pneumothoraces.[12] This is consistent with clinical practice. A significant hemothorax is an indication for chest tube insertion to evacuate blood from the pleural space and avoid complications such as infection and fibrothorax, and when combined with the presence of a pneumothorax, this provides a strong incentive for intervention.

In this study, patients who did not require prehospital or admission chest procedures generally did not require a chest procedure later during hospitalization. When this information is combined with previous trials on traumatic pneumothoraces, it appears that there is a subpopulation that can be managed conservatively. Certainly, when there is no significant hemopneumothorax (< 2 cm), there can be consideration for expectant management. Mechanism of injury, ISS, or size of the pneumothorax does not appear to provide a strong indication for intervention. Additionally, in our study, clinical condition did not confer an adverse prognosis, although in other studies, respiratory distress did.[12] Although the use of ventilation has been controversial, it appears from our findings and previous studies that pneumothoraces can be managed conservatively with careful observation in patients receiving PPV with no increased risk of harm.[6,12]

This is a retrospective observational trial and as such is subject to the inherent limitations of such a study. The data were collected from a single center with a low rate of penetrating chest wall injuries (5%), which should be considered when generalizing the findings to other centers. Selection bias may have been introduced by physician selection and variation in initial imaging modality, and the decision to intervene may have affected the conservatively treated cohort characteristics, and it is likely that high-risk unwell patients were underrepresented in the conservatively treated arm. Those treated with an immediate intervention, despite a similar ISS, likely represented a more unwell population, with higher rates of cardiorespiratory compromise, PPV use, surgical referral rates, and mortality. The length of stay criteria (length of stay = 3 days or more, or admittance to a high-dependency area regardless of

length of stay) is likely to have been biased against patients conservatively managed successfully and not requiring a prolonged hospital admission, suggesting that the overall rate of effective conservative management is probably greater. Efforts were made to minimize bias by including a large number of consecutive unselected patients into the analysis and careful documentation and comparison of cohort characteristics.

Conclusions

Our study represents the largest observational study on traumatic pneumothoraces to date. It demonstrates that the majority of conservatively managed patients were successfully managed without requiring a chest drain. This includes the majority of patients receiving PPV, the use of which did not present an increased risk of failure of expectant management. This study provides support for an observational expectant approach if the treating physician does not believe that an immediate chest drain is warranted in a patient with a traumatic pneumothorax. Future prospective randomized trials examining the outcomes of a conservative approach in traumatic pneumothorax, regardless of pneumothorax size or use of PPV, would help clarify which patients are best managed expectantly.

References

1. Di Bartolomeo S, Sanson G, Nardi G, Scian F, Michelutto V, Lattuada L. A population-based study on pneumothorax in severely traumatized patients. *J Trauma Acute Care Surg.* 2001;51(4):677-682.

2. Idris BM, Hefny AF. Large pneumothorax in blunt chest trauma: is a chest drain always necessary in stable patients? A case report. *Int J Surg Case Rep.* 2016;24:88-90.

3. Kshettry VR, Bolman R, 3rd. Chest trauma. Assessment, diagnosis, and management. *Clin Chest Med.* 1994;15(1):137.

4. Centers for Disease Control and Prevention NCfHSN. National hospital discharge survey: 2007 summary. National health statistics reports, no. 29. National health statistics reports, no. 29. Atlanta, GA: National Center for Health Statistics; 2010.

5. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS), 2007. http://www.cdc.gov/injury/wisqars. Accessed xxx.

6. 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.

7. ATLS Subcommittee; American College of Surgeons' Committee on Trauma; International ATLS working group. Advanced trauma life support (ATLS®): the ninth edition. *J Trauma Acute Care Surg.* 2013;74(5):1363.

8. Ball CG, Kirkpatrick AW, Feliciano DV. The occult pneumothorax: what have we learned? *Can J Surg.* 2009;52(5):E173.

9. 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 Acute Care Surg.* 1993;35(5):726-730.

10. Plurad D, Green D, Demetriades D, Rhee P. The increasing use of chest computed tomography for trauma: is it being overutilized? *J Trauma Acute Care Surg.* 2007;62(3):631-635.

11. Brasel KJ, Stafford RE, Weigelt JA, Tenquist JE, Borgstrom DC. Treatment of occult pneumothoraces from blunt trauma. *J Trauma Acute Care Surg.* 1999;46(6):987-991.

12. Moore FO, Goslar PW, Coimbra R, et al. Blunt traumatic occult pneumothorax: is observation safe?—results of a prospective, AAST multicenter study. *J Trauma Acute Care Surg.* 2011;70(5):1019-1025.

13. Ryan MT, Caputo ND, Lakdawala V, Jara F. Spontaneous resolution of a large traumatic pneumothorax. *Am J Emerg Med.* 2012;30(5):833.e3.

14. Etoch SW, Bar-Natan MF, Miller FB, Richardson JD. Tube thoracostomy: factors related to complications. *Arch Surg.* 1995;130(5):521-526.

15. Bailey R. Complications of tube thoracostomy in trauma. *J Accid Emerg Med.* 2000;17(2):111-114.

16. Ball CG, Lord J, Laupland KB, et al. Chest tube complications: how well are we training our residents? *Can J Surg.* 2007;50(6):450.

17. De Moya MA, Seaver C, Spaniolas K, et al. Occult pneumothorax in trauma patients: development of an objective scoring system. *J Trauma Acute Care Surg.* 2007;63(1):13-17.

18. Mowery NT, Gunter OL, Collier BR, et al. Practice management guidelines for management of hemothorax and occult pneumothorax. *J Trauma Acute Care Surg.* 2011;70(2):510-518.

19. Garramone R, Jr, Jacobs L, Sahdev P. An objective method to measure and manage occult pneumothorax. *Surg Gynecol Obstet.* 1991;173(4):257-261.