Research Article

Prevalence and risk factors of pneumothorax among patients admitted to a Pediatric Intensive Care Unit

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Abstract

Objective: Pneumothorax should be considered a medical emergency and requires a high index of suspicion and prompt recognition and intervention. **Aims:** The objective of the study was to evaluate cases developing pneumothorax following admission to a Pediatric Intensive Care Unit (PICU) over a 5-year period. **Settings and Design:** Case notes of all PICU patients (n = 1298) were reviewed, revealing that 135 cases (10.4%) developed pneumothorax, and these were compared with those patients who did not. The most common tool for diagnosis used was chest X-ray followed by a clinical examination. **Subjects and Methods:** Case notes of 1298 patients admitted in PICU over 1-year study. **Results:** Patients with pneumothorax had higher mortality rate ($P < 0.001$), longer length of stay ($P < 0.001$), higher need for mechanical ventilation (MV) ($P < 0.001$), and were of younger age ($P < 0.001$), lower body weight ($P < 0.001$), higher pediatric index of mortality 2 score on admission ($P < 0.001$), higher pediatric logistic organ dysfunction score ($P < 0.001$), compared to their counterpart. Iatrogenic pneumothorax (IP) represented 95% of episodes of pneumothorax. The most common causes of IP were barotrauma secondary to MV, central vein catheter insertion, and "other" (69.6%, 13.2%, and 17.2%, respectively). Compared to ventilated patients without pneumothorax, ventilated patients who developed pneumothorax had a longer duration of MV care ($P < 0.001$) and higher nonconventional and high-frequency oscillatory ventilation settings ($P < 0.001$). **Conclusions:** This study demonstrated that pneumothorax is common in Alexandria University PICU patients, especially in those on MV and emphasized the importance of the strict application of "protective lung strategies" among ventilated patients to minimize the risk of pneumothorax.

Keywords: Barotrauma, high-frequency oscillatory ventilation, mechanical ventilation, pediatrics, pneumothorax

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Introduction

Pneumothorax is the accumulation of extrapulmonary air within the chest, most commonly from leakage of air from within the lung. Pneumothorax can be spontaneous or iatrogenic, with iatrogenic pneumothorax (IP) being more common worldwide.[1] In the USA, the incidence of spontaneous pneumothorax is approximately 7.4–18

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cases per 100,000.[2] Pneumothorax in critically ill patients remains a common problem in the Intensive Care Unit (ICU, occurring in 4–15% of patients).[3,4]

Pneumothorax should be considered a medical emergency and requires a high index of suspicion and prompt recognition and intervention. The diagnosis of pneumothorax can be made by physical examination or imaging studies including chest X-ray, ultrasonography, and computed tomography (CT) scan.[5]

Pneumothorax is associated with prolonged length of stay (LOS), increased morbidity and mortality.[6] Most cases of pneumothorax are iatrogenic in origin caused by barotrauma secondary to mechanical ventilation (MV).[7] IP is related to underlying lung disease along with high ventilatory settings.[8]

This study aimed at evaluating the incidence of this complication in critically ill patients admitted to Alexandria University Pediatric ICU (PICU) over a 5-year period, to determine its risk factors and diagnostic strategies, and to study its impact on the prognosis of these patients with an aim to prevent pneumothorax and improve its management.

Subjects and Methods

This retrospective study was conducted in Alexandria University PICU. All case notes of patients admitted between January 1, 2009, and December 31, 2013, were reviewed, and the following data were extracted: personal characteristics, age of the patient, diagnosis, outcome, pediatric index of mortality 2 (PIM2) score[9] on admission and pediatric logistic organ dysfunction (PELOD) score[10] on day 1, LOS in days, and MV parameters were studied.

Case notes of patients with pneumothorax were thoroughly examined to collect further data concerning the pneumothorax episode, namely, the possible cause, severity, first diagnostic tool used, and the MV parameters including mode, settings, and duration.

To compare the outcomes, the study patients were categorized into two groups: Group 1, those who developed pneumothorax, and Group 2, who did not. Pneumothorax as a result of rupture of the lung parenchyma and visceral pleura with no demonstrable cause was considered as spontaneous pneumothorax, whereas those cases who developed pneumothorax after a medical procedure were considered to have IP.

Diagnosis depended on clinical suspicion. Clinically, cases presented with chest pain, respiratory distress, tachypnea, decrease or absent breath sounds, and absent chest movement on the affected side. Diagnosis was then approved by plain X-ray chest posteroanterior view (erect position) and CT chest.

Data were analyzed using the Statistical Package for Social Sciences (SPSS version 20 (IBM), Chicago, IL, USA). The distributions of quantitative variables were tested for normality using the Kolmogorov–Smirnov test. Parametric tests were applied for normally distributed data and nonparametric tests for nonnormally distributed data. Logistic regression analysis was performed to detect the individual contribution of various significant predictors on the occurrence of pneumothorax. A logistic regression model was built with adjusted odds ratio. Survival analysis was carried out for the studied groups using length of survival till the end of the study and the outcome. The Kaplan–Meier survival curve was used to demonstrate whether there was a significant difference in the cumulative freedom from death between the two groups. In all statistical tests, $P \leq 0.05$ was adopted as the level of statistically significant.

This study was approved by the Alexandria University Ethics Committee of the Faculty of Medicine, and informed consent was obtained from patients' parents and legal guardians for publishing the data.

Results

This retrospective study included 1298 patients admitted to Alexandria University PICU over 5 years. It was found that 10.4% (n = 135) of patients developed 151 episodes of pneumothorax (Group 1) and the remaining patients 89.6% (n = 1163) did not (Group 2). Spontaneous pneumothorax represented only 5% of pneumothoraces and only 0.6% of total ICU patients, whereas IP represented 95% of episodes of pneumothorax.

Table 1 indicates that the pneumothorax group was of younger age and had lower body weight, higher PIM2 score, higher PELOD score on day 1, longer LOS, higher need for MV, higher likelihood of having an underlying respiratory disease, sepsis and septic shock, and higher mortality rate ($P < 0.001$, $P < 0.001$, $P < 0.001$, $P < 0.001$, $P < 0.001$, $P < 0.001$, $P = 0.001$, $P = 0.007$, and $P < 0.001$, respectively).

Table 2 showed that cases with respiratory diseases on admission showed significantly younger age, lower

Table 1: Comparison of personal and clinical characteristics on admission of cases with (Group 1) and without pneumothorax (Group 2)

Characteristics	Group 1 (*n*=135)	Group 2 (*n*=1163)	*P*
Age (mean month)	12.29±22.59	25.75±37.02	<0.001*
Weight (kg)	6.88±5.29	10.14±7.87	<0.001*
Sex, *n* (%)			
Female	71 (52.6)	525 (45.1)	0.100
Male	64 (47.4)	638 (54.9)	
PIM2 score[a]	39.82±29.61	27.88±25.64	<0.001*
PELOD score day 1[b]	11.89±9.78	9.22±8.93	<0.001*
Diagnostic category, *n* (%)			
Respiratory	53 (39.3)	278 (23.9)	0.001*
Sepsis and septic shock	47 (34.8)	280 (24.1)	0.007*
Others[†]	35 (25.9)	605 (52)	0.005*
LOS (days)	13.48±12.39	6.44±8.95	<0.001*
Mechanical ventilation, *n* (%)	125 (92.6)	614 (52.8)	<0.001*
Fate, *n* (%)			
Discharged	55 (40.75)	1043 (89.7)	<0.001*
Deceased	80 (59.25)	120 (10.3)	

[a]PIM: Pediatric index of mortality; [b]PELOD: Pediatric logistic organ dysfunction; *Statistically significant at $P \leq 0.05$; [†]Other diagnostic categories included neurological, cardiac, hematological, digestive, renal, endocrine, and immune emergencies.
LOS: Length of stay

Table 2: Personal and clinical characteristics of cases with and without respiratory diseases on admission

	Respiratory diseases (*n*=331)	Nonrespiratory diseases (*n*=967)	*P*
Age (month)	13.06±17.99	28.21±39.66	<0.001*
Sex (%)			0.126
Male	191 (57.7)	511 (52.8)	
Female	140 (42.3)	456 (47.2)	
Weight (kg)	7.92±4.53	10.45±8.43	0.005*
Length of stay (days)	6.90±8.01	7.27±10.10	0.151
PIM2 score[a]	25.10±23.12	30.50±27.21	0.004*
PELOD score[b]	6.38±6.06	10.57±9.65	<0.001*
Mechanical ventilation (%)			
Yes	234 (70.7)	505 (52.2)	<0.001*
No	97 (29.3)	462 (47.8)	
Day of mechanical ventilation	6.54±8.12	7.87±9.56	0.061
Pneumothorax (%)			
Yes	53 (16)	82 (8.5)	<0.001*
No	278 (84)	885 (91.5)	
Fate (%)			
Discharged	270 (81.6)	828 (85.6)	0.336
Deceased	61 (18.4)	139 (14.4)	

[a]PIM: Pediatric index of mortality; [b]PELOD: Pediatric logistic organ dysfunction; *Statistically significant at $P \leq 0.05$

body weight, lower PIM2 score, lower PELOD score on day 1, higher need for MV, and higher incidence of pneumothorax episodes ($P < 0.001$, $P < 0.005$, $P < 0.004$, $P < 0.001$, $P < 0.001$, and $P < 0.001$, respectively).

The clinical examination as the first diagnostic tool was helpful in the diagnosis of 27.2% of episodes of pneumothorax, and plain X-ray diagnosed 70.2% of cases. CT was used to detect pneumothorax in the remaining 2.6% of episodes. Ultrasonography was used to follow-up proper thoracocentesis and tube placement, rather than diagnosis.

In the current study, 95% of pneumothorax episodes were iatrogenic: of these, barotrauma secondary to MV accounted for 69.6%, 41.1% of which were tension pneumothoraces, central venous catheter (CVC) insertion accounted for 13.2%, and other causes including transthoracic needle aspiration, transbronchial, or pleural biopsy accounted for 17.2%.

Table 3 shows a statistically significant difference between the two groups in terms of their MV data. The results indicate the longer duration of ventilation, higher conventional ventilation settings, and higher mean airway pressure in high-frequency oscillatory ventilation (HFOV) in the pneumothorax group ($P < 0.001$, $P < 0.001$, and $P < 0.001$ respectively).

Table 4 illustrates the predictors of pneumothorax using multiple logistic regression analysis. The following variables in order of importance were found to be significant risk factors for the occurrence of pneumothorax: Peak inspiratory pressure (PIP), partial pressure of carbon dioxide ($PaCO_2$), fraction of inspired oxygen (FiO_2), and serum bicarbonate level (HCO_3) on admission.

Figure 1 shows the Kaplan–Meier survival curve of cases with and without pneumothorax in relation to the cumulative hazard of mortality with LOS. A higher survival probability was found for the group that did not develop pneumothorax, compared with the pneumothorax group ($P < 0.001$).

In the present study, the prevalence of pneumothorax in Alexandria PICU during the 5-year study was 10.4%. This was found to be within the range of pneumothorax reported in several studies (4–15%).[3,4]

Discussion

In the present study, the mean LOS was 7 days longer in cases with pneumothorax compared with those without pneumothorax. Zhan *et al*. found that patients with pneumothorax usually have extra 4.4 days added to the LOS, an extra cost of $18000 US, and have a 6% higher risk of hospital death.[11] Hsu *et al*. demonstrated that in patients on MV, pneumothorax was associated with a significant increase in the ICU LOS and mortality rate.[8] The mortality rate was 59% in Group 1 compared to 10% in Group 2. The Kaplan–Meier survival curve revealed that most of the fatalities occurred within an LOS of 30 days in patients with pneumothorax compared with 50

Table 3: Comparison of cases with and without pneumothorax as regard mechanical ventilation

	Group 1 (*n*=135)	Group 2 (*n*=1163)	*P*
	n=125	*n*=614	
Days of mechanical ventilation (mean±SD)	12.24±11.73	4.46±8.19	<0.001*
Starting mode of ventilation (%)			
SIM/PS[a]	66 (52.8)	403 (65.7)	<0.001*
SIM/VC[b]	6 (4.8)	10 (1.6)	
PC[c]	32 (25.6)	83 (13.5)	
VC[d]	3 (2.4)	6 (1.0)	
HFOV[e]	18 (14.4)	39 (6.3)	
CPAP/PS[f]	0 (0)	73 (11.9)	
	n=107	*n*=575	
Mean ventilator settings of conventional ventilation			
PEEP (cm H_2O)[g]	6.92±3.93	5.31±1.79	<0.001*
PIP (cm H_2O)[h]	28.29±6.32	19.56±5.22	<0.001*
Rate (cycle/min)	39.85±10.89	33.35±7.35	<0.001*
FiO_2 (%)[i]	67.95±18.83	52.03±12.82	<0.001*
	n=18	*n*=39	
Mean ventilator settings for HFOV (mean±SD)			
Mean airway pressure (cm H_2O)	30.11±5.80	25.33±7.71	0.020*
Delta P (amplitude)	59.32±7.61	53.15±9.14	0.017*
Frequency (Hz)	6.59±1.50	5.95±0.94	0.145
FiO_2 (%)	72.45±19.41	53.70±14.82	<0.001*

[a]SIMV/PS: Synchronized intermittent mandatory ventilation/pressure support; [b]SIMV/VC: Synchronized intermittent mandatory ventilation/volume control; [c]PC: Pressure control; [d]VC: Volume control; [e]HFOV: High frequency oscillatory ventilation; [f]CPAP/PS: Continuous positive airway pressure/pressure support; [g]PEEP: Positive end-expiratory pressure; [h]PIP: Peak inspiratory pressure; [i]FiO_2: Fraction of inspired oxygen; SD: Standard deviation; *Statistically significant at $P \leq 0.05$

Table 4: Multiple logistic regression model for risk factors that predict pneumothorax

	B	SE	Significant	OR	95% CI	
					Lower limit	Upper limit
PIP[a]	0.360	0.056	<0.001*	1.434	1.284	1.602
FiO_2[b]	0.044	0.021	0.035*	1.045	1.003	1.088
$PaCO_2$[c]	−0.081	0.033	0.014*	0.922	0.864	0.984
HCO_3[d]	0.129	0.065	0.047*	1.137	1.002	1.291

[a]PIP: Peak inspiratory pressure; [b]FiO_2: Fraction of inspired oxygen; [c]$PaCO_2$: Partial arterial carbon dioxide tension; [d]HCO_3: Bicarbonate content; Predictors: Only significant factors included. SE: Standard error; OR: Odds ratio; CI: Confidence interval

days in patients without pneumothorax and that the difference was statistically significant. This impact of pneumothorax on critically ill patients is in agreement with findings from other studies: [6,12] A French study involving 11 ICUs revealed that those who develop pneumothorax during the first 30 days of admission are more than twice as likely to die as those who do not.[5]

In the present study, high index of suspicion as the first screening tool was helpful in the diagnosis of 27.2%

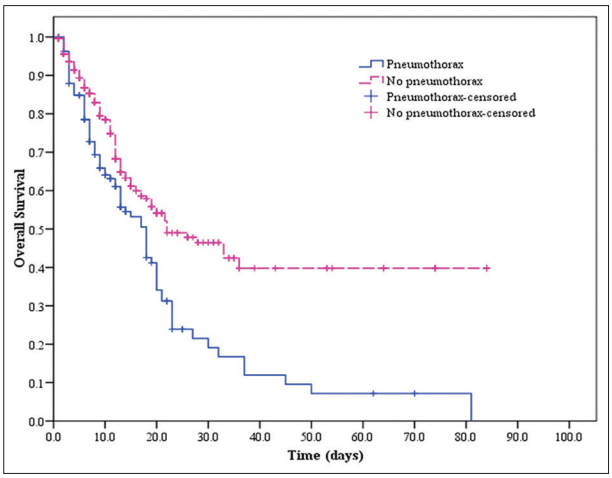

Figure 1: Kaplan–Meier survival curve Log-rank test comparing survival in cases with and without pneumothorax

of episodes. Plain chest X-ray diagnosed 70.2% of cases and ultrasonography was used for follow-up. CT was used to detect 2.6% of episodes of pneumothorax. This corroborates with Wilkerson and Stone,[12] Rowan *et al*.[13] who reported that the plain radiograph is the primary radiological tool for screening for pneumothorax with a sensitivity of 80% in erect posture and 36–48% in the supine anteroposterior position. Ultrasonography has become more readily available at the bedside, and a recent literature review has reported a sensitivity of 86–98% and a specificity of 97–100% for diagnosing pneumothorax.[14] CT chest scanning is the gold standard test for both diagnosing and determines the size of pneumothorax,[15] but the problem of mobilizing hemodynamically unstable PICU patients for a CT scan precludes the use of CT for diagnosing pneumothorax in critically ill patients.

The present study revealed that pneumothorax occurred in younger patients (mean 12 months of age vs. 26 months of age in the nonpneumothorax group). Furthermore, pneumothorax occurred in patients with lower body weight (6 kg vs. 10 kg), and those with worse general condition on admission as shown by the higher PIM2 score compared with patients without pneumothorax (39.82% vs. 27.88%). The risk factor for acquiring pneumothorax was high in some diagnostic categories of patients such as those with respiratory diseases (39.4% vs. 23.9%) and sepsis and septic shock (34.8% vs. 24.1%). Many investigators have emphasized that pneumonia is an important predisposing factor in the development of pulmonary barotrauma in mechanically ventilated patients.[16] Patients with other lung diseases such as severe acute respiratory syndrome have a high incidence of pneumothorax (20–34%) in mechanically ventilated patients.[17]

MV and CVC insertion accounted for more than 82% of episodes of pneumothorax, which is why tension pneumothorax represented 41.1% of pneumothorax episodes. CVC insertion alone accounted for 13.2% in our PICU, which is relatively high and this might be attributed to the blind technique not aided with US guidance. Many investigators agreed that IP can also be induced by thoracic procedures or any procedures involving the neck.[5,14,18,19] Many researchers highlighted that pneumonia is an important predisposing factor in the development of barotrauma in ventilated patients.[16] A recent study revealed that duration of ventilation is thought to be a risk factor for developing barotraumas.[20]

The present study showed that conventional MV CMV, synchronized intermittent mandatory ventilation/ pressure support represented the major starting modes of ventilation and that pressure control comes next. A number of studies have concluded that the incidence of barotrauma does not relate to ventilator mode.[21-23]

A multiple logistic regression model revealed that the risk factors that predicted pneumothorax were PIP, FiO_2, $PaCO_2$, and HCO_3. In the present study, PIP was significantly higher in cases with pneumothorax. Their mean PIP was <30 cm H_2O which is within the accepted range for the new protective lung strategies, which proves that PIP level should individualized depending on the underlying lung condition. In adults, PIP ≥50 cm H_2O is associated with increased risk of alveolar rupture during MV.[24] A correlation between high PIP and pneumothorax has been observed.[25,26] On the other hand, other studies have shown that the incidence of barotrauma is more related to the underlying lung disease than to the ventilatory settings.[6,21-23]

In the present study, as a protective lung strategy, HFOV was applied to all cases of acute respiratory distress syndrome (ARDS) and 31.5% of them developed pneumothorax. Mean airway pressure was significantly higher in cases with pneumothorax. The dependent lung regions tend to be collapsed consequently the nondependant lung regions may become subject to high-pressure over-inflation and alveolar rupture.[27,28] However, HFOV is a protective lung strategy with the slight possibility of causing pneumothorax. A number of investigators have shown that subpleural and intrapulmonary air cysts occur in ARDS patients, and the rupture of these air cysts may lead to pneumothorax.[29] Whether the pneumothorax in ARDS arises from over-inflation of normal lung regions or from cyst rupture has not yet been conclusively established.

Conclusion

Pneumothorax in critically ill patients remains a common problem. In this study, we concluded that: Firstly, pneumothorax is considered as a major complication associated with increased LOS, increased morbidity and mortality among PICU patients. Second, most cases of pneumothorax were iatrogenic caused by barotrauma and CVC insertion coming next. Pneumothorax in mechanically ventilated patients is related to underlying lung disease along with high ventilatory settings. Lastly, pneumothorax could be prevented by strict application of protective lung strategies for all mechanically ventilated patients and it is highly recommended to monitor those patients closely for early detection of signs of pneumothorax.

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Conflicts of interest

There are no conflicts of interest.

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