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Effect of Ultrasound-Guided Thoracocentesis on Clinical and Physiological Outcomes in Mechanically Ventilated Patients

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Abstract

Background: Pleural effusions are common in critically ill patients, causes are multifactorial. Mechanical ventilation and critical illness lead to disturbance of the normal physiological processes which regulate pleural fluid homeostasis. Ultrasound can detect small volume of pleural effusion up to 20 mL.

Aim of the work: We investigated the influence of large pleural effusion drainage on oxygenation, hemodynamics, and respiratory mechanics in mechanically ventilated patients.

Methodology: We performed a prospective observational study on 65 mechanically ventilated patients examining the effects of large pleural fluid drainage on oxygenation; PaO_2/FiO_2 and Respiratory mechanics; peak inspiratory pressures, plateau pressures, dynamic compliance and total PEEP. Hemodynamics and complications also recorded at baseline, 6 h and 24 h after drainage.

Results: Among 65 patients, the mean volume of effusion drained was (1868 ± 640) ml at 24 h. Uncomplicated pneumothorax occurred in two patients. When compared baseline; 6 h and 24 h after drainage,PaO_2/FiO_2 ratio significantly improved (196.69 ± 34.27, 227.02 ± 35.81, 269.78 ± 48.39; p<0.001), with a decrease in peak inspiratory pressure (38.23 ± 5.71, 34.14 ± 4.70, 29.89 ± 4.58 cm H_2O, p<0.001) and plateau pressures (21.06 ± 3.47, 18.77 ± 3.17, 15.49 ± 2.91 cm H_2O, p<0.001) and a large increase in dynamic compliance (17.48 ± 4.12, 21.79 ± 4.47, 26.77 ± 4.94 ml/cm H_2O, p<0.001). Hemodynamics were not changed by drainage apart from respiratory rate which decreased significantly (19.4 ± 5.5, 17.4 ± 5, 16.5 ± 6.8 breaths/min, P=0.019).

Conclusions: Ultrasound pleural effusion drainage in mechanically ventilated patients is safe. It appears to ameliorate oxygenation and respiratory mechanics and reducing the respiratory rate without affecting hemodynamics.

Keywords: Pleural effusion; Thoracocentesis; Oxygenations; Respiratory mechanics

Introduction

Pleural effusion is common in the critically ill, occurring in over 60% of patients in some series [1,2]. Causes are multifactorial as pneumonia, heart failure, excessive intravenous fluid administration, hypoalbuminemia, atelectasis and positive ventilation [1].

Mechanical ventilation and critical illness lead to disturbance of the normal physiological processes which regulate pleural fluid homeostasis, and failure of normal pleural function occurs. Effusions can lead to harmful effects on gas exchange and respiratory mechanics, large pleural effusion may lead to hemodynamic compromise. The bedside ultrasound has a beneficial role in earlier detection of pleural effusions and safer fluid drainage. To confirm the diagnosis in patients with suspected pleural effusion especially in the case of a white hemithorax on chest X-rays, ultrasound is a useful method because it allows differentiating between lung consolidations and effusion [3].

Ultrasound has a higher accuracy in detecting pleural effusion in comparison with bedside chest X-rays it has (93% *vs.* 47%) [4] chest X-rays can detect pleural effusion in patients in the orthostatic position if the volume of the effusion is more than 200 mL [5], and in the supine position the sensitivity of X-rays decreases, whereas ultrasound can detect effusions as small as 20 mL [6]. Ultrasound allows the identification of surrounding structures: chest wall, visceral pleural surface, and hemidiaphagm. This is important during thoracocentesis in order to avoid an organ injury. We thus investigated the influence of large pleural effusion drainage on oxygenation, hemodynamics, and respiratory mechanics in mechanically ventilated patients.

Methodology

This was an observational study which conducted in the surgical ICU of Ain Shams University hospital 42 beds from February 2016 to February 2017, after obtaining approval of the Ain Shams University Hospital ethics committee.

Inclusions criteria

(1) Mechanically ventilated patients

(2) Presence of a large pleural effusion on supine chest X-Ray confirmed by ultrasound as an end-expiratory pleural distance of at least 25 mm (predicting pleural fluid volume of at least 500 ml) [7].

ARDS patients were excluded from the study.

Oral and written information was given to patient's next of kin. The following clinical data were collected: sex, age, and Acute Physiology and Chonic Health Evaluation (APACHE) II score, pleural side drained and mean volume of pleural fluid drained in first 24 h.

A pigtail was placed under ultrasound guidance by intensivist. The following parameters were recorded before ultrasound-guided drainage of pleural fluid (baseline) and repeated at 6 h and 24 h after effusion drainage. Primary outcome was hypoxic index PaO_2/FiO_2 and secondary outcomes were hemodynamic: mean arterial blood pressure, heart rate, and respiratory rate, respiratory mechanics: peak inspiratory pressure, plateau pressure, total PEEP, dynamic compliance, and complications of pleural drainage (pneumothorax, hemothorax, and hemoptysis) were also recorded.

Dynamic compliance of the respiratory system was calculated as follows: VT ÷ (peak inspiratory pressure-total PEEP). Total PEEP included intrinsic PEEP if any was present. A standardized weaning protocol from mechanical ventilation was not imposed. However, the qualitative respiratory support step down was recorded: volume or pressure-controlled mandatory breaths>pressure supported spontaneous breaths>continuous positive airway pressure>spontaneous ventilation without positive pressure

Sample size

Using PASS program, setting alpha error at 5% and power 90%. Results from previous research Razazi et al. [8], showed that PaO_2/FiO_2 before drainage and 24 h after drainage was 191 ± 69 versus 250 ± 106 respectively. Based on this the needed sample is 40 cases.

Statistical analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 20. The quantitative data were presented as mean, standard deviations and ranges when their distribution found parametric. Repeated measures ANOVA was used to compare between reading at 0 h, 6 h and 24 h. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant at the level of<0.05.

Results

During the 12-months study period out of 191 patients assessed for eligibility, 123 were excluded: 100 not meeting inclusion criteria and 23 meeting exclusion criteria. 3 lost to follow-up. Finally, 65 patients were allocated for statistical analysis (Figure 1).

The clinical characteristics of the patients studied are shown in table 1 (mean age=55.5 ± 3.85 years, including 39 men), mean volume of pleural drainage in first 24 h was 1868 ± 640 ml, pleural side drained was the right side in 51%, left side in 31% and bilateral in 18% of the patients. An illustrative example of lung ultrasound for pleural effusion was shown in (Figure 2).

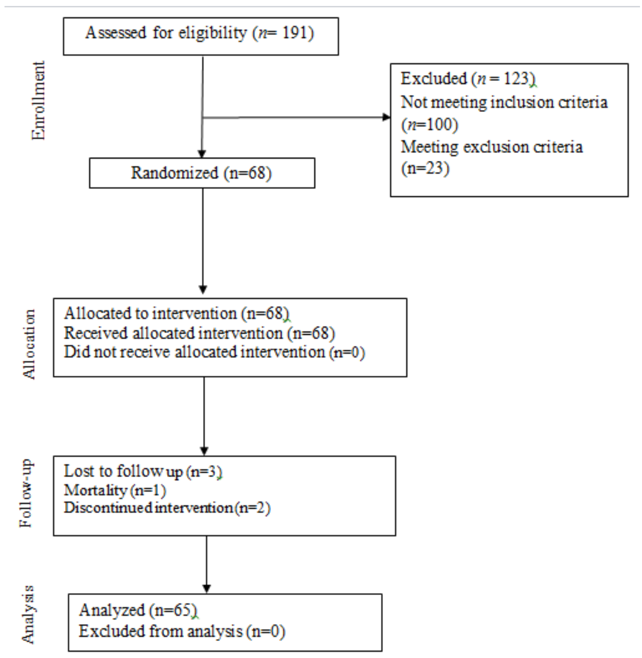

Figure 1: Consort E flow chart.

Variable	Result
Age (years)	55.5 ± 3.85
Males (%)	39 (60%)
APACHE II score	18.7 ± 2.0
Pleural Side drained (%)	
Right	33 (50.76%)
Left	20 (30.8%)
Bilateral	12 (18.46%)
Mean volume of pleural fluid drained in first 24 h (ml)	

Table 1: Patients characteristics. Data are mean ± SD or number (%).

The arterial oxygen tension (PaO_2)/fractional inspired oxygen (FiO_2) ratio (P/F ratio) is simple and one of the most commonly used measures for assessment of oxygenation, it significantly improved after effusion drainage (mean ± SD, baseline 196.69 ± 34.27 , 6 h after drainage 227.02 ± 35.81 and 24 h after drainage 269.78 ± 48.39; p=0.000) Table 2.

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Figure 2: Ultrasound image for pleural effusion. 1=Liver, 2=Diaphagm, 3=Pleural effusion, 4=Lung.

When compared baseline; 6 h and 24 h after drainage, the peak inspiratory pressure (38.23 ± 5.71, 34.14 ± 4.70, 29.89 ± 4.58 cm H_2O, P<0.001) and Plateau pressure (21.06 ± 3.47, 18.77 ± 3.17, 15.49 ± 2.91 cm H_2O, P<0.001) showed statistically significant reduction, dynamic compliance statistically significant improvement (17.48 ± 4.12, 21.79 ± 4.47, 26.77 ± 4.94 ml/cm H_2O, P<0.001) and total PEEP significantly decreased (6.86 ± 1.49, 6.40 ± 1.07, 5.60 ± 0.92 cm H_2O, P<0.001) (Table 2).

Mean arterial blood pressure and heart rate did not change significantly (Table 3). There was a reduction in respiratory rate after thoracocentesis (19.4 ± 5.5, 17.4 ± 5, 16.5 ± 6.8 breaths/min, P=0.019). An improvement of mode of ventilation by the end of 24 h was recorded in 41 patients (63%).

Two cases developed pneumothorax that necessitated intercostal tube insertion and were not included in the final analysis.

Parameter		At 0 h	At 6 h	At 24 h	Repeated measures ANOVA	
		n=65	n=65	n=65	F	P-value
PaO_2/FiO_2	Mean ± SD	196.69 ± 34.27	227.02 ± 35.81	269.78 ± 48.39	486.806	<0.001
	Range	140-280	170-300	200-380		
PIP(cm H_2O)	Mean ± SD	38.23 ± 5.71	34.14 ± 4.70	29.89 ± 4.58	390.191	<0.001
	Range	28-50	25-44	20-40		
Plateau pressure (cm H_2O)	Mean ± SD	21.06 ± 3.47	18.77 ± 3.17	15.49 ± 2.91	365.940	<0.001
	Range	12-25	11-23	10 – 20		
Dynamic compliance (ml/cm H_2O)	Mean ± SD	17.48 ± 4.12	21.79 ± 4.47	26.77 ± 4.94	455.742	<0.001
	Range	10-25	12-30	16-37		
PEEP (cm H_2O)	Mean ± SD	6.86 ± 1.49	6.40 ± 1.07	5.60 ± 0.92	75.267	<0.001
	Range	5-10	5-8	4-8		
Data are mean ± SD. 0 h=0 h denotes before effusion drainage, 6 h=6 h after effusion drainage, 24 h=6 h after effusion drainage.						

Table 2: Oxygenation and respiratory mechanics at 0 h, 6 h and 24 h after pleural drainage.

Hemodynamics		At 0 h	At 6 h	At 24 h	Repeated measures ANOVA	
		n=65	n=65	n=65	F	P-value
Mean blood pressure (mmHg)	Mean ± SD	86.2 ± 19	85.5 ± 17	86 ± 18	1.197	0.512
	Range	65-130	62-130	63-131		
Heart rate (beat/ min)	Mean ± SD	104 ± 19	102 ± 17	102 ± 19	2.415	0.237
	Range	80-130	78-130	80-130		
Respiratory rate (breaths/ min)	Mean ± SD	19.4 ± 5.5	17.4 ± 5	16.5 ± 6.8	5.920	0.019
	Range	12-36	12-34	12-30		
Data are mean ± SD. 0 h=0 h denotes before effusion drainage, 6 h=6 h after effusion drainage, 24 h=6 h after effusion drainage.						

Table 3: Hemodynamics at 0 h, 6 h and 24 h after pleural drainage.

Discussion

This study demonstrated that ultrasound-guided thoracocentesis in mechanically ventilated patients is associated with improvement of oxygenation with low risk of peri-procedural complications, as regard ventilator mechanics thoracocentesis associated with statistically significant decrease in peak airway pressure, plateau pressure and total PEEP with improvement of dynamic compliance.

There were no data on the effect of pleural effusion drainage on duration of mechanical ventilation; we recorded only the qualitative step down in respiratory support. When the pleural effusion is large or chest wall compliance is reduced, effusions cause hypoxia by collapsing lung with consequent physiologic shunt [9]. Drainage of pleural effusions allowing re-expansion of collapsed lung and improvement of hypoxia, which yield variably over the subsequent 24 h and may continue for several weeks [10].

In agreement with current study Talmor and colleagues [11] concluded that pleural fluid drainage improved oxygenation in acute respiratory failure patients who were refractory to treatment with mechanical ventilation and PEEP. Intercostal tubes (ICT) improved oxygenation and compliance immediately after insertion in 17 of 19 patients and PaO_2/FiO_2 remained statistically higher (245 ± 29 versus 151 ± 13, P 0.01).

Brims and colleagues [12] examined the effect of pleural fluid drainage on the lung function indices of patients after cardiac surgery and require mechanical ventilation for more than 7 days. The arterial oxygen tension (PaO_2)/fractional inspired oxygen (FiO_2) (P/F) ratio improved on day 1 after ICT placement (mean (SD), day 0:31.01 (8.92) *vs.* 37.18 (10.7) kPa; p<0.05) and both the P/F ratio and oxygenation index (OI: $kPa/cmH_2O = PaO_2/\text{mean airway pressure} \times FiO_2$) demonstrated sustained improvement to day 5 (P/F day 5:39.85 (12.8); OI day 0:2.88 (1.10) *vs.* day 5:4.06 (1.73); both p<0.01).

A further study [8] in a medical ICU demonstrated an early improvement in P/F ratio at 3 h post pleural drainage, and sustained at 24 h post intervention. A recent meta-analysis of a total 118 patients demonstrated an overall 18% improvement in the PaO_2/FiO_2 ratio after effusion drainage [13]. Improvement in oxygenation may occur after drainage as areas of collapsed, poorly ventilated lung reexpand, improving ventilation–perfusion matching in these areas and reducing arteriovenous shunting [9].

Roch and colleagues [14] found a correlation between the effusion volume drained and improvement in the PaO_2/FiO_2 ratio (r=0.5, P=0.01) in the patients with pleural effusions ≥ 500 mL.

On the contrary, Talmor and colleagues [10] found no correlation between the drained volume and oxygenation response.

In our study, there was no correlation between the physiological indices and the volume of pleural fluid drained, which is consistent with other reports [15,16].

Some studies have reported improvement in pulmonary mechanics; peak inspiratory pressure, plateau pressure and dynamic compliance within an hour of pleural fluid drainage [13].

Talmor and colleagues recorded an immediately increase in dynamic compliance after the drainage by 30% and Doelken et al. [15] recorded an increasing trend in dynamic compliance, they also found a statistically significant reduction in the work of inflation per cycle after pleural fluid drainage. Ahmed and colleagues [16] reported a reduction in the respiratory rate after thoracocentesis without significant change in lung mechanics.

Conclusions

Ultrasound pleural effusion drainage in mechanically ventilated patients is safe. It appears to improve oxygenation and respiratory mechanics and reducing the respiratory rate without affecting hemodynamics. Further studies needed to evaluate the effect of pleural effusion drainage on duration of mechanical ventilation and ICU days.

Limitations

We didn't measure the effect of pleural drainage on weaning from mechanical ventilation; we measured only qualitative step-down of respiratory support by the end of 24 h after pleural effusion drainage. In this study only large pleural effusions were drained; in patients with small or moderate effusions the results may have been different.

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