Gharraf and AbdAllah *The Egyptian Journal of Bronchology* (2020) 14:27
https://doi.org/10.1186/s43168-020-00028-9

The Egyptian Journal of Bronchology

RESEARCH

Open Access

Drainage of transudative pleural effusion: how does it affect weaning from mechanical ventilation?

Heba Said Gharraf* and Alaa El Din AbdAllah

Abstract

Background: Pleural collections of the transudative type occur frequently in patients who need mechanical ventilation (MV). Treatment of the etiology of the effusion takes a prolonged duration of time. The study intended to assess the effect of transudative effusion drainage through chest tube on the process of weaning from MV.

Results: No statistically significant difference was found between the two studied groups regarding age, sex, and comorbidities. Total duration of MV was significantly shorter in patients of group I compared with patients of group II ($P = 0.002$). Successful weaning from MV within 2 days after the start of the study was statistically significantly more achieved in patients of group I (56.7%) compared with patients of group II (23.3%) ($P = 0.017$). One and 3 days after beginning of the study, patients in group I showed a significant improvement in oxygenation as demonstrated by a statistically significantly higher value of PaO_2/FiO_2 ratio compared with patients of group II ($P = 0.003$ and 0.008, respectively).

Conclusion: More work is needed to determine the physiological benefits of transudate pleural effusion drainage and the effect of the specific procedure on the clinical parameters. Further studies are needed to study different modalities or tools of drainage of transudate effusion and the effect of each on the different clinical outcomes in comparison with each other to reach the optimum way of drainage of transudate effusion with the best results and least complications.

Keywords: Transudate, Drainage, Weaning, Mechanical ventilation

Background

Context and purpose

Rarely, the pleura can be implicated as a causative agent of respiratory system failure. However, it is frequently affected in patients on mechanical ventilation (MV) [1].

Most transudative pleural effusions are caused by cardiac, renal, and hepatic failure and fluid therapy overload [2]. These effusions clear with the use of diuretics and proper medical treatment of the underlying disease, but this would take a considerable duration of time [3].

Therefore, we aimed to study the effects of chest tube drainage of these transudative pleural effusions on liberation from MV.

* Correspondence: hebagharraf@gmail.com
Chest Disease Department, Faculty of Medicine, Alexandria University, 42 Abdel Aziz Fahmy Street, Stanly, Egypt

Methods

Settings and design

This observational study with simple randomization was performed in respiratory ICU of the Chest Department in Alexandria University Hospital in the period from May 2018 to May 2019. This study included 60 patients admitted to respiratory ICU, and they were mechanically ventilated. They experienced transudative pleural effusion owing to any of congestive heart failure, renal failure, or hypoalbuminemia.

Patients

Patients were randomly divided into two equal groups:

(1) Group I included 30 patients who were subjected to standard care plus chest tube drainage, of

whom 16 patients were males, whereas 14 patients were females.

(2) Group II included 30 patients who were subjected to standard care only, of whom 16 patients were males, whereas 14 patients were females.

This was an observational study. Simple randomization was performed based on chance alone by which study participants were assigned to a treatment group to minimize the differences among groups by equally distributing people with particular characteristics among all the trial arms. We did not know which treatment is better.

Inclusion criteria were as follows: adult patients receiving invasive ventilatory support; transudate type of pleural effusion confirmed by any imaging modality (pleural ultrasonography) and biochemical analysis.

Exclusion criteria were as follows: loculated/encysted effusions, empyema, and patients at the extreme points of life who could not obey breathing instructions. Patients with thoracic deformities, patients with diaphragmatic pathology, patients with previous chest surgery, and patients with pleural effusions who had absolute indications for drainage (e.g., empyema, hemothorax) were also excluded.

The primary outcome was duration of ventilator support, and secondary outcomes included changes in oxygenation.

All participants in this study or their relatives signed a written consent, and the research was then approved by the Ethics Committee Panel in the Faculty of Medicine, Alexandria University.

Methods

A small-bore catheter or chest tube was placed under ultrasound guidance by a senior intensivist. The effusion was characterized as either transudative or exudative using Light's criteria [4, 5]. Patients with exudative effusions were excluded. A chest radiograph was obtained immediately after the procedure. The amount of effusion drained was estimated.

Statistical analysis

Statistical analysis was performed with IBM-SPSS software version 20. Categorical variables were described as number and proportions and continuous variables as mean and SD. Differences between the two groups were tested with the $\chi 2$ test or the Fisher exact test for categorical variables, and with the t test for continuous variables.

Results

Demographic data of the studied population

We found that ischemic cardiomyopathy; liver insufficiency; renal impairment; impending respiratory failure owing to exacerbation of chronic obstructive pulmonary disease, mostly secondary to bacterial infection; and cardiac decompensation were the primary diagnoses. There was no statistically significant difference between the two groups regarding age, with mean ± SD age of groups I and II being 63.33 ± 7.317 and 63.03 ± 5.744 years, respectively (P = 0.988). No statistically significant difference existed between the two studied groups regarding age, sex, and coexisting morbidities: congestive heart failure, renal failure, and hypoalbuminemia (Table 1).

Duration of mechanical ventilation

There was no statistically significant difference between the two groups regarding duration of MV support before the start of the study, with 2.53 ± 1.008 and 2.10 ± 0.845 days, in groups I and II, respectively (P = 0.073). There was a statistically significant difference between the two groups regarding total duration of MV support, which was statistically significantly shorter in patients of group I (5.03 ± 1.066 days) compared with patients of group II (6.17 ± 1.599 days) (P = 0.002).

Statistically significant more success in weaning from MV within 2 days after start of the study was seen in patients of group I [n = 17 (56.7%)] compared with patients of group II [n = 7 (23.3%)], with P = 0.017. Successful liberation from invasive MV was considered when it occurred without failure of weaning and also in the absence of delayed reintubation. These later patients were not considered successfully weaned.

Patients with delayed successful weaning—after 2 days from removal of the transudative—were not also included,

Table 1 Comparison between the two groups regarding demographic data

	Group 1 [*n* (%)]	Group 2 [*n* (%)]	*P* value
Age			
Minimum–maximum	50–79	51–74	0.988
Mean ± SD	63.33 ± 7.317	63.03 ± 5.744	
Sex			
Male	16 (53.3)	16 (53.3)	1.000
Female	14 (46.7)	14 (46.7)	
Renal failure			
Present	11 (36.7)	5 (16.7)	
Absent	19 (63.3)	11 (83.3)	
Hypoalbuminemia			
Present	13 (43.3)	13 (43.3)	1.000
Absent	17 (56.7)	17 (56.7)	
CHF			
Present	14 (46.66)	15 (50)	
Absent	16 (53.33)	15 (50)	

CHF congestive heart failure

because this weaning was not directly related to the procedure of removal of the effusion (Table 2).

Comparison between the two groups regarding PaO_2/FiO_2

Regarding baseline oxygenation index, there were no statistically significant differences between patients in group I with PaO_2/FiO_2 ratio of 387.77 ± 15.489 compared with patients of group II, with PaO_2/FiO_2 ratio of 372.57 ± 20.969, with $P = 0.072$.

Regarding oxygenation index 1 day after study entry, patients in group I showed statistically significant improvement in oxygenation as demonstrated by a statistically significantly higher value of PaO_2/FiO_2 ratio (391.60 ± 14.578) compared with patients of group II (377.93 ± 18.800), with $P = 0.003$. Regarding oxygenation index 3 days after study entry, patients in group I showed statistically significant improvement in oxygenation as demonstrated by a statistically significantly higher value of PaO_2/FiO_2 ratio (394.40 ± 13.467) compared with patients of group II (383.07 ± 18.298), with $P = 0.008$ (Table 3).

Comparison between the two groups regarding amount of transudative pleural effusion

Ultrasonographically, pleural effusion volume can be estimated quantitatively or qualitatively. *Qualitative* estimations classify effusion as minimal, moderate, or massive [6, 7], whereas a *quantitative* approach involves the use of various formulae [8–11]. The ideal ultrasonographic formula for pleural effusion volume estimation should be simple, accurate, and rapidly/easily performed.

Supine 1 (*Eibenberger*): EV ¼ 47:6*X*—837, where EV = estimated effusion volume (ml) and *X* = maximum perpendicular distance between the pulmonary surface and the chest wall at maximal inspiration (mm) with the probe in the transverse position, perpendicular to the chest wall.

Table 2 Comparison between the two groups regarding duration of mechanical ventilation

	Group 1 [*n* (%)]	Group 2 [*n* (%)]	*P* value
Duration of MV support before the start of the study [*n* (%)]			
Minimum–maximum	1–5	1–4	0.073
Mean ± SD	2.53 ± 1.008	2.10 ± 0.845	
Total duration of MV support			
Minimum–maximum	3–7	3–8	0.002*
Mean ± SD	5.03 ± 1.066	6.17 ± 1.599	
Weaning from MV within 2 days after start of the study [*n* (%)]			
Yes	17 (56.7)	7 (23.3)	0.017*
No	13 (43.3)	23 (76.7)	

MV mechanical ventilation

Table 3 Comparison between the two groups regarding PaO_2/FiO_2

PaO_2/FiO_2	Group 1 [*n* (%)]	Group 2 [*n* (%)]	*P* value
Baseline			
Minimum–maximum	355–420	329–410	0.072
Mean ± SD	387.77 ± 15.489	372.57 ± 20.969	
1 day after study entry			
Minimum–maximum	360–415	335–415	0.003*
Mean ± SD	391.60 ± 14.578	377.93 ± 18.800	
3 days after study entry			
Minimum–maximum	365–416	345–418	0.008*
Mean ± SD	394.40 ± 13.467	383.07 ± 18.298	

Supine 2 (*Balik*): EV ¼ 20*X*, where EV = estimated effusion volume (ml) and *X* = maximum perpendicular distance between the pulmonary surface and chest wall at maximal inspiration (mm) with the probe in transverse position, perpendicular to the chest wall.

Thoracocentesis was then performed under ultrasound guidance. A 28-Fr chest tube was inserted in the midaxillary line through the fifth intercostal space and connected to underwater seal drainage. Complete lung expansion on radiography and less than 5 mm separation of the pleural layers on ultrasonography were taken as evidence of total drainage of the effusion. The drained volume was then recorded as the total effusion volume.

No statistically significant differences existed between the two groups concerning the amount of transudative pleural effusions, with mean ± SD of 1–2.25 l and 1–2.70 l in groups I and II, respectively, with $P = 0.279$.

Intercostal tube insertion was performed in group I only, with mean ± SD duration of chest tube drainage of 3.00 ± 0.830 days.

Discussion

There was a statistically significant difference between the two groups regarding total duration of MV support, which was statistically significantly shorter in patients of group I (5.03 ± 1.066 days) compared with patients of group II (6.17 ± 1.599 days), with $P = 0.002$. Statistically significant more successful weaning was seen within 2 days after start of the study in group I (56%) compared with group II (23.3%). The volume of effusion drained whether more or less than 500 ml did not affect significantly the duration of ICU stay in a study done by Roch et al. [12].

Regarding oxygenation parameters, oxygenation index 1 day after study entry, patients in group I showed statistically significant improvement in oxygenation as demonstrated by a statistically significantly higher value of PaO_2/FiO_2 ratio (391.60 ± 14.578) compared with patients of group II (377.93 ± 18.800), with $P = 0.003$.

Regarding oxygenation index 3 days after study entry, patients in group I showed statistically significant improvement in oxygenation as demonstrated by a statistically significantly higher value of PaO_2/FiO_2 ratio (394.40 ± 13.467) compared with patients of group II (383.07 ± 18.298), with $P = 0.008$.

On the contrary, great variability was noted regarding different aspects such as the time of gas exchange evaluation, volume of fluid drained, adjustments of ventilator settings, and the measured value in oxygenation after pleural drainage. A meta-analysis demonstrated an 18% improvement in the P:F ratio after thoracentesis, corresponding to an increase of 31 mmHg. Different possible predictors of improved oxygenation after thoracentesis are suggested by several studies. In a study done by Roch et al. [12] involving 44 patients, it was found that the increase in the oxygenation ratio correlated with the amount of effusion drained ($r = 0.5$, $P = 0.01$) in those patients with pleural effusions more than 500 ml in size ($n = 24$). In another study done by Talmor et al. [13] including 19 patients, no relationship between oxygenation change and the amount of effusion drained was detected.

In a multivariate analysis by De Waele et al. [14] on 24 patients, a P:F ratio of value less than 180 mmHg was the main independent predictor of improved P:F ratio after pleural effusion aspiration. They concluded that there is no sure level of data to advice for or against draining pleural fluids in mechanically ventilated patients searching for amelioration of major clinical parameters like mortality, length of MV, and ICU or hospital stay.

Significant clinically relevant hypoxemia does not occur in cases of small to moderate effusions owing to the effect of chest wall compliance and diaphragm lowering that can accommodate this extra fluid [15–19]. Decreased chest wall compliance or larger amounts of effusion lead to extensive lung collapse with resultant frank relevant hypoxemia owing to shunt effect [20, 21]. Thus, re-expansion of collapsed lung over 24 h—up to several weeks—following aspiration of pleural fluids can improve hypoxemia [22, 23].

One study [12] found marvelous amelioration in oxygenation with drainage of effusions when including patients whose hypoxemia was not responsive to high positive end-expiratory pressure. This approach uncovers those patients with diminished chest wall or abdominal compliance who are expected to benefit from pleural fluid drainage [24]. In addition, the administration of high positive end-expiratory pressure can enhance and accelerate recruitment of collapsed lung after removal of the effusion. Accumulation of pleural fluid decreases respiratory system compliance, which is why removal of this fluid restores normal mechanics of the respiratory system and facilitates weaning from MV. Two uncontrolled studies [13, 25] found only minor improvements in compliance after effusion drainage, and it is questionable whether these changes can fasten liberation from MV.

More extensive work is needed to determine the physiological benefits of pleural effusion drainage, the effect of the specific procedure on the clinical parameters, and the criteria of patients who would benefit the most from these therapeutic modalities. The advantages of removing pleural collections in mechanically ventilated patients are different from one study to another [26–30]. The discrepancy and variability in volume of pleural effusion drained may explain some of these differences among various studies. Moreover, none of the previous studies assessed lung volumes; however, improvements in oxygenation after effusion drainage may depend on the re-expansion of collapsed and improperly aerated lung regions, leading to amelioration of ventilation-perfusion matching in these areas and abolishing arteriovenous shunting.

In a study [30], oxygenation ratio improvement was significantly related to the increase in end-expiratory lung volume, but not to the amount of effusion drained. The main clinical importance of this study is that when a pleural effusion is large (> 500 ml using ultrasonography, i.e., an end-expiratory interpleural distance > 25 mm), effusion drainage is highly expected to improve oxygenation indices and respiratory mechanics, including lung volumes, which could help to reduce the load posed on the lung by a given ventilatory regimen [24].

Conclusions

More work is needed to determine the physiological benefits of transudate pleural effusion drainage and the effect of the specific procedure on the clinical parameters. Further studies are needed to study different modalities or tools of drainage of transudate effusion and the effect of each on the different clinical outcomes in comparison with each other to reach the optimum way of drainage of transudate effusion with the best results and least complications.

Acknowledgements

The authors thank all patients for the use of their data in this research. The authors also thank our colleagues in the Chest Diseases Department, Alexandria University, for their assistance.

Authors' contributions

H.G: case selection, follow-up for the medical issues of the patients, assessing the weaning parameters and oxygenation issues, writing the paper, and being the corresponding author. A.A: supervising the study, performing the invasive procedure, and analyzing the radiological findings. Both authors have read and approved the manuscript.

Funding

The authors state that this work has not received any funding.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Alexandria University. reference number of approval: IORG0008812. All patients' relatives included in this study gave written informed consent to participate in this research (all the patients were older than 16 years old).

Consent for publication
All patients' relatives included in this research gave written informed consent to publish the data contained within this study.

Competing interests
The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Received: 31 March 2020 Accepted: 27 August 2020
Published online: 10 September 2020

References

1. Azoulay E, Fartoukh M, Similowski T, Galliot R, Soufir L, Le Gall JR et al (2001) Routine exploratory thoracentesis in ICU patients with pleural effusions: results of a French questionnaire study. J Crit Care 16:98–101
2. Mattison LE, Coppage L, Alderman DF, Herlong JO, Sahn SA (1997) Pleural effusions in the medical ICU: prevalence, causes. and clinical implications Chest 111:1018–1023
3. Vinaya S, Karkhanis S, Joshi JM (2012) Pleural effusion: diagnosis, treatment, and management. Open Access Emerg Med 4:31–52
4. Light RW, MacGregor MI, Luchsinger PC et al (1972) Pleural effusions: the diagnostic separation of transudates and exudates. Ann Intern Med 77:507–514
5. Light RW (2013) The Light Criteria: The beginning and why they are useful 40 years later. Clin Chest Med 34:21–26
6. Tsai TH, Yang PC (2003) Ultrasound in the diagnosis and management of pleural disease. CurrOpinPulm Med 9:282–290
7. Ferreira AC, Filho FM, Braga T, Fanstone GD, Chodraui IC, Onari N (2006) The role of ultrasound in the assessment of pleural effusion. Radiol Bras 39:145–150
8. Eibenberger KL, Dock WI, Ammann ME, Dorffner R, Hormann MF, Grabenwoger F (1994) Quantification of pleural effusions: sonography versus radiography. Radiology 191:681–684
9. Mathis G (2011) Pleura. In: Mathis G (ed) Chest sonography, 3rd edn. Springer-Verlag, Heidelberg, pp 30–32
10. Balik M, Plasil P, Waldauf P, Pazout J, Fric M, Otahal M et al (2006) Ultrasound estimation of volume of pleural fluid in mechanically ventilated patients. Intensive Care Med 32:318
11. Cerquitella M, Saccomandi P, Schena E, Silvestri S, Scarlata S, Giua R. Ultrasound estimation of pleural effusion in geriatric patients. In: XX XX. IEEE International Symposium on Medical Measurements and Applications (MeMeA). Benevento, Italy; 2016. 15–18. No. 16211740
12. Roch A, Bojan M, Michelet P, Romain F, Bregeon F, Papazian L et al (2005) Usefulness of ultrasonography in predicting pleural effusions >500 ml in patients receiving mechanical ventilation. Chest 127:224–232
13. Talmor M, Hydo L, Gershenwald JG, Barie PS (1998) Beneficial effects of chest tube drainage of pleural effusion in acute respiratory failure refractory to positive end-expiratory pressure ventilation. Surgery 123:137–143
14. De Waele JJ, Hoste E, Benoit D, Vandewoude K, Delaere S, Berrevoet F et al (2003) The effect of tube thoracostomy on oxygenation in ICU patients. J Intensive Care Med 18:100–104
15. Krell WS, Rodarte JR (1985) Effects of acute pleural effusion on respiratory system mechanics in dogs. J ApplPhysiol 59:1458–1463
16. Estenne M, Yernault JC, De Troyer A (1983) Mechanism of relief of dyspnea after thoracocentesis in patients with large pleural effusions. Am J Med 74: 813–819
17. Wang JS, Tseng CH (1995) Changes in pulmonary mechanics and gas exchange after thoracentesis on patients with inversion of a hemidiaphragm secondary to large pleural effusion. Chest 107:1610–1614
18. Light RW, Stansbury DW, Brown SE (1986) The relationship between pleural pressures and changes in pulmonary function after therapeutic thoracentesis. Am Rev Respir Dis 133:658–661
19. Anthonisen NR, Martin RR (1977) Regional lung function in pleural effusion. Am Rev Respir Dis 116:201–207
20. Perpina M, Benlloch E, Marco V, Abad F, Nauffal D (1983) Effect of thoracentesis on pulmonary gas exchange. Thorax 38:747–750
21. Agusti AG, Cardus J, Roca J, Grau JM, Xaubet A, Rodriguez-Roisin R (1997) Ventilation-perfusion mismatch in patients with pleural effusion: effects of thoracentesis. Am JRespir Crit Care Med 156:1205–1209
22. Altschule MD, Zamcheck N (1944) The effects of pleural effusion on respiration and circulation in man. J Clin Invest 23:325–331
23. Yoo OH, Ting EY (1964) The effects of pleural effusion on pulmonary function. Am Rev Respir Dis 89:55–63
24. Graf J (2009) Pleural effusion in the mechanically ventilated patient. CurrOpinCrit Care 15:10–17
25. Doelken P, Abreu R, Sahn SA, Mayo PH (2006) Effect of thoracentesison respiratory mechanics and gas exchange in the patient receiving mechanical ventilation. Chest 130:1354–1361
26. Ahmed SH, Ouzounian SP, Dirusso S, Sullivan T, Savino J, DelGuercio L (2004) Hemodynamic and pulmonary changes after drainage of significant pleural effusions in critically ill, mechanically ventilated surgical patients. J Trauma 57:1184–1188
27. Guinard N, Beloucif S, Gatecel C, Mateo J, Payen D (1997) Interest of a therapeutic optimization strategy in severe ARDS. Chest 111:1000–1007
28. Walden AP, Garrard CS, Salmon J (2010) Sustained effects of thoracocentesis on oxygenation in mechanically ventilated patients. Respirology 15:986–992
29. Chen WL, Chung CL, Hsiao SH, Chang SC (2010) Pleural space elastance and changes in oxygenation after therapeutic thoracentesis in ventilated patients with heart failure and transudative pleural effusions. Respirology 15: 1001–1008
30. Razazi K, Thille AW, Carteaux G, Beji O, Brun-Buisson C, Brochard L et al (2014) Effects of pleural effusion drainage on oxygenation, respiratory mechanics, and hemodynamics in mechanically ventilated patients. Ann Am Thorac Soc 11:1018–1024

Publisher's Note