Prevalence, characteristics, drainage and outcome of radiologically diagnosed pleural effusions in critically ill patients

Davina Bates, Natalie Yang, Michael Bailey and Rinaldo Bellomo

ABSTRACT

Objective: Pleural effusions in the intensive care unit (ICU) are clinically important. However, there is limited information regarding effusions in such patients. We aimed to estimate the prevalence, patient characteristics, mortality, effusion duration, radiological resolution, drainage, and reaccumulation rates of pleural effusions in ICU patients.

Methods: This retrospective cohort study assessed all patients admitted to a tertiary hospital ICU from 1 January to 31 December 2015 with a chest x-ray report of pleural effusion. All chest x-ray reports were reviewed and data were combined with an established clinical ICU database. Statistical analysis of the combined dataset was performed.

Results: Among 2094 patients admitted to the ICU, 566 (27%) had pleural effusions diagnosed by chest x-ray. The effusion median duration was 3 days (IQR, 1–5 days). Radiologically documented clearance of the effusion occurred in 243 patients (43%) and drainage was performed in 52 patients (9%). Among patients with effusion clearance, 80 (33%) reaccumulated the effusion. Drainage was more common in patients who experienced reaccumulation (19% *v* 7%; $P = 0.004$). Overall, 89 patients (16%) died, with 20% mortality among those with reaccumulation versus 9% among patients without reaccumulation ($P = 0.037$).

Conclusion: Pleural effusions are common in ICU patients and drainage is infrequent. One-third of effusions reaccumulate, even after drainage, and one in six patients with an effusion die in hospital. This information helps clinicians estimate resolution rates, advantages and disadvantages of effusion drainage, and overall prognosis.

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Pleural effusions are typically a secondary finding in the critically ill patient and are multifactorial in origin.[1,2] While the aetiologies are broad, the supportive measures specific to the care of critically ill patients are an important causal consideration. These supportive measures include mechanical ventilation, paralysis and sedation, and aggressive fluid resuscitation.[3] Primary causes, such as infection, malignancy, hypoalbuminaemia, trauma, and post-operative pleural inflammation, are not specific to the critically ill patient but remain important aetiologies.[3-5]

The classic division of effusions into transudates and exudates is based on fluid evaluation (Light's criteria) and narrows the differential and subsequent treatment goals. Transudative effusions result from systemic factors that increase production or reduce absorption of pleural fluid without capillary injury. The cause can typically be discerned from the patient's clinical presentation (eg, congestive heart failure, liver failure, hypoalbuminaemia), and intervention is typically directed at the underlying systemic condition. Exudative effusions develop from increased capillary permeability and obstructed lymphatic drainage. The differential is more varied than for transudates, with the most common causes including infection, malignancy, trauma, and gastrointestinal disease.[6]

While ultrasound is gaining popularity and is more sensitive and accurate than chest x-ray for identifying a pleural effusion,[7-9] routine (and serial) ultrasonography of all intensive care unit (ICU) patients is not readily available. Thus, the chest x-ray remains the first line and readily available diagnostic tool to study the epidemiology of effusions in the ICU. Moreover, comparison of serial chest x-rays is both logistically achievable and helpful in assessing pleural effusion changes over time.

Pleural effusions of unclear cause and effusions requiring culture or cytology are indications for fluid sampling and analysis. This is achieved by needle aspirate or drain insertion (in-dwelling pigtail catheter or chest tube). Drain insertion is preferred, when safe to do so, in order to achieve potential symptomatic relief at the same time. Therapeutic drainage is the other indication for drain insertion and is performed to improve symptoms such as dyspnoea and haemodynamic compromise or eliminate any source of infection.[10-12]

There is a paucity of data on the prevalence, patient characteristics, duration, radiological resolution, drainage, reaccumulation and associated mortality of pleural effusions in ICU patients. This study highlights how an electronic word search engine facilitates rapid and accurate identification of all chest x-ray reports documenting pleural effusions over a

given period. Accordingly, we combined these data with a detailed post-identification review process and ICU clinical database to generate an epidemiological overview of ICU patients with pleural effusions diagnosed by chest x-ray.

Methods

Patients and data collection

This retrospective cohort study was approved by the Austin Hospital Human Research Ethics Committee with waiver for informed consent (reference No. LNR/17/Austin/49).

The study was performed in patients admitted to a tertiary ICU, with a mix of medical and surgical patients. Patients were identified as having a pleural effusion using an electronic word search engine of all chest x-ray reports stored in the Picture Archive Communication System (PACS) research database. The natural language terms "pleural effusion", "pleural fluid" and "pleural collection" were searched to identify all positive reports of pleural effusion. Reports of "no pleural effusion" were excluded. This analysis was performed for all ICU chest x-ray reports in the 12-month period from 1 January to 31 December 2015.

Pleural effusion clearance was assessed radiologically and recorded if there was a subsequent chest x-ray during the hospital admission documenting no effusion. Post-surgical patients with intercostal catheters inserted at the time of surgery were not included in the effusion drainage group unless there was a new drain inserted after surgery.

Available fluid analysis results of the drained effusions were categorised into transudates and exudates based on Light's criteria,[6] or as a haemothorax if the red blood cell count exceeded 100 000/μL.

The data extracted from the ICU clinical database included age, gender, length of hospital and ICU stay, Acute Physiological and Chronic Health Evaluation (APACHE) scores, and patient mortality. Data collected in relation to the pleural effusion included duration, clearance of the effusion, drainage, and the presence of reaccumulation during the hospital admission. The data were recorded in a standardised Microsoft Excel spreadsheet and combined with clinical data from an established ICU clinical database.

Table 1. Key characteristics of the study population and pleural effusions

Characteristics	Number
Total number of patients	566
Age (years)	
Mean (SD)	64 ± 15
Median (IQR)	66 (56–75)
Sex	
Male	363 (64%)
Female	203 (36%)
Number of deaths	89 (16%)
APACHE III score, mean (SD)	60 ± 25
Primary admission diagnosis	
Cardiac surgery	168 (30%)
Cardiovascular disease	74 (13%)
Sepsis/pneumonia	83 (15%)
Gastrointestinal disease	70 (12%)
Liver disease/transplant	42 (7%)
Pulmonary disease	46 (8%)
Renal disease	14 (2%)
Trauma	20 (4%)
Other (haematological/neurological)	49 (9%)
Medical ICU admission	275 (49%)
Surgical ICU admission	291 (51%)
Location of effusion at first chest x-ray	
Left	128 (22.5%)
Right	242 (43%)
Bilateral	196 (34.5%)
Time from diagnosis (days) to:	
Clearance, median (IQR)	3 (1–5)
Drainage, median (IQR)	7 (2–11)

APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; IQR = interquartile range; SD = standard deviation.

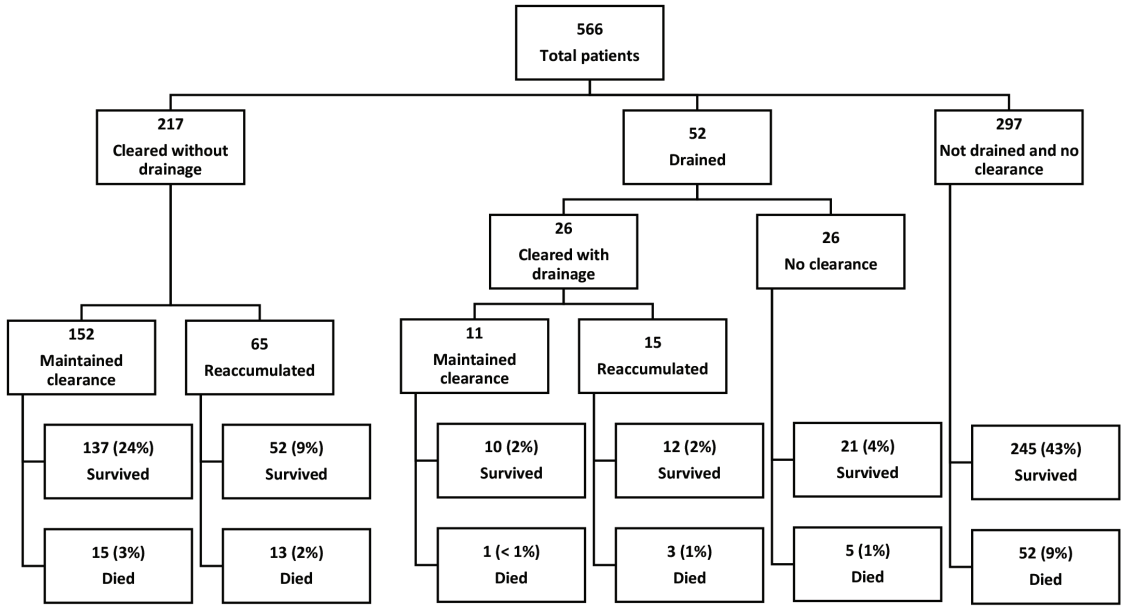
Data analysis

Within the study population, univariate analysis was performed to compare patient characteristics according to survival, effusion clearance, drainage and reaccumulation.

Comparisons were performed using χ^2 tests for equal proportion, Student *t* tests for normally distributed data, and Wilcoxon rank sum tests otherwise, with results reported as number and percentages, mean (standard deviation) or median (interquartile range [IQR]) respectively.

Time to effusion clearance was assessed using a log-rank test and presented using Kaplan–Meier survival curves. Independent predictors or mortality were determined using multivariable logistic regression, with results presented as odds ratios (95% confidence interval). The multivariate model was constructed using stepwise selection and backwards elimination techniques considering all available baseline variables before a final assessment of clinical and biological plausibility. To increase the robustness of the prediction model and reported analysis, a two-sided *P* value of 0.01 was used to indicate statistical significance. All analysis was performed using SAS version 9.4 (SAS Institute).

Figure 1. Radiologically diagnosed pleural effusion outcomes and associated in-hospital mortality



Results

During the 12-month study period (1 January to 31 December 2015), 2094 patients were admitted to the ICU and 566 patients (27%) had a positive pleural effusion chest x-ray report. The chest x-rays were typically performed erect, with a 7% rate of supine films.

Patient and effusion characteristics

The key characteristics of study patients and their effusions are shown in Table 1. Patients with pleural effusions were predominantly male, with a median age of 66 years (IQR, 56–75 years). A similar proportion of patients were admitted to the ICU for medical and surgical reasons. Cardiac surgery, cardiovascular disease, and sepsis were the most common admission diagnoses. Most pleural effusions were not present at admission but developed during the ICU admission. One-third of pleural effusions were bilateral.

Patient and effusion outcomes

Pleural effusion and patient outcomes are outlined in Figure 1. Radiological clearance was achieved in 323 patients (57%) — this includes both drained and non-drained effusions. Patients who achieved radiological clearance had a later diagnosis of their effusion, longer ICU and hospital admissions, longer time on mechanical ventilation, and were more likely to receive continuous renal replacement therapy (CRRT). Most effusions cleared during ICU treatment and the median time to clearance was 3 days (IQR, 1–5 days). Mortality was similar to that of patients who did not achieve radiological resolution (Table 2).

Pleural effusion drainage

Overall, almost one in ten patients underwent pleural effusion drainage (after exclusion of patients with post-operative intercostal catheters inserted at the time of operation) with a median time from diagnosis to drainage of 7 days (IQR, 2–11 days) (Table 2). All drainage procedures were performed via a chest tube or pigtail drain insertion. Drainage was associated with significantly longer median effusion duration, longer median length of mechanical ventilation and ICU and hospital stay. Effusion confirmation with additional imaging modalities was also more common in the drainage group, as was reaccumulation of the effusion. However, patients who received drainage achieved an overall pleural effusion clearance rate similar to the non-drainage group and time to clearance was also similar (Figure 2). There was a low rate of pleural fluid analysis for the drained effusions (Table 3). Only 19% underwent biochemistry testing and 63% underwent culture and Gram stain. Exudates (excluding haemothorax) were more common than transudates, and haemothorax was twice as common as plain exudates and three times as common as transudates. Only three positive organisms (3%) were identified by culture or Gram stain.

Pleural effusion reaccumulation

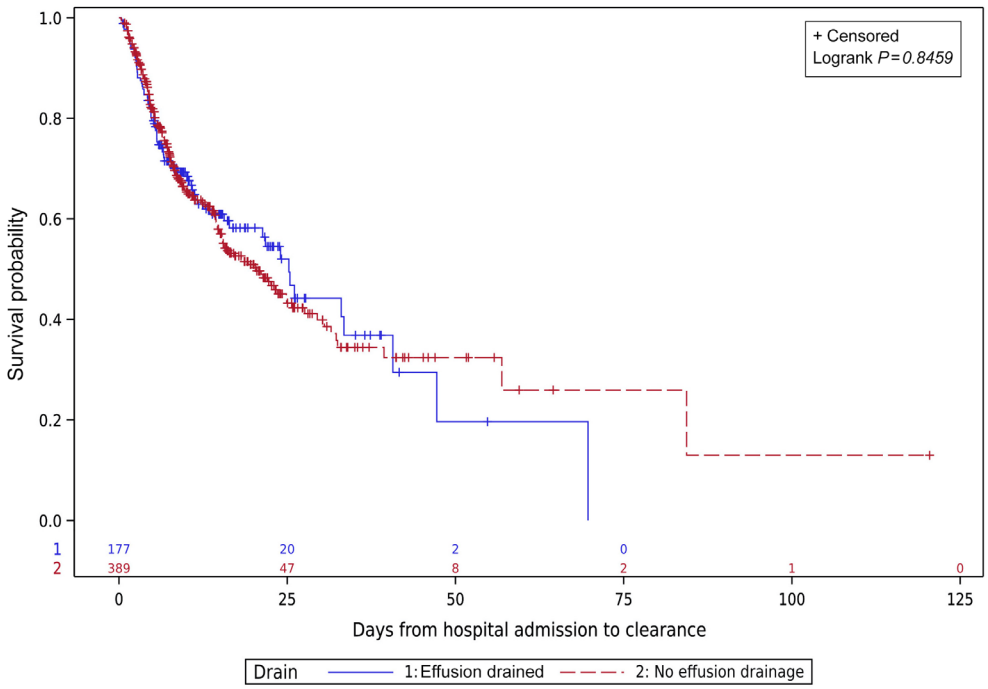
Reaccumulation occurred in one-third of patients with radiological clearance (Table 2). It was associated with longer median effusion duration, longer duration of mechanical ventilation and longer median ICU and hospital stay.

Table 2. Comparison between patients with or without radiological clearance, drainage and reaccumulation of their pleural effusion*

	Clearance	No clearance	*P*	Drained	Not drained	*P*	Reaccumulation	No reaccumulation	*P*
Number of patients	243 (43%)	323 (57%)		52 (9%)	514 (91%)		80 (33%)	163 (67%)	
Age (years), mean (SD)	63 ± 15	66 ± 14	0.017	62 ± 18	65 ± 14	0.18	64 ± 15	62 ± 16	0.59
Mortality	32 (13%)	57 (18%)	0.14	9 (17%)	80 (16%)	0.75	16 (20%)	17 (10%)	0.037
Effusion duration (days), median (IQR)	1 (0–4)	4 (1–8)	< 0.0001	12 (4–18)	2 (0–6)	< 0.0001	2 (0–7)	1 (0–3)	0.039
Days, median (IQR) from:									
Diagnosis to clearance	3 (1–5)								
Diagnosis to drainage				7 (2–11)					
Clearance to reaccumulation							4 (2–8)		
Time from hospital admission to CXR diagnosis (days), median (IQR)	3 (1–7)	2 (0–5)	0.002	2 (1–7)	2 (1–5)	0.6	3 (1–7)	2 (1–5)	0.08
Admission length (days), median (IQR)									
Hospital	20 (11–37)	11 (7–21)	< 0.0001	24 (17–42)	14 (8–24)	< 0.0001	30 (14–55)	18 (10–32)	< 0.0001
ICU	6 (3–11)	3 (1–5)	< 0.0001	6 (3–10)	4 (2–7)	0.001	9 (5–19)	5 (3–8)	< 0.0001
Mechanical ventilation	201 (83%)	229 (71%)	0.001	42 (81%)	388 (76%)	0.4	71 (89%)	132 (81%)	0.09
Duration (hours), median (IQR)				27 (9–140)	14 (2–60)	0.008	93 (13–250)	19 (5–121)	< 0.0001
CRRT	58 (24%)	38 (12%)	< 0.0001	10 (19%)	86 (17%)	0.65	30 (38%)	28 (17%)	< 0.0001
Effusion confirmation with another imaging modality	86 (35%)	112 (35%)	0.86	44 (85%)	154 (30%)	< 0.0001	44 (55%)	42 (26%)	< 0.0001
CT abdomen pelvis	35 (14%)	31 (10%)	0.08	11 (21%)	55 (11%)	0.025	24 (30%)	11 (7%)	< 0.0001
CT chest	46 (19%)	67 (21%)	0.59	28 (54%)	85 (17%)	< 0.0001	20 (25%)	26 (16%)	0.08
US chest	19 (8%)	32 (10%)	0.39	27 (52%)	24 (5%)	< 0.0001	13 (16%)	6 (4%)	0.001
US abdomen	6 (3%)	8 (3%)	1.00	1 (2%)	13 (3%)	0.79	3 (4%)	3 (2%)	0.4
Drained other than post-operative drains	26 (11%)	26 (8%)	0.28				15 (19%)	11 (7%)	0.004
Post-operative drain	52 (21%)	81 (25%)	0.31				19 (24%)	114 (24%)	0.95
Reaccumulation	80 (33%)		< 0.0001	15 (29%)	65 (13%)	0.001			

CT = computed tomography; CXR = chest x-ray; CRRT = continuous renal replacement therapy; ICU = intensive care unit; IQR = interquartile range; SD = standard deviation; US = ultrasound. * Drained pleural effusion group does not include routine post-operative drains inserted at the time of operation.

Figure 2. Kaplan–Meier curves comparing the probability of pleural effusion clearance during the admission with and without drainage



The Kaplan–Meier curves demonstrate that the time course of radiological pleural effusion clearance is very similar between patients who undergo a drainage procedure and those who do not.

Moreover, CRRT and drainage were both twice as common in patients who reaccumulated their effusion. Median time to reaccumulation was 4 days (IQR, 2–8 days), and mortality was twice as high in patients with reaccumulation.

Mortality

A comparison of survivors with non-survivors is presented in Table 4. Non-survivors had higher APACHE III scores, higher serum creatinine and lower trough albumin levels on the day of admission. They experienced longer duration of mechanical ventilation and ICU stay, as well as greater use of CRRT. Finally, non-survivors were more likely to undergo a different imaging modality confirming the pleural effusion and were more likely to have had chest drains in situ at the time of diagnosis. The risk of in-hospital mortality increased by 3% for every one-point increase in the patient's APACHE III derived risk of death, and more than doubled if the patient underwent CRRT (Table 5). In contrast, elective admissions and radiological clearance of the effusion without drainage were independent predictors of lower in-hospital mortality.

Table 3. Fluid Analysis results of the drained pleural effusions

Characteristic	Number
Total number of pleural effusions drained	52
Number of drained pleural effusions not sent for fluid analysis	18 (35%)
Biochemistry	10 (19%)
Transudate*	3 (6%)
Exudate (excluding haemothorax)*	5 (10%)
Culture, Gram stain and cell count	33 (63%)
No growth or organism	30 (58%)
Organism identified	3 (6%)
Haemothorax (RBC > 100 000/μL)	9 (17%)

RBC = red blood cell. * Classification of effusions as transudates and exudates based on Light's criteria.

Discussion

We performed an electronically assisted identification of all patients with a chest x-ray report of pleural effusion during their ICU stay. We found that about one in four patients had a pleural effusion diagnosed by chest x-ray; one-third of these effusions were bilateral and two-thirds of such effusions developed during ICU treatment. The

Table 4. Comparison of survival and death during the admission where a pleural effusion was diagnosed

	Survivors	Non-survivors	*P*
Number of patients	477 (84%)	89 (16%)	
Deaths in ICU		50 (9%)	
Age (years)			
Median (IQR)	66 (56–75)	70 (59–77)	
Mean (SD)	64 ± 15	67 ± 14	0.03
APACHE III score, mean (SD)	55 ± 22	84 ± 27	< 0.0001
Duration of effusion (days), median (IQR)	3 (0–6)	2 (0–6)	0.86
Time to effusion CXR diagnosis from hospital admission			
Median (IQR)	2 (1–5)	3 (1–11)	
Mean (SD)	4 ± 5	8 ± 13	0.002
Length of admission (days), median (IQR)			
Hospital	15 (8–26)	17 (6–25)	0.64
ICU	4 (2–6)	6 (3–13)	< 0.0001
Mechanical ventilation	358 (75%)	72 (81%)	0.24
Duration of mechanical ventilation (hours), median (IQR)	12 (1–44)	74 (19–182)	< 0.0001
CRRT	59 (12%)	37 (42%)	< 0.0001
Confirmation of effusion with another imaging modality	154 (32%)	44 (49%)	0.002
CT abdomen pelvis	45 (9%)	21 (24%)	< 0.0001
CT chest	89 (19%)	24 (27%)	0.07
US chest	47 (10%)	4 (5%)	0.11
US abdomen	12 (3%)	2 (2%)	0.88
Effusion clearance confirmed radiologically	211 (44%)	32 (36%)	0.15
Drained other than post-operative drains	43 (9%)	9 (10%)	0.74
Post-operative drain	129 (27%)	4 (5%)	< 0.0001
Reaccumulation	64 (13%)	16 (18%)	0.26
Highest heart rate in the first 24 hours in ICU (beats per min), mean (SD)	103 ± 22	112 ± 29	< 0.0001
Lowest MAP in first 24 hours in ICU (mmHg), mean (SD)	62 ± 10	64 ± 11	0.048
Highest creatinine in first 24 hours in ICU (μmol/L), median (IQR)	96 (74–150)	142 (88–205)	< 0.0001
Lowest albumin in first 24 hours in ICU (g/L), median (IQR)	28 (24–31)	25 (22–29)	0.001

APACHE = Acute Physiology and Chronic Health Evaluation; CT = computed tomography; CXR = chest x-ray; CRRT = continuous renal replacement therapy; ICU = intensive care unit; IQR = interquartile range; SD = standard deviation; US = ultrasound.

majority of effusions failed to achieve clearance at the last available chest x-ray. If clearance was achieved, one-third developed reaccumulation. One in ten effusions was treated with a drainage procedure, at a median of one week (IQR, 2–11 days) after diagnosis, and in about one-third of these patients, the effusion re-accumulated. Finally, one in six patients with an effusion did not survive to hospital discharge.

Relationship with previous literature

Prevalence rates for pleural effusions have been highly variable and uncommonly reported in the literature. In 1997, in a study of 100 medical patients[5] which used both x-ray and ultrasound, the prevalence was 62% for mostly small pleural effusions — of which two-thirds were detected at admission. Over a one-year period, French investigators[13] reported that 8.4% of medical ICU patients had a pleural effusion on clinical examination and chest x-ray, with 72% of such patients having a thoracentesis. Among ICU patients in Taiwan,[14] clinical examination, chest x-ray, ultrasound and drainage in 94 febrile medical patients were reported with no overall prevalence of pleural effusion. Using ultrasound,

Table 5. Independent predictors of in-hospital mortality in patients with a pleural effusion while in the intensive care unit using multivariate logistic regression analysis

Variable	Survivors	Non-survivors	Odds ratio (95% CI)	*P*
Risk of death according to APACHE III score, median (IQR)	6% (2–18%)	39% (18–71%)	1.03* (1.02–1.04)	< 0.0001
CRRT	59 (12%)	37 (42%)	2.31 (1.25–4.26)	0.008
Elective admission	218 (46%)	7 (8%)	0.26 (0.11–0.62)	0.002
Effusion clearance without drainage	190 (40%)	29 (33%)	0.37 (0.20–0.69)	0.002

APACHE = Acute Physiology and Chronic Health Evaluation; CRRT = continuous renal replacement therapy; IQR = interquartile range. * Increased risk of death associated with a 1% increase in APACHE III derived risk of death.

other investigators[15] reported a prevalence of 37% in 136 mechanically ventilated patients, but only and specifically at the time of ventilation liberation. Others[16] reported a much higher rate of pleural effusion (83% of 129 patients) but using computed tomography and only in a cohort with acute respiratory distress syndrome.

Pleural effusions have been associated with increased mortality. Walker and colleagues[17] report one-year mortality rates of 25–50% with newly diagnosed non-malignant effusions, with particular high mortality rates associated with bilateral effusions (57%). The published data on patient outcomes after effusion drainage are also variable and inconsistent.[18] DeBiasi et al[19] described a 30-day mortality of 21% and 11% in 308 patients undergoing drainage of effusions caused by congestive heart failure and infection respectively. No data exist on longitudinal assessment and reaccumulation rates of effusions with or without drainage.

Implications of study findings

Our study implies that, in a mixed medical and surgical ICU population, pleural effusions diagnosed by chest x-ray affect a quarter of patients, typically develop while the patient is in the ICU, and are associated with a one in six mortality rate. Moreover, our study implies that most effusions do not achieve radiological clearance and that only a minority are treated with a drainage procedure. Of the effusions that are drained, few undergo complete fluid analysis and are thus typically performed for therapeutic indications. Even after effusion resolution, reaccumulation occurs in one-third of the patients, even in those who receive a drainage procedure. Finally, the association between longer hospital and ICU admissions with effusion drainage and reaccumulation implies these patients are generally very unwell. This information has implications for clinicians tasked with estimating the likely risk, outcome and resolution rates of pleural effusions in ICU patients and considering the advantages and disadvantages as well as the duration of drainage in light of the risk of reaccumulation.

Study strengths and limitations

To the best of our knowledge, this is the first study to investigate the prevalence, characteristics, drainage and outcome of pleural effusions in a general university-affiliated ICU in a high income country. This is also the largest study of pleural effusions in the ICU to date, with a study population that is at least double the size of previous studies. Moreover, it is the first study to report on the resolution and reaccumulation rates of such effusions or on the confirmation by other imaging modalities. Therefore, our information provides the first comprehensive description of pleural effusions diagnosed by chest x-ray among critically ill patients.

Our study has several limitations. The use of chest x-ray reports to identify and follow pleural effusions in the ICU has limited sensitivity and specificity compared with ultrasound. However, unlike daily chest x-rays, ultrasound screening of all ICU patients is not usual care and it remains unclear whether a pleural effusion diagnosed on ultrasound and not seen on chest x-ray is clinically important. Secondly, using radiology reports may incur a degree of error without inter-observer confirmation. Taking this into account, the number of effusions may have been underestimated. However, the missed pleural effusions would likely have been small and thus of limited clinical importance. This was only a single site study and without long term follow-up. Moreover, the study was not designed to investigate the cause of the identified pleural effusions. However, it is the first to provide a detailed description of multiple aspects of such effusions, their drainage, and hospital outcome.

Conclusion

Pleural effusions diagnosed by chest x-ray affected a quarter of patients in a general academic ICU setting, with associated mortality of one in six patients. Less than half

of the effusions achieved radiological resolution, with one in ten achieving resolution only via drainage and one-third re-accumulating. This information is important for clinicians in estimating likely risk, outcome, and resolution rates of such effusion as well as the advantages and disadvantages of drainage.

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Competing interests

None declared.

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