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Management of pneumothorax in mechanically ventilated COVID-19 patients: early experience

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Abstract

A significant proportion of patients infected with the novel coronavirus, now termed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), require intensive care admission and subsequent mechanical ventilation. Pneumothorax, a potential fatal complication of mechanical ventilation, can further complicate the management of COVID-19 patients, whilst chest drain insertion may increase the risk of transmission of attending staff. We present a case series and a suggested best-practice protocol for how to manage and treat pneumothoraces in COVID-19 patients in an intensive care unit setting.

Keywords: COVID-19 • Chest drain • Pneumothorax

INTRODUCTION

The novel coronavirus, now termed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has caused a significant global impact in the space of 4 months. COVID-19 has been declared a pandemic by the World Health Organisation and is having a major impact on the already constrained health service in the UK. Early data from Italy suggest that up to 12% of all positive cases required intensive care unit (ICU) admission with a significant proportion of these requiring mechanical ventilation [1]. Pneumothorax, a major and potential fatal complication of mechanical ventilation, can further complicate the management of COVID-19 patients, whilst chest drain insertion may increase the risk of transmission of attending staff. The rate of pneumothorax in such patients has not yet been quantified. However, previous experience from the SARS outbreak, also caused by a coronavirus, suggests a high incidence (20–34%) of pneumothorax in mechanically ventilated SARS patients [2, 3].

Mechanical ventilation is the most common cause of iatrogenic pneumothoraces in the ICU setting [4]; however, it is a rare occurrence in intubated patients who have relatively normal lung parenchyma. Most pneumothoraces related to mechanical ventilation are associated with a combination of high ventilation pressures and underlying chronic lung pathology such as

emphysema. Previous studies have suggested that high inspiratory airway pressures and positive end-expiratory pressure were correlated with increased incidence of barotrauma [5].

Currently, there is limited literature on how to manage pneumothoraces in mechanically ventilated COVID-19 patients. We present a case series and a suggested protocol for how to manage and treat pneumothoraces in COVID-19 patients in an ICU setting.

CASES

We report 9 COVID-19 patients who developed a pneumothorax or surgical emphysema once established on mechanical ventilation in our ICU. All patients had progressively worsening respiratory failure in a non-ICU setting and were transferred for invasive respiratory support. They were all intubated after admission to ICU. Their baseline respiratory parameters and demographics are detailed in Table 1. Only 2 patients had underlying chronic lung diseases such as chronic obstructive pulmonary disease or emphysema. Four patients had known chronic kidney disease and 6 patients had a background of type 2 diabetes mellitus and/or hypertension. Surgical chest drains were inserted in 8 of the patients with confirmed pneumothoraces on computed tomography (CT) or X-Ray imaging and 1 patient with surgical

Table 1: Demographics, patient characteristics and outcomes in mechanically ventilated COVID-19 patients with a pneumothorax

Patient	1	2	3	4	5	6	7	8	9
Gender (male/female)	M	M	M	M	M	M	F	M	F
Age (years)	49	40	56	49	61	48	58	71	53
Body mass index (kg/m ²)	42.6	48.6	24.6	28.6	27.7	52.2	47.7	30.9	31.6
Pre-existing comorbidities									
CKD	Y	Y	N	N	N	N	Y	N	Y
Diabetes	Y	Y	Y	N	N	Y	Y	N	N
HTN	Y	Y	Y	Y	N	Y	Y	Y	Y
Chronic lung disease	N	N	N	N	N	Y	N	Y	N
Ischaemic heart disease	N	N	Y	Y	N	N	N	N	N
On ICU admission (not ventilated)									
Baseline respiratory rate	27	28	24	27	40	30	33	30	40
Baseline PaO ₂ /FiO ₂ ratio	85.38	86.26	55.88	103.13	53.78	124.51	103.13	57.71	62.03
Baseline PaCO ₂ (kPa)	3.50	5.07	9.92	4.17	2.89	7.3	4.23	8.42	3.56
Time from intubation to drain insertion (days)	5	4	1	NA	34	2	47	1	16
Drain insertion site	R	L	B/L	B/L SE	R	L	R	R	B/L
				No drain					
Drain size (Fr)	28	28	28/24	NA	28	28	24	28	24/32
Air leak	N	N	Y	NA	Y	N	Y	Y	Y
Ventilatory pressure, cmH ₂ O or volume									
PEEP D1 postintubation	5	18	10	10	14	10	16	10	13
PEEP 24 h predrain	14	19	12	15	8	12	14	12	8
Tidal volume (ml), D1 postintubation	650	639	460	500	504	657	432	509	418
Tidal volume (ml), 24 h predrain	714	566	510	480	398	571	620	511	429
ARDS/ALI	N	Y	N	Y	N	N	Y	N	N
Drain status	Removed D9	<i>In situ</i>	Removed D12/D25	NA	<i>In situ</i>	Removed D5	<i>In situ</i>	<i>In situ</i>	Removed D9/D14
Mortality	Alive	Died	Alive	Died	Alive	Alive	Alive	Died	Alive
CPAP use prior to intubation	1 day	1 day	5 days	1 day	1 day	N	1 day	1 day	N

All patients were admitted to ICU prior to being mechanically ventilated.

ALI: acute lung injury; ARDS: acute respiratory distress syndrome; B/L: bilateral; CKD: chronic kidney disease; CPAP: continuous positive airway pressure; HTN: hypertension; ICU: intensive care unit; L: left; PEEP: positive end-expiratory pressure; R: right; SE: surgical emphysema.

emphysema was managed conservatively. Not all patients underwent CT imaging, as they were deemed unstable for transfer. The time from intubation to drain insertion was ≤ 5 days for 5 patients and >15 days for 3 patients. Table 1 also outlines the basic ventilator parameters at day 1 and in the 24 h prior to drain insertion with the highest pressure or volume being recorded.

DISCUSSION

Approximately two-thirds of COVID-19 patients who require critical care admission needed mechanical ventilation in the UK [6]. Although definitive evidence is lacking, there seems to be general consensus that the threshold for intubation should be lowered in order to maximize the potential for recovery. Previous experience from the SARS outbreak suggests that barotrauma is a common complication in intubated patients, particularly when they develop acute respiratory distress syndrome [2, 3]. Several other studies have found a high incidence of pneumomediastinum and pneumothorax in SARS patients who were not mechanically ventilated, suggesting that it is part of the disease process itself [7, 8]. The precise respiratory pathophysiology of COVID-19 has yet to be determined and patients with severe respiratory compromise are currently being treated under established acute respiratory distress syndrome protocols.

In our case series, 8 patients had a pneumothorax in an ICU setting that is currently accommodating 90 COVID-19 patients. One patient had developed pneumomediastinum and bilateral

surgical emphysema, without a pneumothorax and managed conservatively.

The majority of our patients were relatively young with comorbidities. Surprisingly, only 2 patients had an underlying chronic respiratory condition, raising the suspicion that pneumothoraces are in part mediated by the disease process itself. At the time of admission to ICU, most of the patients were in type 1 respiratory failure who then deteriorated, necessitating intubation. Four patients were morbidly obese with high positive end-expiratory pressure requirements and peak pressures on mechanical ventilation. Obese patients tend to be more prone to alveolar recruitment secondary to the weight of the chest wall and raised intra-abdominal pressures. As a consequence, higher positive end-expiratory pressures are often used to counteract these effects. This can come at the expense of increased ventilator-associated lung injury and may in part explain why these patients developed a pneumothorax. It has been reported that the median time to develop a pneumothorax secondary to barotrauma is 4–5 days postintubation, a finding which we saw in 5 of our patients [4]. It is also probable that a significant proportion of these patients had a degree of microscopic barotrauma prior to intubation whilst on continuous positive airway pressure, leading to earlier onset of pneumothoraces in some patients.

We have developed a simple best-practice protocol for the insertion of chest drains at our institution (Fig. 1). The usual principles and techniques of drain insertion still apply with COVID-19 patients with the additional precautions described below. We felt

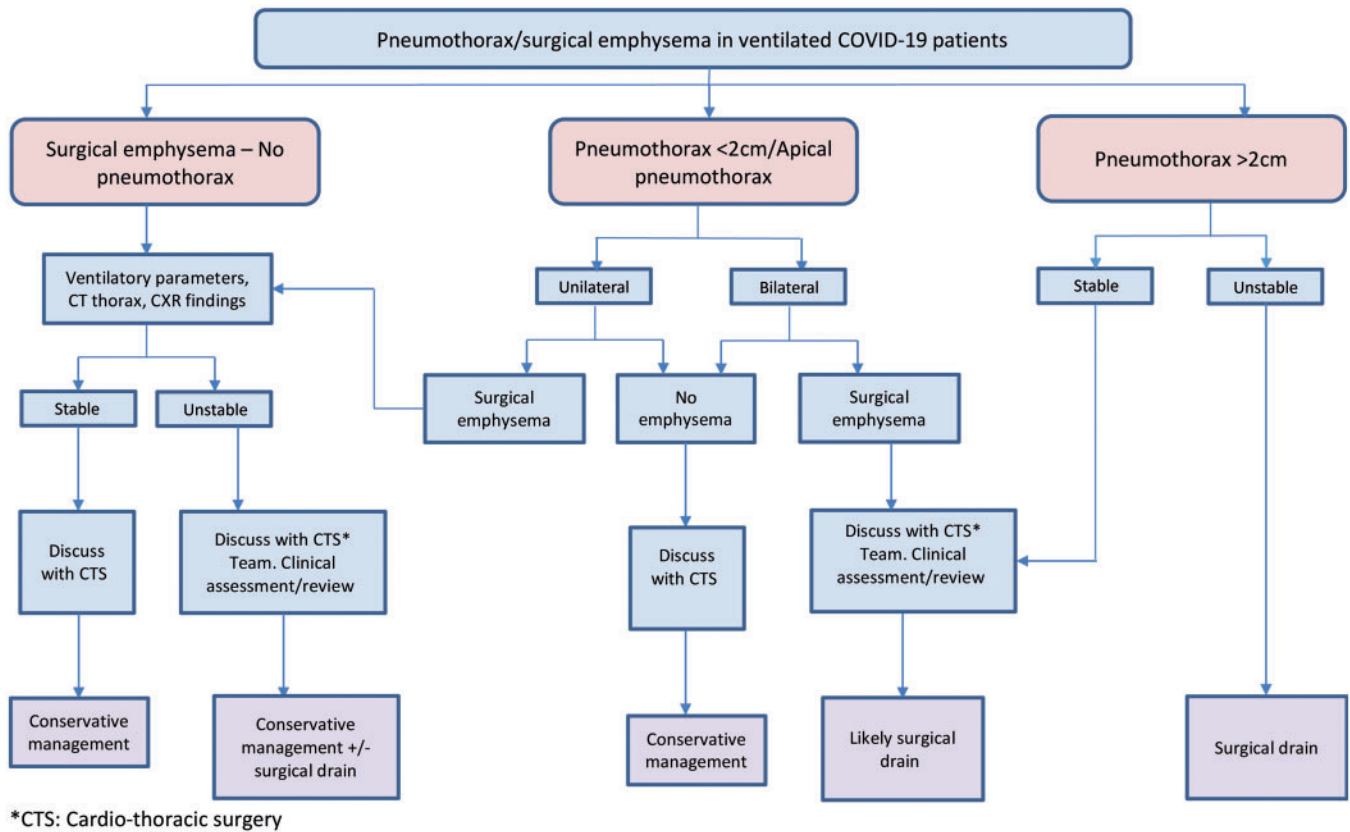


Figure 1: Schematic representation of chest drain insertion protocol in COVID-19 patients in an intensive care unit setting. CT: computed tomography; CTS: cardio-thoracic surgery; CXR: Chest X-Ray.

that the likely benefit of a chest drain is lower than in normal circumstances taking into consideration the higher risks to the patient and caring staff from aerosol contamination. As such, we have taken a cautious decision to closely observe patients with a pneumothorax <2cm to mitigate this risk. We have recommended surgical chest drains as opposed to Seldinger chest drains in this patient cohort for several reasons. First, we found that Seldinger drains were more technically challenging and prone to malfunction, particularly in patients with a large body habitus. In order to reduce exposure, we found it safer and more successful to bluntly dissect into the pleural space to insert a drain. Furthermore, Seldinger drains are often inserted 'blind', which, in combination with a poorly compliant lung, could theoretically increase the risk of parenchymal damage. This may manifest itself as an air leak with subsequent risk to attending staff and other patients. We recommend that all decisions to insert chest drains should be discussed (with the thoracic surgical team) on a case by case basis with thorough review of available imaging and patient's clinical status to ensure that appropriate decisions are made.

Protocol

1. Chest drain insertion (and removal) are aerosol-generating procedures and so, full Personal Protective Equipment (PPE) equipment (respirator mask, visor, full gown and double gloves) should be worn by the operator and any assistants or nearby staff.

2. Do not commence the procedure until all staff are wearing the PPE and the drain apparatus including the connected suction tubing are in place.
3. In order to keep the amount of aerosol generated to a minimum, the chest drain circuit must be a 'closed circuit'.
4. Keep the skin incision to the minimum required to safely insert a finger and ensure that the lung is clear. This will reduce any air leak around the drain at the insertion site.
5. If the patient will tolerate it, stop ventilation for a few moments at the actual time point that the drain is being inserted. DO NOT disconnect the ventilator but just stop positive pressure.
6. Even with the above manoeuvre, the lung is likely to be stiff and may not fall away from the chest wall and so take extra care to avoid the lung when inserting the drain.
7. As soon as the drain is in place, clamp the drain while the drain is being sutured in place. If necessary, use extra sutures at the insertion site to make the insertion site air-tight.
8. Before connecting the drain to the underwater seal and releasing the clamp, have the wall suction connected to the underwater seal bottle and switched on. Only then, connect the drain and release the clamp.

CONCLUSION

It is likely that the number of patients with a pneumothorax or surgical emphysema in ventilated COVID-19 patients will increase over the coming weeks and months. Our experience is very limited and we are in the process of prospectively analysing

all of our ICU COVID-19 inpatients to assess specific risk factors for the development of pneumothorax/surgical emphysema in addition to measuring outcomes. It is hoped that we will be able to identify variables that predict not only significant barotrauma in mechanically ventilated COVID-19 patients but also a safe management pathway that protects both staff and patients.

Conflict of interest: None declared.

Reviewer information

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