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Pneumomediastinum in the COVID-19 era: to drain or not to drain?

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Abstract

Pneumomediastinum (PNM) is a rare clinical finding, usually with a benign course, which is managed conservatively in the majority of cases. However, during the COVID-19 pandemic, an increased incidence of PNM has been observed. Several reports of PNM cases in COVID-19 have been reported in the literature and were managed either conservatively or surgically. In this study, we present our institutional experience of COVID-19 associated PNM, propose a management algorithm, and review the current literature. In total, 43 Case Series were identified, including a total of 747 patients, of whom 374/747 (50.1%) were intubated at the time of diagnosis, 168/747 (22.5%) underwent surgical drain insertion at admission, 562/747 (75.2%) received conservative treatment (observation or mechanical ventilation. Inpatient mortality was 51.8% (387/747), while 45.1% of the population recovered and/or was discharged (337/747). In conclusion, with increased incidence of PNM in COVID-19 patients reported in the literature, it is still difficult to assign a true causal relationship between PNM and mortality. We can, however, see that PMN plays an important role in disease prognosis. Due to increased complexity, high mortality, and associated complications, conservative management may not be sufficient, and a surgical approach is needed.

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Introduction

The outbreak of the respiratory symptoms associated with atypical pneumonia and severe respiratory syndrome that has spread around the globe over the past two years has been extensively described and attributed to the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1,2]. SARS-CoV-2 infection has been associated with rapidly progressing respiratory failure, increased oxygen demands, and need for intensive care unit (ICU) level of care, including intubation and mechanical ventilation [3].

Pneumomediastinum (PNM) and associated conditions are well described complications of mechanical ventilation, but they may occur spontaneously as well [4,5]. PNM may occur more commonly in the presence of underlying lung disease, such as chronic obstructive pulmonary disease (COPD) and asthma, or in hyperventilation states, such as infections, diabetic ketoacidosis, and inhalational drug abuse [6].

PNM is a medical condition characterised by the presence of air within the mediastinal cavity and can be further divided into 2 broad categories: spontaneous and secondary. Spontaneous PNM occurs when air tracks into the mediastinum without any clear identifiable cause. It is a rare condition and has a reported incidence of around 1 in 33,000 hospital admissions [7]. Secondary PNM is more common and is associated with an identifiable cause.

Pathogenetic mechanisms and causes of PNM can be further broken down into 3 categories: traumatic; non-traumatic, and iatrogenic [8,9]. The pathogenesis of air leakage into the mediastinum is thought to be due to alveolar rupture leading to air dissecting along the broncho-vascular sheaths and to pulmonary interstitial emphysema that spreads into the mediastinum [5,10,11]. Diagnosis is usually made radiologically, either by CXR or CT, and management can be either conservative or aimed at the underlying cause. PNM is associated with a good overall prognosis; however increased air accumulation may result in significant complications including subcutaneous emphysema, PTX and pneumopericardium, which may warrant surgical intervention [12].

Chest X-rays (CXR) are the most easily accessible imaging tests and can be diagnostic for PNM in approximately 48.4% of cases [10]. In addition, CXR may reveal relevant conditions, such as pneumopericardium and surgical emphysema [13] and complicated pneumonias. SARS-CoV-2 most commonly leads to the development of atypical pneumonias, seen as ground glass appearance (due to pulmonary infiltrates), which may develop following an acute lung injury [13]. Currently, computerised tomography (CT) is considered superior to CXR in the evaluation of acute lung injury (ALI); acute respiratory distress syndrome (ARDS); thrombotic phenomena; progression of consolidation; and response to treatment. CT is also useful in defining the extent of PNM and elucidating the potential reasons for its development, due to its ability to assess the parenchymal quality.

The most common radiological findings of COVID-19 pneumonia on CT include multifocal bilateral peripheral ground glass lesions, associated with patchy consolidations predominantly involving the dependent part of the lungs [14]. PNM has been reported in patients with COVID-19 [15], however, previously it was reported as a rare complication of viral pneumonia [16]. Direct visualisation may provide further insight compared to radiologic imaging tests. For example, endoscopy could be a valuable modality to confirm or exclude PNM and has been diagnostic in previous reports unrelated to COVID-19 symptoms [oesophagography (11.0%), oesophagoduodenoscopy (1.1%), and bronchoscopy (5.5%)]. However, these should be performed selectively when there is clinical suspicion of tracheal or oesophageal trauma, such as tracheobronchial injury at intubation [4].

The natural progression of COVID-19 and uncertainty among surgeons and intensivists, indicate the need for a surgical algorithm for the management of PNM and associated surgical emphysema (SE) and pneumothorax (PTX). In this paper, we aim to present our own experience of COVID-19 associated PNM and design an appropriate management algorithm based on a comprehensive review of the relevant literature.

Methods

A comprehensive literature search was performed, in lines with PRISMA guidelines, including PubMed (Medline), Embase, and Google Scholar. Search terms used were "pneumomediastinum" and "COVID-19" with the associated MeSH terms also included. Eligible studies were included without strict limitations based on type of study, type of publication, language, or date. Institutional data was reviewed retrospectively and cases with PNMs were identified and analysed. Data extracted included: CT findings; intubation status at time of PNM diagnosis; management and mortality.

The algorithm

COVID-19 patients often present with shortness of breath and increased oxygen requirements that warrant subsequent imaging studies [15,17-20]. With an increased number of PNM or complex air space cases, a management algorithm is necessary to deal with the different entities of PNM, PTX, SE distinctly or in combination. Follow up CT imaging is recommended in all patients with PNM. In the event of cardiorespiratory compromise and progressing PNM, a subxiphoid drain alone may preserve cardiopulmonary function and may prevent further air space accumulation. In this scenario, a subxiphoid drain insertion may be considered as a last resort especially if cardiorespiratory compromise is considered to be attributable to an increase in size of the PNM or pneumopericardium.

In the event of subcutaneous (SC) emphysema, this can be followed up conservatively especially in non-intubated patients. In intubated patients, the progression of both the PNM and the SE has to be monitored closely as these patients are at higher risk. If no improvement on follow-up imaging is seen, a subcutaneous drain insertion is suggested. In this scenario, if follow up imaging reveals an increase in SC emphysema with further respiratory compromise, one should consider a subcutaneous drain which may reduce the size of the emphysema. If PNM or pneumopericardium is also present, a subxiphoid drain as a last resort may be considered.

In the event of PTX, regardless of associated PNM or SC emphysema, a pleural drain and follow up with imaging is advisable [15,18-26].

No intrapleural drains were inserted pre-emptively at our institution, however in high-risk patients, in the eventuality of a pneumothorax occurring, surgical prep and materials necessary for chest insertion were made available at the bed of the patient [15,18-27]. Figure 1 summarises the above management algorithm.

Technique and Case Presentations

In performing a subxiphoid drain insertion we need to consider that some patients receive anticoagulation, normally with low molecular weight heparin, as part of COVID-19 protocols [28] for pulmonary emboli, which increases the risk of periprocedural bleeding. The technique of subxiphoid drains insertion for pneumomediastinum can be adapted from the previously described technique of subxiphoid pericardial drainage techniques first described by Larrey [29] and popularised by Allingham [30]. By making the incision on the xiphoid process and palpating the xiphoid, a tunnel can be made underneath it close to the sternum and above the pericardium through the usual insertions of the diaphragmatic defects described by Larrey [29]. A small diameter drain can be inserted in that space and the channel created is enough for air to escape, along the path of least resistance, especially with the use of suction (-3kpa to -5kpa) [30,31].

Our institutional experience

We report five cases of PNM and associated conditions (surgical emphysema, PTX, pneumopericardium) secondary to COVID-19 in patients with or without mechanical ventilation (Summarised in Table 1).

Case #1: A 59-year-old male with minimal pneumomediastinum and bilateral consolidated COVID-19 changes, complicated by surgical emphysema which was managed conservatively. Patient acutely deteriorated while in prone position and bedside examination revealed a right sided tension pneumothorax – a chest drain was inserted (Figure 2a).

Case #2: A 68-year-old intubated male with massive subcutaneous emphysema and pneumomediastinum associated with bilateral consolidative changes in the dependent areas of the lung. Management with subcutaneous drain insertion resulting in resolution of both the pneumomediastinum and the surgical emphysema (Figure 2 b,c).

Case #3: A 60-year-old intubated woman with pneumomediastinum that resolved with conservative management (Figure 2d).

Case #4: A 75-year-old intubated female with massive subcutaneous emphysema and COVID-19 related bilateral consolidation associated with pneumomediastinum that resolved after drain insertion (Figure 2e).

Case #5: 60-year-old patient with right sided pleural drain and subxiphoid drain inserted for pneumomediastinum associated with pneumothorax (Figure 2f).

Table 1. Summary of COVID-19 cases documented at our institution presenting with pneumomediastinum.

	Case				
	1	2	3	4	5
Age	59	59	68	60	75
Sex	M	M	M	M	F
Ventilation	MV	CPAP	CPAP	MV	MV
PE	Bilateral	-	-	-	-
SC Emphysema	+	+	+	-	+
PTX	-	-	-	+	-
PNM	+	+	+	+	+
Management	Conservative	MV + Chest drain	SC + Chest drains	Conservative	SC drain
Mortality	+	+	+	-	-

M, male; F, female; MV, mechanical ventilation; CPAP, continuous positive airway pressure; PE, pulmonary embolism; SC, subcutaneous; PTX, pneumothorax; PNM, pneumomediastinum.

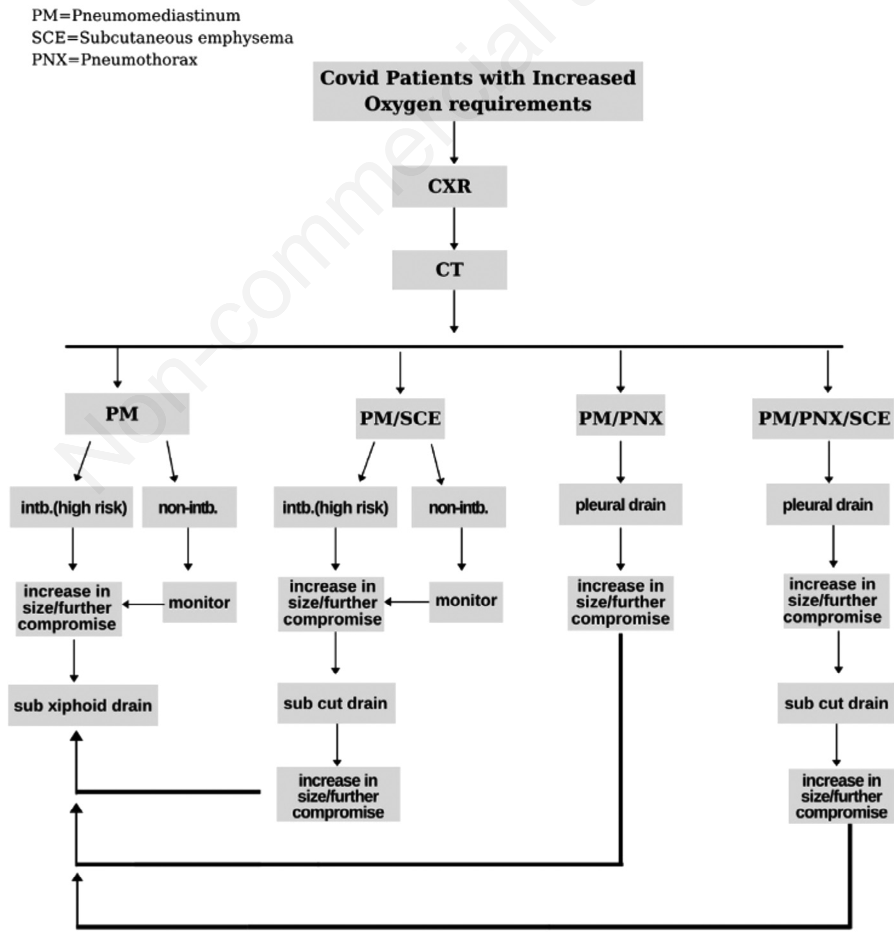

Figure 1. Diagrammatic representation of the proposed management algorithm for different air space collections including subcutaneous emphysema (SCE), pneumothorax (PTX), pneumomediastinum (PM).

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Discussion

In our analysis we summarise 43 studies which report PNM in patients with known SARS-CoV-2 infection. These studies report a total of 747 cases diagnosed with PNM and 374/747 (50.1%) were intubated at the time of diagnosis, 168/747 (22.5%) required surgical drainage at admission, 562/747 (75.2%) received conservative treatment (observation or mechanical ventilation), and 17/747 (2.3%) cases had no recorded management. Inpatient death was reported in 387/747 (51.8%) cases and resolution/discharge in 337/747 (45.1%). Given the limitations of the included studies it was often difficult to determine whether the observed deaths were specifically due to the presence of PNM. However, we can see that our observed death rate of 51.8% is higher than the reported mortality rate of 120.3 deaths per 100,000 during the initial pandemic [32]. A summary of the included studies can be found in Table 2.

It is becoming increasingly evident that there is a relatively high incidence of pneumomediastinum in COVID-19 patients compared to the general population [33]. The underlying pathogenetic mechanisms have not been fully elucidated. COVID-19 primarily affects the respiratory system as patients present with a dry cough and shortness of breath being reported as two of the most common symptoms [34]. Typical CT findings include ground glass opacities and/or consolidations. The combination of opacities and septal thickening also gives rise to the characteristic "crazy-paving" pattern often seen on CT imaging [35]. Therefore, this increased incidence could be partially attributed to the pathological lung parenchymal changes caused by COVID-19. Further, severe COVID-19 can lead to ARDS [36], need for invasive or non-invasive mechanical ventilation, which are well documented causes of pneumomediastinum [9].

From the cases identified in the literature, 49.9% and 50.1% were diagnosed with PNM prior to or after intubation respectively. However, it is difficult to confirm whether the increased incidence is due to non-traumatic or traumatic factors and further studies are required. On the other hand, we could postulate that the increased incidence rates observed may be due to diagnostic bias. Acute deterioration of patients may have resulted in increased number of radiological imaging studies. Therefore, the observed increase in incidence may merely be due to increased detection rates of otherwise clinically insignificant PNM. Further study is needed to investigate the severity of PNM and compare the severity and incidence between COVID-19 patients and non-COVID-19 patients.

The majority, 562/747 (75.2%) of PNM cases reported in this study were managed conservatively, whereas only 168/747 (22.5%) received insertion of a surgical drain. The current management for PNM is aimed at symptomatic management and slow spontaneous resolution/reabsorption of the collected air [9]. We found that 564/747 (75.5%) cases present with PNM alongside other air space collections such as: subcutaneous emphysema, PTX, or Pneumopericardium; or embolic phenomena. Therefore, we propose that conservative management may not be sufficient in these cases. Given the high inpatient death rates observed from the studies summarised in Table 2 (51.8%) we should consider whether an early surgical drainage of the air collections may reduce the rate of related complications and decrease mortality rates.

When considering surgical interventions, it is important to mention that some patients are not good surgical candidates. In these patients, the risks of the procedure often outweigh the potential benefits and therefore the intervention would not be safe. The ASA Physical Status Classification System is a critical tool that is used to assess patients' suitability for surgery [37].

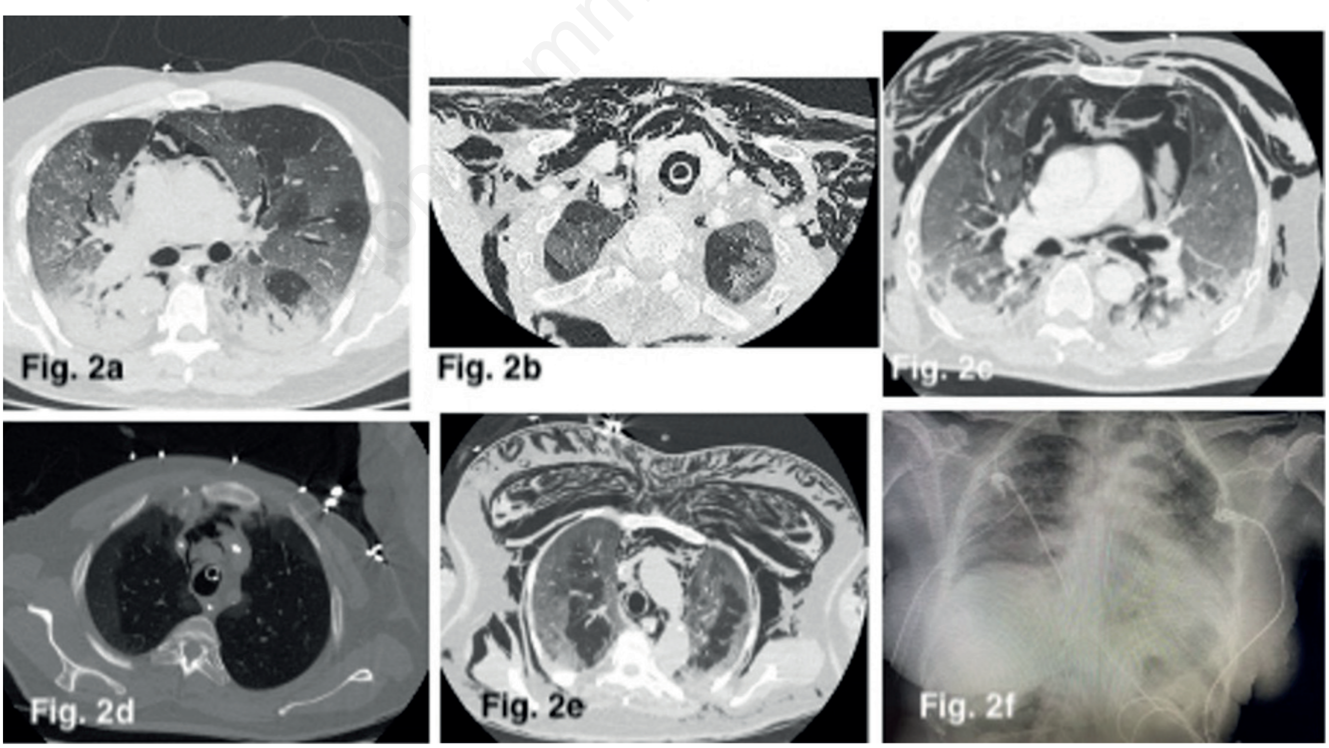

Figure 2. Radiological findings of the 5 cases we report identified from our own institutional experiences. a-e) Computed tomography (CT) images and (f) chest X-ray demonstrating different air space collections.

Table 2. Summary of the reported COVID-19 cases presenting with pneumomediastinum documented in the literature.

Study (year published)	Number of cases	Intubated	Other CT findings	Management	Outcomes Resolution / ongoing treatment	Mortality
Gorospe [39] (2020)	4	0	1 + gas dissection along both main bronchi 1 + gas in pre-vascular mediastinal fat 1 + PE	4/4 conservative	3	1
Al-Azzawi [26] (2020)	3	3	2 + SC emphysema (1 prior to intubation) 1 + SC emphysema and PTX	2/3 conservative 1/3 pleural chest tube insertion	1	2
Reyes [40] (2020)	2	0	2 + SC emphysema (1 + PE and PTX)	1/2 conservative 1/2 chest drain insertion	0	2
Manna [41] (2020)	10	0	10 + SC emphysema (1+ PTX)	10/10 conservative (7/10 MIV)	6	4
Volpi [42] (2020)	3	3	3 + SC emphysema (1 + PTX)	3/3 conservative	3	0
Suwanwongse [43] (2020)	4	4	2 + SC emphysema (1+ tension PTX, 1 + PTX) 1 + PTX	4/4 inter pleural chest drain	0	4
Romano [18] (2020)	2	0	2 + SC emphysema	2/2 conservative	2	0
Wadhawa [44] (2020)	4	1	3 + SC emphysema	4/4 conservative	2	2
Loffi [27] (2020)	6	0	2 + SC emphysema 1 + SC emphysema + pneumopericardium	6/6 conservative (3/6 MIV)	5	1
Oye [45] (2020)	2	0	1 + PTX + SE emphysema 1 + bilateral PTX + pulmonary oedema	2/2 thoracostomy tube insertion + MIV	NR	NR
López Vega [24] (2020)	3	0	1 + bilateral hydroPTX 1 + PTX 1 + bilateral segmental PE	2/3 conservative (1/2 NIV) 1/3 chest drain insertion (PTX)	0	3
Mallick [46] (2020)	2	0	1 + bilateral PTX + SC emphysema 1 + PTX + SC emphysema + thrombosis of pulmonary artery/vein	1/2 conservative 1/2 bilateral chest drain insertion	2	0
Eperjsiova [19] (2020)	5	0	1 + SC emphysema (extending into the neck) 3 + SC emphysema 1 + PTX	4/5 conservative (3/5 MIV) 1/5 chest tube	5	1
Wali *et al.* [47] (2020)	5	5	4 + surgical emphysema (2/3 + tamponade) 1 + PTX	1/5 conservative 2/5 bilateral intrapleural chest drain insertion + SC drains 1/5 intrapleural chest drain insertion 1/5 bilateral chest drain insertion (+ ECMO)	4	2
Brogna [48] (2020)	2	0	1 + pneumopericardium 1 + PTX (loculated) + SC emphysema	1/2 conservative (NIV) 1/2 intercostal chest drain insertion	2	0
Juárez-Lloclla [49] (2021)	12	0	1 + PTX5 + pneumopericardium 1 + pneumopericardium + PTX 2 + pneumopericardium + SC emphysema 3 + pneumopericardium + PTX + SC emphysema	12/12 conservative	6	6
Rafiee [50] (2021)	1	0		1/1 conservative	1	0
Protrka [51] (2021)	3	0	2 + SC emphysema (1 + PTX)	1/3 conservative 2/3 thoracic drainage catheter	2	1
Tacconi [52] (2021)	16	7	4 + PTX	15/16 conservative1/16 SC drainage	2	14
Iuorio [53] (2021)	2	0	1 + PTX	2/2 conservative	1	1
Machiraju [54] (2021)	3	1	2 + SC emphysema 1 + pneumopericardium	3/3 conservative	1	2
Diaz [55] (2021)	3	0	1 + PTX 1 + pneumopericardium	2/3 conservative 1/3 chest drain insertion	2 (1+ persistent PNM	0
Jamil [56] (2021)	5	5	3 + PTX	3/5 conservative 2/5 chest drain insertion	2	3
Adhikary [57] (2021)	5	1	3 + PTX1 + SC emphysema	3/5 conservative 2/5 chest drain insertion	2	3
Sabharwal [58] (2021)	2	1	2 + SC emphysema	2/2 conservative	0	2
Sethi [59] (2021)	10	3	10 + SC emphysema (4 + PTX)	5/10 conservative 5/10 chest drain insertion	3	7

To be continued on next page

For patients that sit higher on the ASA classification, a big risk of surgery is general anaesthesia and often this requires significant pre-operative planning to optimise patients whenever possible. Most included studies report patients with an acute presentation, which precludes adequate preoperative preparation and optimisation prior to surgical intervention. However, drain insertion procedures are relatively simple and can be done with local anaesthetic and sedation [38] at the bedside. Therefore, as general anaesthetic is not required, extensive planning is not needed, and higher ASA patients may receive potentially lifesaving interventions.

In our analysis, data related to confounders, such as patient demographics or background health conditions were missing or not reported in several of the included studies. These variables could have an impact on patient outcomes, and it would be crucial for future studies to explore their effect. Furthermore, many studies included in this paper did not explicitly report mortality classified

Table 2. Continued from previous page.

Study (year published)	Number of cases	Intubated	Other CT findings	Management	Outcomes Resolution / ongoing treatment	Mortality
Damous [60] (2021)	4	3	1+ SC emphysema 2+ PTX (1+ pneumoperitoneum)	1/4 orotracheal intubation 1/4 bronchoscopy 1/4 thoracic drainage (+ bronchoscopy) 1/4 thoracic drainage	2	2
Edwards [61] (2021)	10	10	2 + PTX + SC emphysema 7 + SC emphysema	6/10 conservative 4/10 chest drain insertion	5	5
Rodriguez-Arciniega [62] (2021)	9	0	2 + bilateral PTX	9/9 conservative (3/9 MIV)	6	3
Shaikh [63] (2021)	21	9	11 + PTX	21/21 conservative (20/21 MIV)	9	12 (7/12 + PTX)
Udi [64] (2021)	5	5	2 + PTX 1 + SC emphysema + pneumopericardium 1 + SC emphysema	3/5 conservative 2/5 chest drain insertion	NR	NR
Kalpaxi [65] (2021)	3	0	1 + PE 1 + PE and SC emphysema and pneumopericardium	3/3 conservative (1/3 MIV)	3	0
Kangas-Dick [66] (2021)	36	34	12 + concurrent or subsequent PTX	20/36 conservative 16/36 chest drain insertion	3 (7 still ongoing management)	24
Mangel and Madden [67] (2021)	3	0	2 + SC emphysema 1 + tracheal defect (SC emphysema + pneumopericardium + worsening PNM post intubation)	3/3 conservative (MIV)	0	3
Kabi [68] (2021)	4	3	1 + SC emphysema + bilateral PTX 1 + bilateral PTX 1 + PTX + PE	2/4 conservative 2/4 chest drain insertion	(1 remain in ICU)	3
Haberal [69] (2021)	7	0	7 + SC emphysema	7/7 conservative	6	1
Cut [70] (2021)	7	0	2 + SC emphysema 1 + SC emphysema + pneumopericardium 4 + SC emphysema + PTX	6/7 conservative 1/7 ECMO	1	6
Coppola [71] (2021)	6	0	1 + PTX	6/6 conservative (4/6 NIV)	5	1
Chen [72] (2021)	4	0	2 + SC emphysema	4/4 conservative	1	3
Gandolfo [73] (2022)	21	4	20 + SC emphysema 11 + PTX	17/21 conservative 4/21 chest drain insertion	12	9
Ozdemir [74] (2022)	24	22	5 + PTX	1/24 conservative 4/24 chest drain insertion 2/24 mediastinal drain insertion 17/24 NR	4	20
Reis [75] (2022)	87	78	23 + PTX 64 + SC emphysema	8/87 conservative 619/87 chest drain insertion	28	59
Melhorn [8] (2022)	377	172	154 + PTX 280 + SC emphysema	294/377 conservative (241/253 MIV) 83/377 chest drain insertion	195 (+ 7 still ongoing treatment)	175
Total	747	374	564 have further CT findings	Conservative: 562 Drain insertion: 168 (17 NR)	337 (+ 7 NR / + 16 ongoing treatment)	387

NIV, non-invasive ventilation; MIV, mechanical intubated ventilation; PE, pulmonary embolism; SC, subcutaneous; PTX, pneumothorax; PNM, pneumomediastinum; ECMO, extracorporeal membrane oxygenation; NR, not recorded.

by treatment. In this paper we highlight the need for a new management algorithm, yet further clinical validation is required to identify potential benefits of the proposed algorithm and its impact on mortality.

Conclusion

An increased incidence of pneumomediastinum in COVID-19 patients has been noticed recently in the literature. However, the pathophysiology and pathogenesis of pneumomediastinum in COVID-19 patients may be confounded by a multitude of precipitating factors, meaning that linking causality is still a matter for debate. The presence of pneumomediastinum poses a significant impact on disease prognosis. Therefore, features such as respiratory deterioration and progression of otherwise benign air spaces may be grounds for careful follow up. This could be achieved with higher resolution imaging and treatment with chest drain insertion. For air space complications such as pneumomediastinum, surgical emphysema, pneumothorax, which may be found simultaneously, a proposed treatment algorithm can be applied knowing that these patients belong to a high-risk group. Whether a drain insertion and the proposed algorithm is the key element in the management of this subpopulation of patients' needs to be explored by further studies, considering the complexity of the disease.

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