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Pneumothorax and pneumomediastinum among COVID-19 patients with mechanical ventilation: a case series

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ABSTRACT

The incidence of pneumothorax is 10% of all COVID-19 patients and increases in patients who develop acute respiratory distress syndrome (ARDS) with mechanical ventilation, responsible for 24% of the population. As many as 60.7% of patients who have complications of pneumothorax or pneumomediastinum lead to mortality. This study was established to determine the potential of early tracheostomy in preventing the occurrence of pneumothorax and pneumomediastinum in COVID-19 and reducing mortality. This research was conducted as a descriptive study by case series of three COVID-19 patients in Jakarta, Indonesia in the span of 2021-2022. Tracheostomy performed within 10 days, did not develop a pneumothorax. Although, the patient did not have any comorbidities, age below 70 years, and coagulopathy problem, there was still a risk of recurrent pneumothorax post COVID-19 after tracheostomy. However, a tracheostomy is a procedure that poses an aerosol risk, so there is concern about the transmission of COVID-19 to medical personnel who perform it. Early tracheostomy has the potential to accelerate the resolution of COVID-19 disease in patients and has a positive impact on lung vitality. It is aimed to prevent hypoxic conditions and optimize the lung recruitment process. In addition, they did not experience complications from COVID-19 in the form of an air leak syndrome such as a pneumothorax or pneumomediastinum.

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1. INTRODUCTION

Based on epidemiological data, COVID-19 has been growing in the last three years. The development of COVID-19 disease initiated various studies, ranging from management to complications of COVID-19 [1]. One of a pivotal complication that commonly occurs in COVID-19 with acute respiratory distress syndrome (ARDS) is pneumothorax [2]. The incidence of pneumothorax reaches 10% of the COVID-19 patient population. Based on research, 33% of patients who experience pneumothorax complications in COVID-19 are associated with pneumomediastinum [3]. The incidence of pneumothorax increases in COVID-19 patients with ARDS by mechanical ventilation usage, responsible for 4% of the population [4]–[6].

Mechanical ventilation is one of airway intervention given to manage COVID-19 patients with severe ARDS [7], [8]. It is beneficial for the lung recruitment process. However, the impact caused by providing positive pressure ventilation on the lungs in COVID-19 will bring pneumothorax and pneumomediastinum [9], [10]. As many as 60.7% of COVID-19 patients who experienced pneumothorax or pneumomediastinum complications had a mortality risk, compared to 38.6% of patients without these COVID-19 complications [11]. Several theories of the pathogenesis of pneumothorax and pneumomediastinum in COVID-19 patients are evolving [12]. Based on a study of lung autopsy samples of eight COVID-19 patients by Felice D'Agnillo and team in 2021 [13], postmortem histopathology results showed excessive thrombosis and late-onset pulmonary tissue and vascular remodeling [14]. It led to progressive diffuse alveolar damage. First, due to the cytokine storm occurred in COVID-19 patients, there was a defect in tissue healing [15]. It will result in acute damage to the alveolar-capillary barrier with loss of surfactant protein expression [16]. Secondly, the cytokine storm process caused raised of plasminogen activator inhibitor-1 level resulting in failure of clot fibrinolysis [17]. Some literatures discuss the potential of tracheostomy in reducing the duration of mechanical ventilation, which is a preventive measure for complications of pneumothorax and pneumomediastinum [11], [18].

Based on previous studies, early tracheostomy reduces the duration of mechanical ventilation use by 6.7 days (p=0.016). In addition, early tracheostomy shortens the length of stay in the intensive care unit, averaging 6.9 days (p=0.005). No surgeons were recorded to be directly infected with COVID-19 after tracheostomy surgery [19]–[21]. It is similar with this study. Ideally, tracheostomy is performed within the first 10 days of mechanical ventilation, with the onset of pneumothorax or pneumomediastinum in the first 5 to 7 days after mechanical ventilation [19], [21], [22]. However, in the second case, patient had no risk factors and comorbidities which increase the risk of air leak syndrome complications. In addition, the hemodynamic condition was stable for ventilator weaning after tracheostomy Figure 1. The patient has a history of tocilizumab administration in COVID-19. According to previous studies, one of the risk factors for pneumothorax in COVID-19 patients is the prescription of tocilizumab (HR 10.7; 95% CI, 3.60-32.0; p<0.001) [5], [23]. However, there is no further research that describes how the process of IL-6 inhibition drugs can affect the incidence of pneumothorax [24].

The aim of this study was to describe cases of COVID-19 with mechanical ventilation who developed complications, such as pneumothorax and pneumomediastinum. Each case was described with different approach of management. This study was intended to observe whether early tracheostomy is beneficial in preventing pneumothorax and pneumomediastinum with mechanical ventilation.

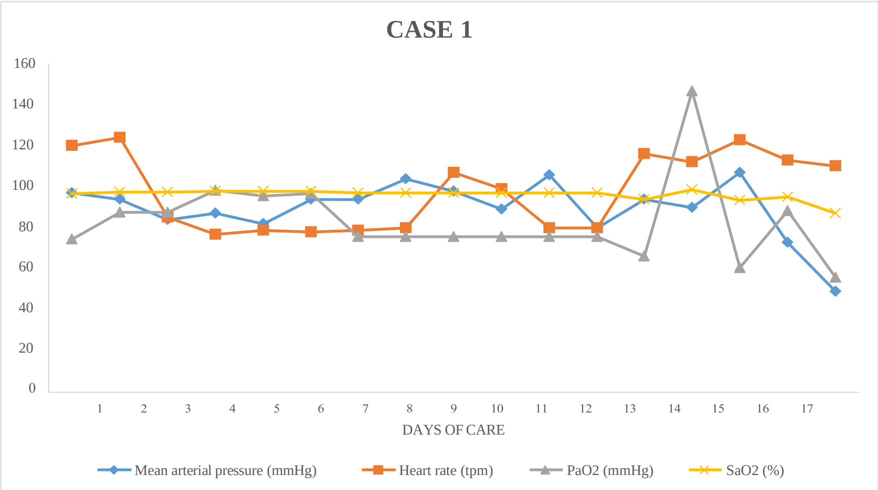

Figure 1. Oxygenation and hemodynamic parameters of case I

2. RESEARCH METHOD

This research was conducted in the form of a descriptive case series study of three COVID-19 patients who had complications of pneumothorax and pneumomediastinum in Jakarta, Indonesia from 2021 to 2022 [25]. All three patients received intervention in the form of tracheostomy within various onset and comorbidities. The aim of this study is to determine the potential of early tracheostomy in preventing pneumothorax and pneumomediastinum in COVID-19, reducing mortality, and shortening the length of stay of ARDS patients in the intensive care unit. Eventually, it is useful as a consideration for a doctor in providing surgical intervention management in COVID-19 patients and reducing patient care costs for hospitals or health insurance.

3. RESULTS AND DISCUSSION

3.1. Patient number one, a 70-year-old man

A 70-year-old man, admitted to intensive care unit (ICU) with desaturation with oxygen saturation below 80% (SaO2 60%) and gasping. He had been symptomatic with cough and shortness of breath for 14 days ago, but the patient was self-isolated. He had a comorbidity of acute coronary syndrome (ACS). When admitted to the ICU, the patient was gasping, tachycardia with HR 121 beats per minute and non-ST elevation myocardial infarction (NSTEMI) due to COVID-19. He was given mechanical ventilation via endotracheal tube (ETT) with ventilator mode pressure control ventilation (PCV) positive end-expiratory pressure (PEEP) 8 cmH2O, FiO2 80%, IP 24.0 cmH2O and tidal volume 778 ml/kg. Computed tomography (CT) scan of the patient's thorax showed multifocal ground glass opacities (GGO) and diffuse consolidation in both lungs. Laboratory examination showed positive Polymerase Chain Reaction (PCR) swab with CT value 22.0, ferritin 1549.95 ng/ml, D-dimer 3.99 mcg/ml, interleukin-6 (IL 6) 381.1 pg/ml, C reactive protein (CRP) 166.25 mg/l and procalcitonin 1.62 ng/ml. Blood gas analysis showed ARDS with PF ratio of 83 mmHg (PaO2 74.4 mmHg; FiO2 90%). He deteriorated ten days after intubation. CT scan of the thorax showed increased infiltrate in both lungs and pneumomediastinum. After 13 days post intubation, a tracheostomy was performed. Post tracheostomy thorax x-ray showed no improvement in ARDS. There was secondary infection in the lungs from the sputum culture results in the form of Klebsiella pneumoniae growth. Mortality in this patient was three days post tracheostomy with symptoms of desaturation 60% on ventilator and symptoms of cardiac tamponade Table 1, Figures 1 and 2.

Table 1. Sociodemographic and clinical profile from three patients of COVID-19

Sociodemographic and clinicalprofile	Case 1	Case 2	Case 3
Sociodemographic profile			
Age (year)	70	45	72
Sex (male/female)	Male	Male	Female
Body mass index (BMI) (kg/m2)	27.7	22.1	17.8
Risk factor			
Smoking (Y/N)	Yes	No	No
Mechanical Ventilation (Y/N)	Yes	Yes	Yes
Tocilizumab (Y/N)	No	Yes	No
Comorbidity			
Asthma	No	No	No
Autoimmune disease	Yes	No	No
COPD (Y/N)	No	No	No
Diabetes mellitus(Y/N)	Yes	No	No
Hypertension (Y/N)	No	No	No
Myocardial infarction (Y/N)	Yes	No	No
Stroke (Y/N)	No	No	Yes
Tuberculosis (Y/N)	No	No	No
Tumor (Y/N)	No	No	No
Clinical profile			
Vasopressor agent	Yes	No	No
D dimer (mcg/ml)	3.99	3.3	3.89
Ferritin (mg/ml)	1549.95	No data	9262.75
C-Reactive Protein (m/l)	166.25	67.7	177.07
Procalcitonin (ng/ml)	1.62	<0.05	0.74
Interleukin-6 (pg/ml)	381.1	19.68	63.59
Radiology findings	ARDS with pneumomediastinum	Left pneumothorax, right hydropneumothorax, subcutaneous emphysema, superior pneumomediastinum	Multiple infiltrates on bilateral lungs (ARDS). No pneumothorax/ pneumomediastinum
Ventilator Mode	PCV	Continuous positive airway pressure (CPAP)	PCV
Tidal volume (ml/kg)	778	387	387
IP (cmH2O)	24	15	21
PEEP (cmH2O)	8	6	8
FiO2 (%)	80	60	80
Length of mechanicalventilation (days)	14	20	10
Length of stay in ICU (days)	17	39	18
Mortality (Y/N)	Yes	No	No
Microbial culture pathogen in airway	*Klebsiella pneumoniae*	*Stenotrophomonas maltophilia*	Negative

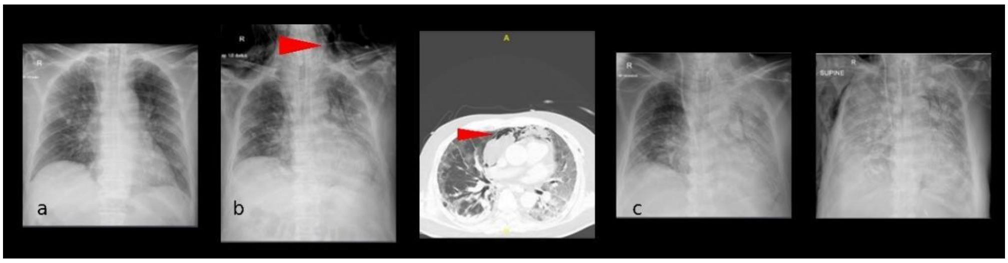

Figure 2. Radiology findings of case I

3.2. Patient number two, a 45-year-old man

A 45-year-old man was admitted to the ICU with complaints of cough and shortness of breath for seven days ago. He was admitted to the ICU with SaO2 65% using non re-breathing mask 15 lpm. Then, he used high flow nasal cannula as mechanical ventilation with FiO2 70-80% and flow 40-60 lpm. The first thoracic CT scan showed pneumonia with bilateral moderate ground-glass opacity (GGO). He received tocilizumab on the second day of COVID-19 infection. He was treated using high flow nasal cannula (HFNC) until the swab converted negative.

Post COVID-19, he still had ARDS and used invasive mechanical ventilation with a history of 2 failed weaning and right lung decortication thoracotomy with the cause of empyema after tocilizumab administration. Laboratory showed D-dimer 3.30 mcg/ml, C reactive protein 67.70 mg/l, IL 6 19.68 pg/ml, and procalcitonin <0.05 ng/ml. One-month post COVID-19 the patient was still admitted to the ICU and had difficulty weaning, with thoracic CT scan images of pneumonia in both lungs accompanied by bilateral pneumothorax. Two days after recurrent pneumothorax was seen, water sealed drainage (WSD) insertion and tracheostomy insertion were performed. In 17 days later, the patient was able to T-Piece 10 lpm and homecare. Prolonged length of stay in ICU led to secondary pulmonary infection in the form of sputum culture results at the end of treatment with Stenotrophomonas maltophilia infection Figures 3 and 4.

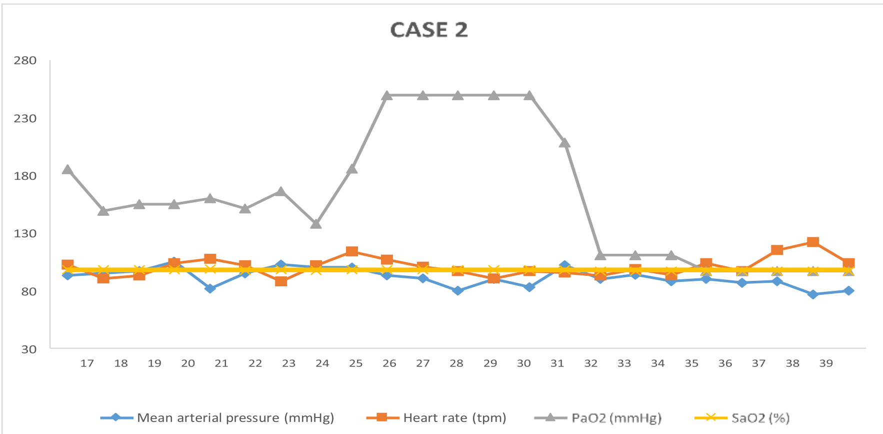

Figure 3. Oxygenation and hemodynamic parameters of case II

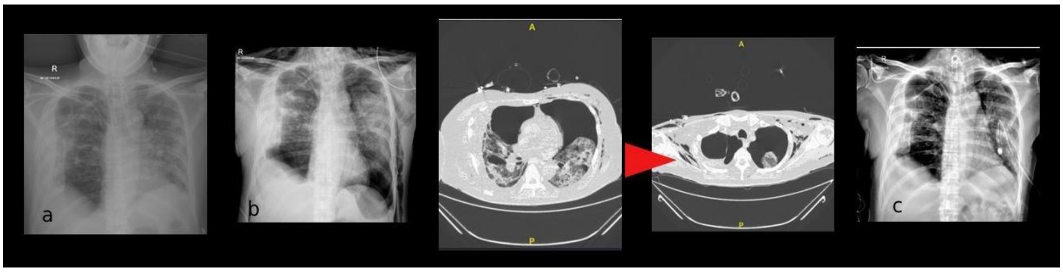

Figure 4. Radiology findings of case II

3.3. Patient number three, a 72-year-old woman

A 72-year-old woman, with complaints of desaturation, gasping breath, and decreased consciousness Glasgow Coma Scale (GCS) E2M4Vaphasia. She had a stroke before COVID-19 diagnosis, with clinical right hemiparesis. Swab PCR was positive with CT value 23.61, other tests included ferritin 9262.75 ng/ml, D-dimer 3.89 mcg/ml, procalcitonin 0.74 ng/ml, C reactive protein 177.07 mg/l, and IL 6 63.59 pg/ml. Radiology showed infiltrates in both lungs and posterobasal atelectasis component of the right lung. She was intubated and used invasive mechanical ventilation with PCV mode: FiO2 80%, PEEP 8 cmH2O, IP 21.8 cmH2O, tidal volume (TV) 387 ml/kg.

Ventilator could be gradually reduced to CPAP at nine days post tracheostomy with FiO2 50% and PEEP 6 cmH2O. On day ten, an early tracheostomy was performed. She can be taken off the ventilator two days later. Five days post tracheostomy, the patient's PCR swab converted to negative. There were no COVID-19 complications due to prolonged mechanical ventilation as evidenced by the post tracheostomy thorax x-ray showing the results of a relatively reduced infiltrate compared to before without any pneumothorax or subcutaneous emphysema Figures 5 and 6.

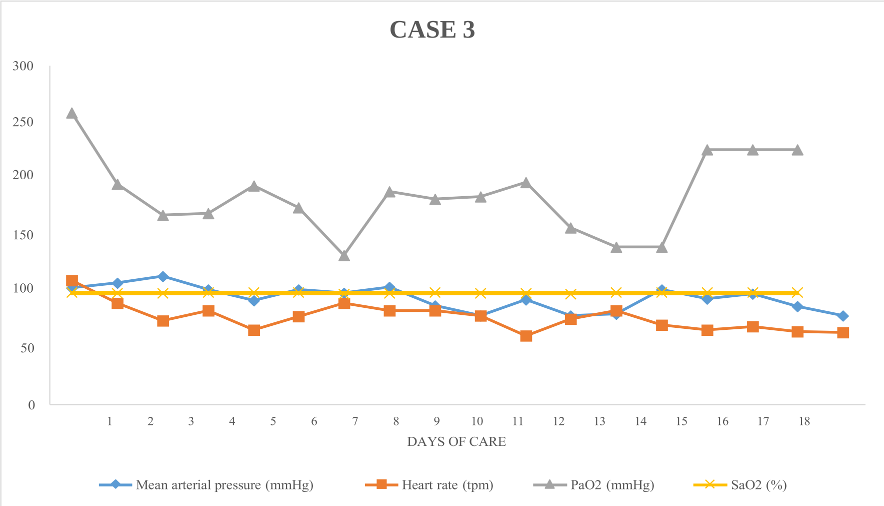

Figure 5. Oxygenation and hemodynamic parameters of case III

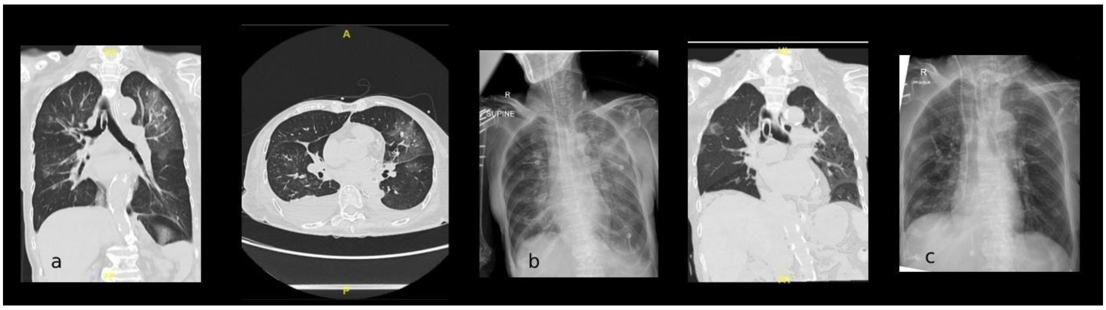

Figure 6. Radiology findings of case III

All three patients underwent tracheostomy procedures at different times. The medical decision was discussed by three intensivists and agreed by two surgeons. Tracheostomies performed ≤10 days did not have pneumothorax as a complication of COVID-19. Third case was >70 years old with moderate to severe CT thoracic ground glass opacity. Third case can be weaned off from ventilator the day after tracheostomy. The patient's PCR swab converted to negative five days later. The other two patients who did not undergo early tracheostomy had complications of pneumothorax or pneumomediastinum. Although second case was without comorbidities, age ≤70 years, but still at risk of recurrent pneumothorax post COVID-19 after tracheostomy. First case with hyper coagulopathy has higher mortality outcomes if tracheostomy is performed. Early tracheostomy has the potential to accelerate the resolution of COVID-19 disease in patients and have a positive impact on lung vitality.

Based on the data in this study, three patients were given mechanical ventilation within various length of mechanical ventilation and PEEE/FiO2 Table 1. The purpose of mechanical ventilation was to prevent hypoxic conditions and optimize the lung recruitment process. Patients were considered for tracheostomy procedures within various onset. Results showed that patients who received early tracheostomy had a significantly improved clinical profile for weaning from mechanical ventilation, which was a day after procedure. In addition, patients with early tracheostomy did not have COVID-19 complications in the form of air leak syndrome such as pneumothorax or pneumomediastinum. This is an advantage because the oxygenation parameters and hemodynamic parameters of patients are relatively more stable to be weaned from the ventilator when compared to patients with delayed tracheostomy Figures 1, 3, and 5. Patients with pneumomediastinum and delayed tracheostomy had a mortality of 28 days if performed on high-risk patients Table 1. Meanwhile, patients who did not have risk factors and comorbidities from COVID-19, still have complications of air leak syndrome and prolong length of stay in the ICU Table 1.

According to the previous studies, pneumothorax and pneumomediastinum are associated with the risk of death in COVID-19 patients. Through a multiple logistic regression analysis, the occurrence of pneumothorax or pneumomediastinum increased the risk of mortality (OR=3.64; 95% CI, 1.24-10.70; p=0.019). It is similar with other studies that patients with pneumomediastinum complications are at risk of mortality due to hemodynamic instability, namely in 52% of patients using vasopressor agents [11], [18]. Based on study above, the first case, a patient with pneumomediastinum, had worsening conditions in the form of hemodynamic instability 48 hours after delayed tracheostomy as confirmed by the prescribed of vasopressor agents. In the second case, a patient with air leak syndrome did not use vasopressor agents and did not have mortality even though the length of stay in the ICU was >28 days Table 1.

Early tracheostomy is a definitive airway technique in the form of a tracheostomy performed within the first 10 days after intubation. The criteria are i) an endotracheal tube has been held for ≥14 days with a lot of bronchial secret production; ii) the decision is determined by two or more intensivists; iii) the surgeon who performs it agrees in determining the urgency of tracheostomy; iv) the patient gets mechanical ventilation with minimum requirement FiO2 ≤50% and PEEP ≤10; e) good prognosis (exclusion if the patient is >70 years old, with multiple organ failure, and does not have severe coagulopathy) [26], [27].

Hereupon COVID-19 infection, respiration cells from the lung parenchyma are infiltrated by inflammatory cells resulting in edema in the lung parenchymal tissue followed by abnormal radiological changes in the form of ground glass opacities evolving consolidation. Histopathological conditions found in COVID-19 patients have air leak syndrome. Alveoli and bronchioles are blocked by exudates and infiltrating inflammatory cells, which form a "ball-valve" mechanism. As a result, the pressure inside the alveoli increases progressively with a peak in the expiratory phase. This inflammatory cell infiltration creates endotheliitis the micro vessels surrounding the lung parenchyma, transforming into thrombosis [28].

Remarkably, in COVID-19 cases, this inflammation is aggravated by hyper coagulopathy, which is found on histopathology in the form of platelet overload triggered by pulmonary megakaryocyte cells. This triggers ischemia in the alveoli so that the alveoli and micro vessels cannot perform their function optimally to diffuse and paradoxically aggravated by high flow barotrauma. All this results in a gap between the alveolar tree and the broncho vascular sheath through the pulmonary hila (Macklin effect), forming air leak syndrome, namely, pneumothorax, pneumomediastinum, and subcutaneous emphysema [28]–[30]. Unlike previous studies, this study presents a data profile of patients without comorbidities with recurrent pneumothorax complications after a month of high flow nasal cannula administration. In addition, geriatric patients who successfully performed early tracheostomy did not have the complication outcome of pneumothorax or pneumomediastinum. This study also describes the clinical profile of patients after tracheostomy by presenting data on oxygenation function and hemodynamics of patients in graphs Figures 1, 3, and 5. It can be a measurable guideline for a surgeon in maximizing interventions to reduce the risk of post-COVID-19 complications.

4. CONCLUSION

Early tracheostomy has the potential to accelerate the resolution of COVID-19 disease in patients and has a positive impact on lung vitality. Hence, it prevents the occurrence of pneumothorax and pneumomediastinum. This research is a descriptive study that has not been able to verify hypothesis of the relationship between risk factors and the occurrence of pneumothorax or pneumomediastinum complications. It may lead to further detailed research involving a large sample and quantitative analytic study.

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