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Case Series on Barotrauma in COVID-19 Infection Patients

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ABSTRACT

As COVID-19 emerged in the world, there was a high prevalence of intubation and intensive care admissions. Many cases of barotrauma were reported in those patients. This condition is caused by alveoli rupture, which causes the air to enter the surrounding extra-alveolar spaces. It mainly happens in intubated patients. Here, we report 14 cases of barotrauma in COVID-19 patients, which appeared either spontaneously or after receiving non-invasive ventilation, some of the patients presented initially with mild-moderate forms of the disease in terms of severity. Developing barotrauma causes a management challenge in COVID-19 patients, where the patients might require invasive mechanical ventilation afterwards, which is a difficult situation. Lung protective measures should be used to reduce the risk of barotrauma in all patients as it is associated with increased mortality.

COVID-19 is an infection that is caused by a new type of coronavirus that was previously not recognized in humans. The first case worldwide was reported in Wuhan, China, in December 2019, and reached Oman in February 2020. The World Health Organization announced the COVID-19 outbreak as a pandemic on 11 March 2020. At the time of writing this report, almost 17 million cases have been reported globally.[1]

Due to the high prevalence of intubation and intensive care unit (ICU) admissions during the current pandemic of the new COVID-19 era, most of the literature nowadays has reported a high prevalence of barotrauma in patients that developed COVID-19 infection. This could be related to the heightened inflammatory response during this infection, which leads to severe acute lung injury.[2]

Barotrauma is a condition in which the alveoli rupture with a subsequent entry of air into the surrounding extra-alveolar space.[3] Spontaneous pulmonary barotrauma is a pulmonary complication typical in intubated patients. However, in the related viral epidemic of SARS in 2002, 6.6–15% of patients on non-invasive ventilation (NIV) were described to developed pulmonary barotrauma.[4] As a result, many studies were conducted regarding developing lung-protective ventilation strategies especially in patients with acute respiratory distress syndrome (ARDS). However, barotrauma continues to be a serious issue posing significant management challenges in ARDS patients.[5,6]

We present here characteristics of 14 cases of barotrauma during SARS-CoV-2 infection, that appeared either spontaneously or after receiving NIV that presented to the COVID-19 Field Hospital and Sultan Qaboos University Hospital. In our study, we focused only on patients who developed these complications spontaneously during acute COVID-19 infection, with some of them having initially mild/moderate forms of the disease that worsened gradually. The aim of this study was to explore the characteristics of patients hospitalized for COVID-19 who developed pneumothorax (PNX), pneumomediastinum (PM), pneumopericardium (PC), and subcutaneous emphysema (SCE) to better understand factors that seem to influence the evolution and prognosis of these complications.

CASE REPORT

We present 14 cases of barotrauma including PNX, PM, PC, and SCE and compared between patients placed on NIV and patients who did not require NIV.

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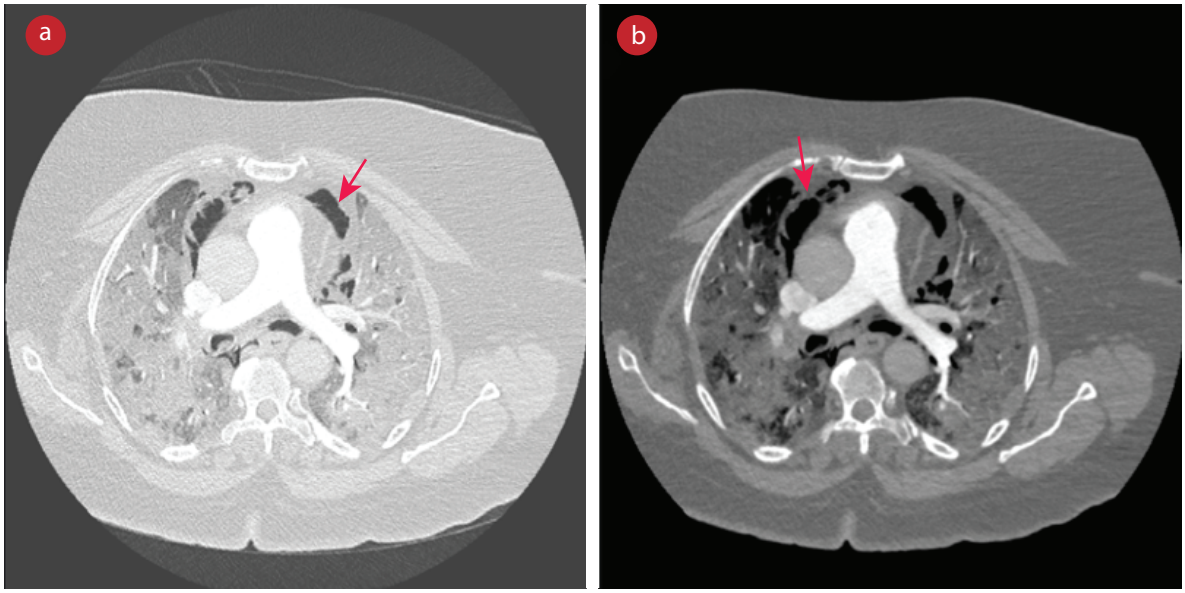

Figure 1: Patient 1. Chest CT **(a)** lung and **(b)** mediastinal window showing spontaneous pneumomediastinum (arrow) bilateral ground-glass opacities of the lung in a patient with COVID-19 pneumonia.

The most common symptoms that our patients presented with were fever, cough, and shortness of breath. One patient was known to have asthma while the others were not diagnosed with any respiratory diseases. Seven (1–7) out of the 14 patients received NIV at some time during their hospital stay, and the other seven (A–G) never used NIV; however, they were kept on ≤ 15 L/minute of oxygen.

The mean age of patients on NIV was 63.5 years. Of the total seven patients, four were female and three were male. One had asthma, while all the others had no underlying lung diseases. Six out of seven patients had PM (Figure 1 – Patient 1, Figure 2 – Patient B, and Figure 3 – Patient D), three had PNX in which intercostal drainage was inserted (Figure 4 – Patient 2), and six patients had SCE (Figure 5 – Patient 6). All had high inflammatory markers including high C-reactive protein, ferritin, and lactate dehydrogenase. However, D-dimer was negative in two of the seven patients. All patients received one dose of intravenous tocilizumab 8 mg/kg. Five out of the seven patients were on continuous positive airway pressure and two were on bi-level

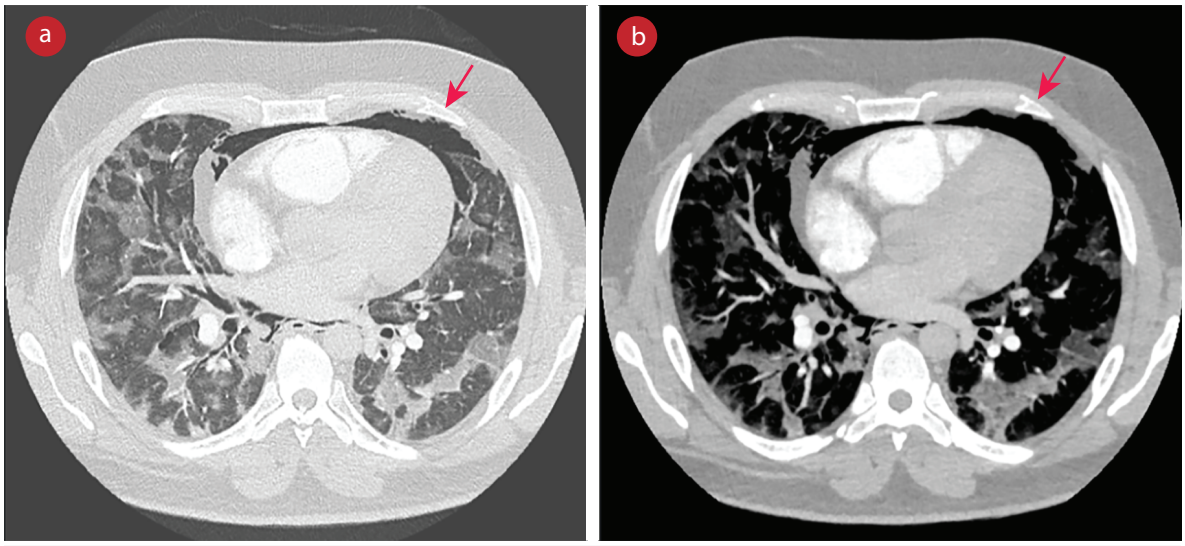

Figure 2: Patient B. Chest CT **(a)** lung and **(b)** mediastinal window showing spontaneous pneumomediastinum (arrow) bilateral ground-glass opacities of the lung in a patient with COVID-19 pneumonia.

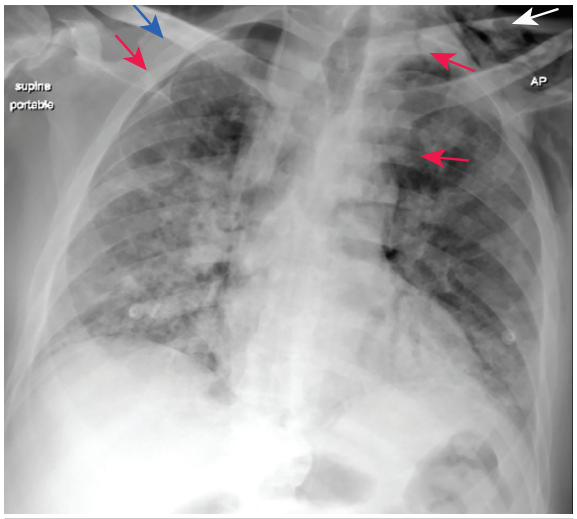

Figure 3: Patient D. Portable anteroposterior chest radiograph shows bilateral ill-defined pulmonary opacities. There is subcutaneous emphysema (white arrow), lucent steaks in the mediastinum in keeping with pneumomediastinum (red arrows), and small right pneumothorax (blue arrow).

positive airway pressure during the development of the barotrauma. The average length of stay (LOS) in hospital was 27.5 days. Four patients were discharged and three died during hospital stay (42.9%) [Table 1].

The mean age of patients who did not require NIV was 51.8 years. PM was seen in all the patients, PNX was observed in one patient who required intercostal drainage insertion, as well as SCE, and PC were noted in two patients. All patients had high inflammatory markers that required tocilizumab. The average LOS was 13.7 days. Five patients were discharged and two were intubated, shifted to ICU then died [Table 2].

The average age was higher in patients who received NIV and developed barotrauma. Patients who received NIV had more PNX and SCE compared to those who did not receive NIV. LOS was longer in patients who received NIV compared to those who did not. The mortality was equal in both groups.

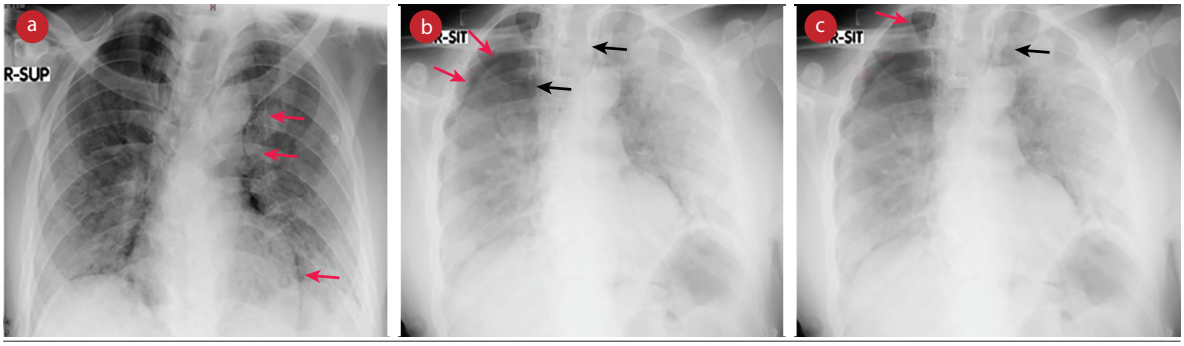

Figure 4: Bilateral chest infiltration with a lower lobe predominance related to COVID-19 pneumonia **(a)** spontaneous pneumopericardium (red arrows) and **(b)** spontaneous pneumopericardium (black arrows) and pneumothorax (red arrows). **(c)** A follow-up chest radiograph for the same patient after the insertion of a left-sided chest tube showing interval improvement of the right sided pneumothorax (red arrow) and a persistent pneumomediastinum (black arrow).

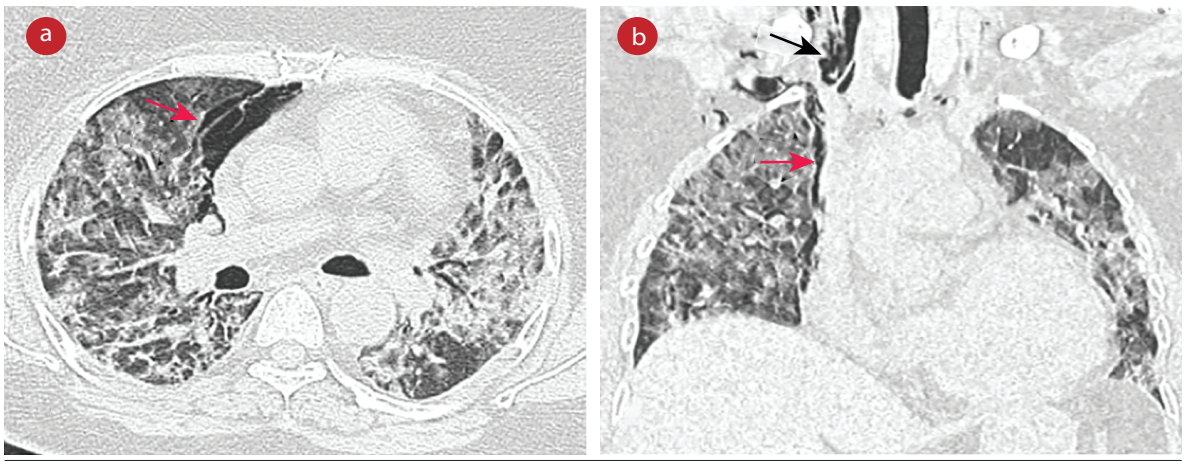

Figure 5: Patient 6. **(a)** Axial and **(b)** coronal unenhanced chest CT images (lung window) show bilateral ground-glass opacities and consolidations. There is subcutaneous emphysema in the right lower neck (black arrow) and right pneumomediastinum (red arrow).

Table 1: Characteristics of the COVID-19 patients who developed barotrauma while using NIV.

Characteristics	Age, years						
	56	58	74	60	70	55	72
Gender	Female	Male	Male	Male	Female	Female	Female
Symptoms at presentation	Fever, cough, and chest pain	Fever, cough, and shortness of breath	Fever, cough, poor oral intake, and progressive shortness of breath	Fever, headache, progressive shortness of breath	Fever and shortness of breath	Cough and shortness of breath	Fever, shortness of breath, fatigue, and mild cough
Medical background	Nil	Asthma, diabetes mellitus, dyslipidemia	Hypertension, diabetes mellitus	Diabetes mellitus	Hypertension, history of PE	Non-ischemic dilated cardiomyopathy	Diabetes mellitus, hypertension
Pneumomediastinum	Y	N	Y	Y	Y	Y	Y
Pneumothorax	N	Y	N	N	Y	Y	N
Surgical emphysema	N	Y	Y	Y	Y	Y	Y
CRP, mg/L	114	58	69	75	66	38	227
LDH, U/L	925	1178	499	296	241	896	288
Ferritin, µg/mL	831	3263	1391	822	195	2528	664
D-dimer, mg/L	23	3.1	2.1	0.4	12.5	0.5	1.2
Intervention	-	Intercostal chest drainage	-	-	Intercostal chest drainage	Intercostal chest drainage	-
Level of respiratory support, settings	BiPAP: 16/8 (50%)	BiPAP: 16/10 and FiO_2: 60%, then CPAP: PEEP: 8 and FiO_2: 65%.	CPAP: 12, 85%.	CPAP: 10, FiO_2: 100%	CPAP: 12, FiO_2: 100%	CPAP: 12, FiO_2: 65%	CPAP: 10, FiO_2: 100%
Length of hospital stay, days	30	42	20	23	34	22	22
Day of illness when pathology was picked up	28	23	-	-	27	10	9
Outcome	Discharged	Discharged	Intubated then died	Discharged	Died	Discharged	Died

NIV: non-invasive ventilation; CPR: C-reactive protein; LDH: lactate dehydrogenase; Y: yes; N: no; BiPAP: bi-positive airway pressure; PEEP: positive end-expiratory pressure;CPAP: continuous positive airway pressure.

DISCUSSION

Patients with COVID-19 present with a wide spectrum of disease severity from asymptomatic to the need for ICU care and death. Many patients in the ICU need invasive mechanical ventilation (IMV) and/or NIV for the management of ARDS and hypoxemic respiratory failure, which is a common presentation of COVID-19.[7]

Many case reports and studies demonstrated barotrauma in COVID-19 patients that requires IMV and NIV.[2,7,8] It was noticed that SARS-CoV-2 infection increases the risk of barotrauma seven-fold in a study done in Italy, and it was attributed to lung frailty rather than barotrauma, having compared 169 COVID-19 related-ARDS to 163 non-COVID-19 related-ARDS.[9]

All the barotrauma that happens occur secondary to airway obstruction, use of mechanical ventilation, or if there is a cause that raises the intrathoracic pressure. However, in most COVID-19 patients, these changes were noticed even before any intervention, which is thought to be a consequence of the disease itself.[10] One of the mechanisms that is thought to be the cause of barotrauma is that COVID-19 disease causes ischemic lung tissue leading to the formation of pulmonary cysts, which ruptures later and causes PNX, PM, or PC. The other proposed mechanism is self-inflicted lung injury, which is caused by tachypnea.[11]

PM and SCE are not uncommon in patients affected with COVID-19, and many had a poor outcome which could be because of the nature

Table 2: Characteristics of the COVID-19 patients who developed barotrauma not kept on NIV.

Characteristics	Patients						
	A	B	C	D	E	F	G
Age, years	53	40	57	53	51	59	50
Gender	Male	Male	Male	Male	Female	Male	Male
Medical background	Nil	Nil	Diabetes mellitus	Chronic lymphocytic leukemia, diabetes mellitus, and hypertension	Epilepsy	Diabetic mellitus	Nil
Symptoms at presentation	Fever, cough, headache, progressive shortness of breath	Fever, cough, progressive shortness of breath	Progressive shortness of breath, cough	Fever, cough, progressive shortness of breath, fatigue	Progressive shortness of breath	Fever, cough, poor oral intake, progressive shortness of breath	Fever, cough, progressive shortness of breath
CRP, mg/L	162	93	288	253	158	69	231
LDH, U/L	437	463	981	743	480	378	683
Ferritin, µg/mL	1428	2529	2853	1565	158	424	2552
D-dimer, mg/L	0.42	1.10	23	6.9	41	0.8	1.19
Pneumomediastinum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pneumothorax	No	No	No	No	No	No	Yes
Surgical emphysema	No	No	No	No	No	No	Yes
Pneumopericardium	No	Yes	Yes	No	No	No	No
Respiratory support	≤ 15 L of oxygen via non-rebreather mask						
Length of stay, days	16	9	13	30	3	13	12
Day of illness when pathology was picked up	16	14	14	15	5	19	24
Intervention	No	No	No	No	No	No	Intercostal chest drainage
Outcome	Discharged	Discharged	Discharged	Died	Intubated then died	Discharged	Discharged

NIV: non-invasive ventilation; CPR: C-reactive protein; LDH: lactate dehydrogenase; BiPAP: bi-positive airway pressure; PEEP: positive end-expiratory pressure; CPAP: continuous positive airway pressure.

of the disease rather than the barotrauma per se. However, patients tend to stay longer in hospital with prolonged weaning/treatment de-escalation as well.[12]

The principal pathophysiologic mechanism of PM is represented by the Macklin phenomenon, explaining the development of an increased pressure gradient between the marginal alveoli and the lung parenchyma, which, in the presence of the extensive alveolar injury, determines air leakage along the surrounding bronchovascular sheaths into the mediastinum. It is known that inflammation could render the alveolar wall more prone to rupture, which could be exacerbated by persistent cough or any factors increasing the intra-alveolar pressure. Some studies included both patients who developed PXN and/or PM spontaneously, as well as those occurring during invasive positive pressure ventilation, where barotrauma could represent the responsible mechanism.[13]

Eperjesiova et al,[14] mentioned that five out of seven of their patients who had spontaneous PM and PNX were intubated. In our case series, one patient was intubated because of the severe COVID-19 infection.

One of the earliest case reports identified a patient with PM which developed within 10 days of admission, this patient was kept on NIV. However, settings were not mentioned, and the patient spent 38 days at the hospital.[15]

Barotrauma in COVID-19 infection is a challenging issue in the management of affected patients, leading to difficulties in using IMV afterward. Hence, protective lung measures should be used even with the use of NIV to avoid the risk of barotrauma as it was noticed in some studies that it increased the mortality.[16,17]

CONCLUSION

Barotrauma is not an uncommon complication of COVID-19 infection. It can occur in all categories of patients, ranging from patients with mild disease to those with critical disease. If barotrauma develops in COVID-19 patients, it causes management challenges; hence, more studies are needed to study the epidemiology and etiology of barotrauma, its relation to COVID-19 pneumonia, and eventually to develop guidelines for prevention and treatment.

Disclosure

The authors declared no conflicts of interest. The ethical approval was obtained from the institiution with Ref number: MoH/CSR/21/24338.

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