

# Surgical Management of Tension Pneumomediastinum in Mechanically Ventilated Coronavirus Disease 2019 Patients

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## Abstract

**Introduction:** Tension pneumomediastinum is an increasingly common condition since the COVID-19 pandemic's onset. It is a life-threatening complication with severe hemodynamic instability that is refractory to catecholamines. Surgical decompression with drainage is the key point of treatment. Various surgical procedures are reported in the literature, but no cohesive approach has yet been developed.

**Aim:** The aim was to present the available options for surgical treatment of tension pneumomediastinum, as well as the post-interventional results.

**Materials and methods:** Nine cervical mediastinotomies were performed on intensive-care unit (ICU) patients who developed a tension pneumomediastinum during mechanical ventilation. The age and sex of patients, surgical complications, pre- and post-intervention basic hemodynamic parameters, as well as oxygen saturation levels, were recorded and analyzed.

**Results:** The mean age of patients was  $62 \pm 16$  years (6 males and 3 females). No postoperative surgical complications were recorded. The average preoperative systolic blood pressure was  $91 \pm 12$  mmHg, the heart rate was  $104 \pm 8$  bpm, and the oxygen saturation level was  $89 \pm 6\%$ , while the short-term postoperative values changed to  $105 \pm 6$  mmHg,  $101 \pm 4$  bpm, and  $94 \pm 5\%$ , respectively. There was no long-term survival benefit, with a mortality rate of 100%.

**Conclusions:** Cervical mediastinotomy is the operative method of choice in the presence of tension pneumomediastinum allowing an effective decompression of the mediastinal structures and improving the condition of the affected patients without improving the survival rate.

## Keywords

mediastinotomy, SARS-CoV-2 infection, tension pneumomediastinum

## INTRODUCTION

One of the observed complications in patients with severe SARS-CoV-2 infection treated with mechanical ventilation is tension pneumomediastinum. In most cases, pneumomediastinum is a self-limiting condition with often spon-

taneously reabsorbed tissue air and no difficulties to the patients.<sup>[1]</sup> In some cases, however, in the presence of SARS-CoV-2, it could be a life-threatening complication requiring an emergency surgical procedure.<sup>[2]</sup> In patients with acute respiratory distress syndrome caused by COVID-19 infection, pneumomediastinum may occur spontaneous-

ly or could be induced by barotrauma during mechanical ventilation with a large tidal volume, which in turn leads to its progressive expansion and inability to self-limit.<sup>[3,4]</sup> At the occurrence of tension pneumomediastinum, the main resuscitation challenges are hemodynamic instability with changes in the cardiac electrical activity and hypotension unresponsive to catecholamines, in which surgical decompression and drainage of the mediastinum are key points in treatment.<sup>[5]</sup> Although the occurrence of tension pneumomediastinum as a consequence of SARS-CoV-2 is increasing since the start of the COVID-19 pandemic and its therapy is insufficiently described in the literature, there is currently no universally acknowledged unified approach to its treatment.

## AIM

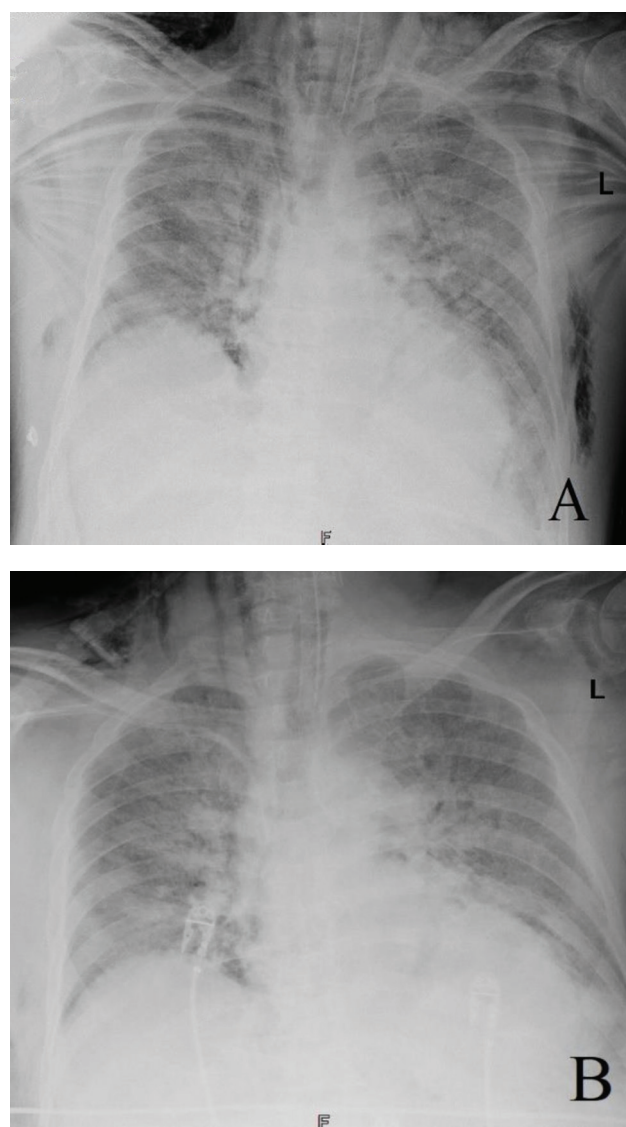
To present the possibilities for surgical decompression and drainage in tension pneumomediastinum, and to assess the short-term and long-term results after the intervention.

## MATERIALS AND METHODS

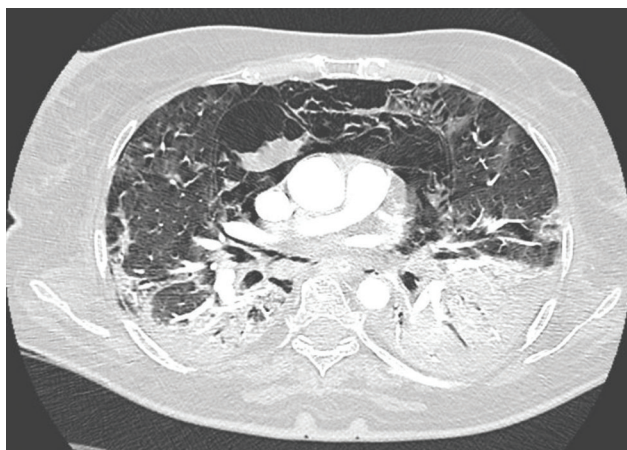
In our hospital from January 2021 to October 2021, 146 patients were treated with invasive mechanical ventilation. Eleven (7.5%) of them developed pneumomediastinum but not all of the patients had tension manifestations. A retrospective analysis was performed in which 9 (6.1%) of these patients met the inclusion criteria - mechanically ventilated patients with SARS-CoV-2 infection that developed tension pneumomediastinum and underwent cervical mediastinotomy. Three of the patients were female and six were male. The mean age of the examined patients was 62 years, with the youngest patient being 43 and the oldest being 75 years old. The patients were mechanically ventilated on intermittent positive pressure ventilation (IPPV) auto-flow mode with tidal volumes of 4 to 6 mL/kg; PEEP – 12-15 cm H<sub>2</sub>O; respiratory rate - 22–26 breaths/min. The onset of pneumomediastinum was manifested in all patients with the appearance of progressively expanding subcutaneous emphysema, spreading in 2 of the cases over a large area from the face to the thighs. In all patients, there were catecholamine-refractory hypotension and decreasing oxygen saturation levels. Seven of the patients underwent chest radiographs (**Figs. 1A, 1B**) and two received computed tomography (CT) scan of the chest (**Fig. 2**), which showed the presence of pneumomediastinum. In 3 of the patients, it was combined with right-sided pneumothorax (**Fig. 3**).

An emergency bedside cervical mediastinotomy was performed as a method of choice for surgical treatment. The surgical access consists of a 30- to 40-mm transverse incision just above the sternal notch, followed by blunt dissection with a finger and Kelly clamp with a plane and direction of dissection along the posterior wall of the sternum, reaching the pericardium and separating its adipose

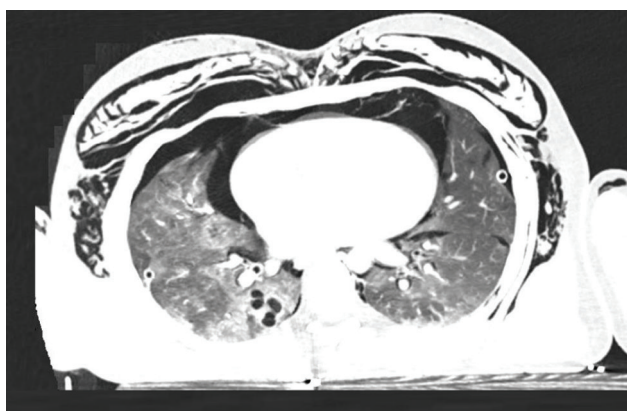
tissue from the bone, opening the mediastinal space, and relieving the compressed anatomical structures of the accumulated air collection. After the blunt dissection, a corrugated drain sheet was placed in the formed tunnel to keep it continuously open and prevent a subsequent recurrence. No suturing was performed except in cases of bleeding from major vessels unable to be stopped by other techniques. In patients with pneumothorax, an additional chest tube was inserted through the 5th or 6th intercostal space along the mid-axillary line and pleural aspiration was performed. The following values were monitored: basic hemodynamic parameters, particularly systolic blood pressure (mmHg) and heart rate (bpm), the oxygen saturation level (%), and the settings of mechanical ventilation parameters at 6 hours of intervention.



**Figure 1. A.** Chest radiography: shows tension pneumomediastinum with massive subcutaneous emphysema; **B.** Chest radiography: the same patient after drainage procedure.



**Figure 2.** CT scan shows tension pneumomediastinum.



**Figure 3.** CT scan shows tension pneumomediastinum with right sided pneumothorax.

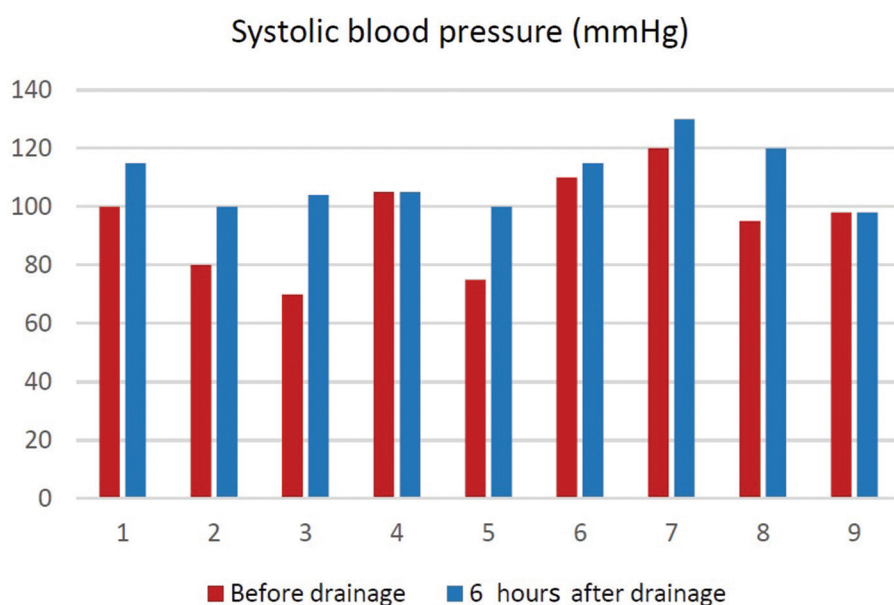
## RESULTS

After performing cervical mediastinotomy for decompression in seven of the patients, an increase in systolic blood pressure by a mean value of 19 mmHg was observed up to 6 hours after the intervention. The other two did not show a significant change in their blood pressure for the first 6 hours (**Fig. 4**)

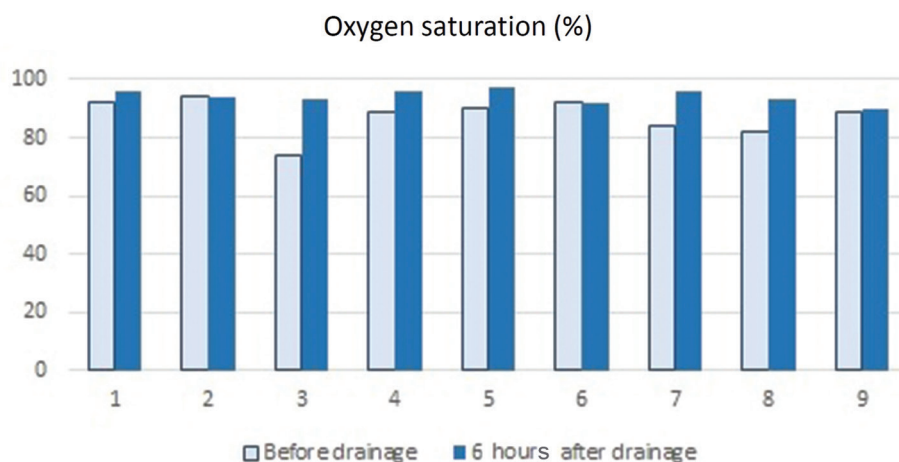
Heart rate in all patients decreased by a mean value of 15 beats per minute after the drainage procedure (**Fig. 5**).

Oxygen saturation levels were increased by a mean value of 7% in 6 patients and no improvement was found in 3 patients (**Fig. 6**).

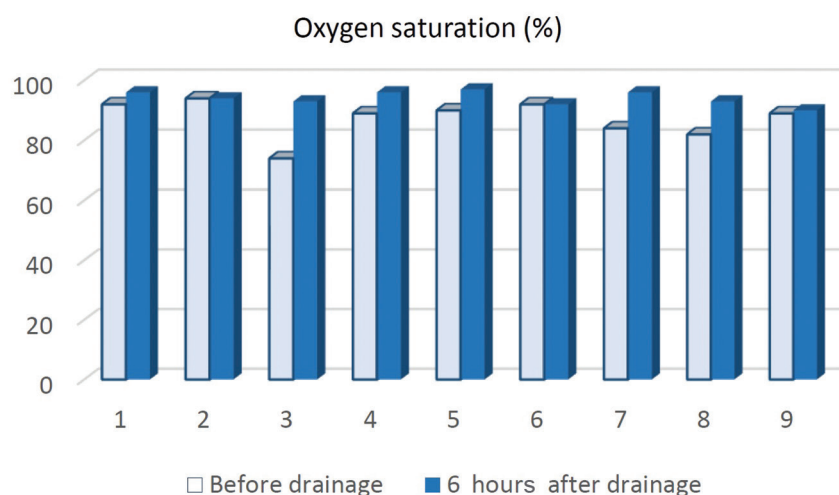
At 6 hours of the procedure, the ventilation mode was reconfigured by reducing the PEEP by 4 cm H<sub>2</sub>O and the respiratory rate to 9 breaths/min on average, as well as increasing the mean value of tidal volume by 0.9 ml/kg. There was one registered complication from all the 9 procedures and it was postoperative bleeding from the wound. Surgical hemostasis with suture was made and the bleeding was stopped. Despite the performed procedures, the registered mortality rate of the studied patients was 100% but none of the death cases was associated with complications from the mediastinotomy procedure. All the patients died due to sepsis-associated multiple organ dysfunction syndrome (MODS) which is one of the major causes of death in all critically ill SARS-CoV-2 patients. The overall mortality rate of the mechanically ventilated patients with SARS-CoV-2 in the intensive care unit for the study period was 91% (133). Patients died on average at 13 (6-31) days after the development of tension pneumomediastinum.



**Figure 4.** Systolic blood pressure (mmHg) before and after the procedure in studied patients.



**Figure 5.** Heart rate (beats/min) before and after the procedure in studied patients.



**Figure 6.** Oxygen saturation level (%) before and after the procedure in studied patients.

## DISCUSSION

There are still insufficient number of published studies on the incidence of pneumomediastinum in COVID-19 with its tension manifestations and surgical treatment. The pneumomediastinum is a condition that can occur spontaneously or secondary due to different factors and in both cases, it is mostly associated with the SARS-CoV-2 infection. In most of the cases described before the COVID-19 pandemic, this is a condition of no particular clinical significance due to its tendency for spontaneous reabsorption and lack of potential for expanding and tension manifestations.<sup>[6]</sup> In the Department of Critical Care Medicine, where critically ill COVID-19 patients were treated, the frequency of pneumomediastinum was 7.5% and 80% of these patients had tension manifestations. Its clinical signs are tachycardia, cardiac electrical activity abnormalities, but the most significant symptoms of tension pneumomediastinum due to compression of the heart and lungs are

manifested by hemodynamic collapse and impaired respiratory functions.<sup>[6,7]</sup>

Tension pneumomediastinum is a rare but life-threatening condition in critically ill patients with SARS-CoV-2 infection. The main cause of this complication is high-end expiratory pressure ventilation, widely used to treat COVID-19-related acute respiratory distress syndrome and the barotrauma caused by mechanical ventilation. As a result of these factors, there is diffuse alveolar damage.<sup>[7]</sup> Most of the affected alveoli are located on the mediastinal surface and rupture due to the pressure gradient from the alveoli to the perivascular sheaths leading to interstitial emphysema in the mediastinum, described in the literature as a Macklin effect. In patients with SARS-CoV-2, the altered lung parenchyma may form a one-way pleural valve within the mediastinal border, subsequently contributing to the retention of air in the mediastinum. Increased pressure leads to compression of the mediastinal contents, particularly the large vessels, and leads to reduced cardiac preload,



hypotension with tachycardia, and subsequent cardiovascular collapse.<sup>[5]</sup>

Several methods for decompression in tension pneumomediastinum have been described and one of the most widely used is the bedside cervical mediastinotomy performed in our study. Other reported techniques include placement of bilateral chest tubes, repeated fluoroscopic-guided percutaneous pneumomediastinum decompression, and thoracoscopic mediastinotomy.<sup>[8]</sup>

Due to the respiratory and hemodynamic instability in the diseased patients, as well as the risk of carrying a viral aerosol during transport, the emergency bedside cervical mediastinotomy technique could be an appropriate option for solving tension pneumomediastinum.<sup>[9]</sup>

In patients requiring mechanical ventilation, mortality rates have been reported to be as high as 97%.<sup>[10]</sup> The tension pneumomediastinum subgrouping made the number of patients too small and is insufficient to establish the differences between the studied patients and those with a condition uncomplicated by pneumomediastinum.

## CONCLUSIONS

Bedside cervical mediastinotomy with drainage for decompression could be considered as an appropriate treatment option of tension pneumomediastinum in patients with SARS-CoV-2. The performed interventions on the examined patients did not show any improvement in survival rate, which we could associate with the severe progression of the main disease with the appearance of pneumomediastinum predicting the poor prognosis of the condition. More studies with a larger number of patients are required

to confirm the need for mediastinotomy, in terms of the benefits of the method and patient survival rate.

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# Хирургическое лечение тензионного пневмомедиастинума у пациентов с коронавирусной болезнью 2019 на ИВЛ

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## Резюме

**Введение:** Тензионный пневмомедиастинум становится всё более распространённым состоянием с начала пандемии COVID-19. Это опасное для жизни осложнение с тяжёлой гемодинамической нестабильностью, рефрактерной к катехоламинам. Хирургическая декомпрессия с дренированием является ключевым моментом лечения. В литературе сообщается о различных хирургических процедурах, но единый подход ещё не разработан.

**Цель:** Представить доступные варианты хирургического лечения тензионного пневмомедиастинума, а также результаты послеоперационного вмешательства.

**Материалы и методы:** Девять шейных медиастинотомий были выполнены у пациентов отделения интенсивной терапии (ОИТ), у которых во время ИВЛ развился тензионный пневмомедиастинум. Регистрировали и анализировали возраст и пол пациентов, хирургические осложнения, основные показатели гемодинамики до и после вмешательства, а также уровень сатурации кислорода.

**Результаты:** Средний возраст пациентов составил  $62 \pm 16$  лет (6 мужчин и 3 женщины). Послеоперационных хирургических осложнений не зарегистрировано. Среднее дооперационное систолическое артериальное давление составило  $91 \pm 12$  mmHg, частота сердечных сокращений  $104 \pm 8$  bpm, уровень сатурации кислорода  $89 \pm 6\%$ , а ближайшие послеоперационные значения изменились до  $105 \pm 6$  mmHg,  $101 \pm 4$  bpm. и  $94 \pm 5\%$  соответственно. Не установлено никакого преимущества в плане долгосрочной выживаемости, смертность составила 100%.

**Заключение:** Шейная медиастинотомия является оперативным методом выбора при наличии тензионного пневмомедиастинума, позволяющим провести эффективную декомпрессию структур средостения и улучшить состояние пострадавших без увеличения выживаемости.

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## Ключевые слова

медиастинотомия, инфекция SARS-CoV-2, тензионный пневмомедиастинум

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