Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Negative pressure therapy as a safe alternative in the treatment of massive subcutaneous emphysema in critically ill patients COVID-19

Álvaro Soler-Silva, MDa,b, Luis Sánchez-Guillén, MD, PhDab, Francisco López Rodriguez-Arias, MSDa,b, Antonio Arroyo, MD, PhDab

A B S T R A C T

Many surgical treatments have been described for massive subcutaneous emphysema (MSE) over the recent years. However, there is no consensus on which is the most recommended and there is great diversity in treatment. With new advances in minimally invasive therapy performed at the bedside, especially in intensive care units, it has been possible to increase therapeutic efficacy. During the COVID-19 pandemic, some therapeutic techniques have been discussed in critically ill patients with SARS-COV-2 respiratory infections, because of the potential overexposure of healthcare personnel to an increased risk of contagion after direct exposure to air trapped in the subcutaneous tissue of infected patients. We present the clinical case of an 82-year-old male patient, SARS COV-2 infected, with MSE after 48 h with invasive mechanical ventilation in critical intensive care. He was treated with negative pressure therapy (NPT) allowing effective resolution of the MSE in a short period (5 days) with a minimally invasive bedside approach, reducing the potential air exposure of health personnel by keeping the viral load retained by the emphysema. Therefore, we present NPT as an effective, minimally invasive and safe therapeutic alternative to be considered in the management of MSE in critically ill patients infected with SARS COV-2.

© 2022 Elsevier Inc. All rights reserved.

Introduction

Minimally invasive techniques have revolutionized the bedside treatment of patients in intensive care. In the treatment of subcutaneous emphysema (SE), numerous strategies have been described to palliate symptoms and ventilatory compromise until the cause is resolved: from surgical procedures by open thoracotomy or video-assisted thoracoscopic surgery (VATS); to less invasive methods, such as simple ‘blow hole’ incisions, with or without compressive bandages; as well as the placement of needles or multiperforated drains. However, some of the techniques are limited in patients with SARS COV-2 infection, because of viral airborne dissemination and the increased risk of exposure for healthcare personnel. This is especially so in intensive care units (ICUs), where numerous bedside treatments are used and sometimes—in situations of acute instability of patients—adequate protective measures are not implemented.

Throughout the COVID-19 pandemic, there has been an increase in the number of patients admitted to ICUs who require invasive mechanical ventilation with protective criteria aimed at preventing ventilator-induced lung injury. The current approach to protective ventilation, which became universally accepted after the acute respiratory distress syndrome (ARDS) Network trial, is based on tidal volume reduction to about 6 ml · kg⁻¹ · ideal body weight while maintaining airway plateau pressure below 30 cm H₂O. Therefore, the occurrence of major macroscopic signs of barotrauma, such as pneumothorax, pneumomediastinum, and SE, has become unusual. However, after the onset of the COVID-19 pandemic, an increase in the incidence of massive subcutaneous emphysema (MSE) has been reported in SARS COV-2-positive patients subjected to the same protective ventilation strategy.

Patients with elevated pulmonary fibrosis such as those with ARDS, obstructive pulmonary diseases or SARS-COV-2 infection who are ventilated with positive pressure ventilation have a major risk of developing pulmonary injury, which can result in complications such as pneumomediastinum, and SE. Positive pressure ventilation can lead to elevation of the transalveolar pressure or to a difference in pressure between the alveolar pressure and the pressure in the interstitial space. This elevation in the transalveolar pressure can lead to...
alveolar rupture, which results in leakage of air into the extra-alveolar tissue, leading to a pneumomediastinum, SE or MSE. \(^9, 10, 11, 12\)

Negative pressure therapy (NPT) is a well-known minimally invasive technique that is not used in the management of MSE but could well be considered. This methodology improves the clinical evolution of the patient because it allows a continuous suction of subcutaneous air and collapse of the dissected cavity. Furthermore, the subcutaneous air is isolated in the NPT device, decreasing the risk exposure to the healthcare personnel in charge of the patient’s care.

**Clinical case**

In this case, NPT was performed in an 82-year-old male patient, American Society of Anesthesiologists (ASA) grade III with SARS COV-2 infection who developed ARDS and required ICU admission for invasive ventilation. After 24 h of intubation, signs of moderate SE were observed, which progressed in the following 24 h to MSE. Treatment with the NPT technique was applied (Fig. B.1) with resolution of the MSE in 5 days.

Pre- and post-NPT control X-rays were performed to verify resolution of the emphysema (Fig. B.2). One minor complication, surgical wound minor bleeding (Clavien–Dindo grade I) secondary to therapeutic anticoagulation doses (120 mg day\(^{-1}\) of Enoxaparine) because of the high risk of thrombotic events in COVID-19 infection, was recorded. This complication was resolved with silver nitrate cauterization at the bedside. The patient stayed in the ICU for 10 days, being extubated on day 7th and was discharged from the hospital on day 16th.

**Discussion**

MSE can have several etiologies (surgical, traumatic, infectious, or spontaneous), the most frequent being traumatic, such as traumatic orotracheal intubation with associated bronchial injury, thoracotomy or placement of a chest tube.\(^13\) On the other hand, possible MSE caused by barotrauma has been described in the literature. This is considered in relation to the increased need for ventilatory pressure during invasive mechanical ventilation; however, in most ICU centers, ventilatory protection protocols are followed, without reaching high pressures. In fact, a study of >5000 mechanically ventilated patients showed that the presence of air outside the tracheobronchial tree (pneumothorax, pneumomediastinum, SE) was not related to airway pressures or tidal volume.\(^7\) Other studies with case series of SARS-COV2-positive patients have described SE without invasive ventilation.\(^11\) According to the literature on the pathophysiology of SARS COV-2, the development of both SE and MSE might arise from inflammation, consolidation and necrosis occurring in the lung parenchyma during infection, leading to the formation of cystic and cavitory lesions in the lungs over time. In fact, because of the increased risk of fistulation between the parenchyma and pleura, a spontaneous pneumothorax can be triggered. Therefore, the automatic association between barotrauma and presence of air outside the tracheobronchial tree in mechanically ventilated patients should be reconsidered.\(^14, 15\) In fact, the term ‘barotrauma’ should be used when air is present outside the tracheobronchial tree when air is circulating at elevated airway pressure. Furthermore, the development of MSE is a complication in the evolution of critically ill patients that affects their prognosis. The lethality of MSE is explained by the increase and entrapment of external air, dissecting the subcutaneous and muscular cellular tissue planes, compromised by the increase of ventilation with extrathoracic pressure, impairing cardiac function and swallowing.

Numerous invasive procedures have been described in the past 20 years to decrease trapped air in cases of MSE, improving ventilation of the patient with different treatment intervals (Table A.1).\(^16, 21\) However, none of these has been established as a reference procedure for MSE because of its aggressiveness and prolonged treatment (some described a resolution in 3 h although they referred to a clinical improvement and not to a complete resolution of the MSE). NPT is employed in daily practice in surgical specialties for the management of complex wounds, stimulating wound microvascularization, granulation tissue proliferation and aspirating various wound secretions.\(^22, 23\) Applying this last therapeutic principle, NPT could be considered in the treatment of MSE. The subcutaneous air can be removed continuously, avoiding the dissemination of the air and the spreading of possible microorganisms. NPT also allows collapse of the dissected cavity, decreasing the rate of wound infection. Therefore, this technique could be considered a therapeutic alternative in the management of patients with respiratory isolation who present with MSE with compromised ventilation, as it has advantages over other treatments described in the literature, being an effective technique. Maintaining a continuous negative pressure over time provides an advantage over other types of drainage with vacuums that decrease their suction capacity over time.\(^24\) The technique is safer in ICUs than conventional drainage procedures in patients requiring air isolation as in the case of patients infected with SARS-COV-2. It reduces the exposure of healthcare personnel to contaminated air that is stored in the MSE device. It also is minimally invasive, as it is performed under local anesthesia at the bedside, which is very useful in critical patients where the risk of a surgical procedure cannot be assumed; and reproducible, as it is already used by medical and nursing personnel in complex cases.

As limitations, minor complications such as local bleeding can occur during the drainage incision, especially in patients with therapeutic doses of anticoagulants, which could be solved with traditional hemostatic measures such as compression or chemical hemoestatica, such as silver nitrate or hemostatic matrices. However this complication could be similar for all procedures. In addition, the duration of treatment is similar to that of other classic techniques; however, the negative pressure also plays a key role to decrease the affected area. To the best of our knowledge, NPT has never been proposed as an effective, minimally invasive and safe strategy for the management of MSE in patients infected by airborne agents such as SARS COV-2.

**Conclusion**

NPT is a safe treatment alternative for MSE, offering greater protection for the healthcare personnel in charge of the SARS-COV2-positive patient and with a duration similar to that described by other classical treatments.

**Funding**

None

**Ethics approval**

The Clinical Ethics Committee of Elche University Hospital approved the use of this technique.

**Consent**

The patient gave written consent for the use of images and personal information for scientific dissemination.

**Authors’ contribution statement**

ASS and LSG analyzed and interpreted patient data regarding the TPN technique. All authors have read and approved the final manuscript.
Appendix

Table A.1

| Treatment strategy                                                                 | Time of treatment |
|-----------------------------------------------------------------------------------|-------------------|
| Manual decompression via 'blow hole' incisions.                                   | 3–4 days          |
| Chest tube in the midaxillary line and tunneling it through the subcutaneous tissues to the jugular notch. Chest tube in the midaxillary line and tunneling it through the subcutaneous tissues to the jugular notch. | Not indicated     |
| Inserting a fenestrated angiocatheter into the subcutaneous spaces at the infraclavicular regions. | 3 h               |
| Subcutaneous Penrose drains and colostomy bags.                                   | Not indicated     |
| Subcutaneous incisions with or without massage.                                   | 2 days            |
| Subcutaneous infraclavicular drain (12 frames) on continuous high suction at −150 mmHg aided by manual decompressive massage. | 3 days            |

Fig. B.1

Fig. B.1. NPT Technique description step by step. A. Locating the area of emphysemia. B. Two simple incisions were made in the subcutaneous cellular tissue. C. These were filled with hydrophobic reticulated polyurethane sponge (HRPS). D. These were covered with two larger HRPS fragments to connect both incisions. E. Applying a perforated dressing. F. Placement of the dressing with aspirative drainage and connecting the NPT device in the continuous therapy mode (−150 mmHg) over 5 days.
References

1. Beckers F, Lange N, Korylos A, Picchioni F, Windisch W, Stoeben E. Unilateral lobe resection by video-assisted thoracoscopic surgery leads to the most optimal functional improvement in severe emphysema. Thorac Cardiovasc Surg. 2016;64(4):336–342. https://doi.org/10.1055-s-0034-1395989. Epub 2014 Dec 23. PMID: 25535772.

2. Herlan DB, Landreneau RJ, Ferson PF. Massive spontaneous subcutaneous emphysema. Acute management with intraclavicular “blow holes”. Chest. 1992;102(2):503–505. https://doi.org/10.1378/chest.102.2.503. PMID: 1340676.

3. Johnson CH, Lang SA, Bilal H, Rammohan KS. In patients with extensive subcutaneous emphysema, which technique achieves maximal clinical resolution: intraclavicular incisions, subcutaneous drain insertion or suction on in situ chest drain? Interact Cardiovasc Thorac Surg. 2014;18(6):825–829. https://doi.org/10.1093/icvts/ivt322. Epub 2014 Feb 26. PMID: 24572767.

4. Acute Respiratory Distress Syndrome Network. Morrow RG, Matthay MA, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for patients with acute lung injury and the acute respiratory distress syndrome. N Engl J Med. 2000;342(18):1301–1308. https://doi.org/10.1056/NEJM200005043421801.

5. Fan E, Del Sorbo L, Goligher EC, et al. An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome [published correction appears in Am J Respir Crit Care Med. 2017 Jun 1;195(11):1540]. Am J Respir Crit Care Med. 2017;195(9):1253–1263. https://doi.org/10.1164/rcrm.201702-048ST.

6. Slutsky AS, Ranieri VM. Ventilator-induced lung injury [published correction appears in N Engl J Med. 2014 Apr 24;370(17):1668-9]. N Engl J Med. 2013;369(22):2126–2136. https://doi.org/10.1056/NEJMoa120707.

7. Anzueto A, Fruutos-Vivar F, Esteban A, et al. Incidence, risk factors and outcome of barotrauma in mechanically ventilated patients. Intensive Care Med. 2004;30(4):612–619. https://doi.org/10.1007/s00134-004-2187-7.

8. Lennfers DHL, Abu Halal M, Bna C, et al. Pneumomediastinum and subcutaneous emphysema in COVID-19: barotrauma or lung lability? Eur Respir Rev. 2020;29(204):00038–02020. https://doi.org/10.1183/23120541.000385-2020. Published 2020 Nov 16.

9. Diaz R., Heller D. Barotrauma and mechanical ventilation. StatPearls. 2021 Aug. PMID: 31424810.

10. Battisti A.S., Haefl H., Murphy-Lavoide H.M. Barotrauma. StatPearls. 2021 Jul. PMID: 29493973.

11. Edwards JA, Brentman I, Bienstock J. Pulmonary barotrauma in mechanically ventilated coronavirus disease 2019 patients: a case series. Ann Med Surg. 2021;24:29. https://doi.org/10.1016/j.amsu.2020.10.054. Jan; 61P/PMC7750442.

12. Jones PM, Hewer RD, Wolfenden HD, Thomas PS. Subcutaneous emphysema associated with chest tube drainage. Respir Med. 2001;95(2):37–89. https://doi.org/10.1056/ijls.2001.00317.x. PMID: 11422886.

13. Jones PM, Hewer RD, Wolfenden HD, Thomas PS. Subcutaneous emphysema associated with chest tube drainage. Respir Med. 2001;95(2):37–89. https://doi.org/10.1056/ijls.2001.00317.x. PMID: 11422886.

14. McGuinness G, Zhan C, Rosenberg N, et al. Increased incidence of barotrauma in patients with COVID-19 on invasive mechanical ventilation. Radiology. 2020;297(2):E252–E262. https://doi.org/10.1148/radiol.2020202352.

15. Sherif HM, Ott DA. The use of subcutaneous drains to manage subcutaneous emphysema. Tex Heart Inst J. 1999;26(2):129-31. PMID: 10397436; PMCID: PMC325617.

16. Ozdogan M, Guer A, Sokokin A, Comolli I, Aydin R. Treatment of severe subcutaneous emphysema by fenestrated angiokatheter. Intensive Care Med. 2005;31(1):168. https://doi.org/10.1007/s00134-004-2443-x. Epub 2004 Sep 15. PMID: 15372149.

17. Matsuhashi T, Hynih AT, Singh T, Thomson D. Management of life-threatening subcutaneous emphysema using subcutaneous penrose drains and colostomy bags. Heart Lung Circ. 2007;16(6):469–471. https://doi.org/10.1016/j.hlc.2006.08.005. Epub 2007 Apr 18. PMID: 17446122.

18. Gunluoglu MZ, Cansever L, Demir A. Diagnosis and treatment of spontaneous pneumomediastinum. Thorac Cardiovasc Surg. 2009;57(4):229–231. https://doi.org/10.1055/s-2009-1009599. Epub 2009 May 20. PMID: 19670118.

19. Tran Q, Mizumoto R, Mehandro D. Management of extensive surgical emphysema with use of a trocar-type chest tube as a subcutaneous drain. Chest. 1993;103(1):323. https://doi.org/10.1016/chest.103.132s3. PMID: 7678081.

20. Anghel EL, Kim PJ. Negative-pressure wound therapy: a comprehensive review of the evidence. Plast Reconstr Surg. 2016;138(3 Suppl). https://doi.org/10.1097/PR.0000000000002645. SEP129S-137SPMID: 27556753.

21. Schalamon J, Petinahay T, Ainsworth H, Castellani C, Till H, Singer G. Experimental comparison of abdominal drainage systems. Am J Surg. 2017;213(6):1038–1041. https://doi.org/10.1016/j.amjsurg.2016.09.043. Epub 2016 Oct 8. PMID: 27765183.