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Modified blowhole skin incision using negative pressure wound therapy in the treatment of ventilator-related severe subcutaneous emphysema

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Abstract

OBJECTIVES: A 2–3-cm blowhole incision in the supraclavicular or infraclavicular area is widely used to eliminate the presence of subcutaneous air in cases of life-threatening subcutaneous emphysema (SE). However, when the patient is supported by mechanical ventilation, it is difficult to eliminate completely such air because mechanical ventilation leads consistently to the formation of large amounts of air. To overcome this, we applied negative pressure wound therapy (NPWT) along with blowhole incisions for the treatment of severe SE.

METHODS: To evaluate the feasibility of NPWT, we retrospectively analysed the clinical outcomes of 10 patients who developed severe SE during ventilator care and were treated with a modified blowhole incision using NPWT from January 2009 to November 2013.

RESULTS: All patients showed immediate improvement in SE after NPWT, and no symptom aggravation occurred after NPWT. The mean duration of NPWT was 7.5 ± 5.1 (range, 3–14) days, and the mean number of dressing changes was 1.5 ± 0.7 (range, 1–2). There were no blowhole-incision-related wound infections or any other complications.

CONCLUSIONS: While it is not necessary to apply a blowhole incision with NPWT in all cases of SE, this therapy can be helpful for patients with severe SE associated with mechanical ventilation requiring rapid decompression.

Keywords: Subcutaneous emphysema • Mechanical ventilation • Negative pressure wound therapy

INTRODUCTION

Subcutaneous emphysema (SE) can develop in various clinical conditions, with spontaneous resolution in most cases. However, if SE progresses to airway obstruction or cardiac tamponade, a rapid air drainage procedure may be required. In particular, SE associated with ventilator support can rapidly progress to life-threatening status, with upper airway compromise, tension pneumomediastinum, pneumopericardium and so on. [1].

Since Herlan *et al*. [1] first described the use of infraclavicular blowhole incisions to subcutaneous tissue for treating SE, blowhole incisions measuring 2–3 cm in size in the supraclavicular or infraclavicular area have been widely used to eliminate subcutaneous air in life-threatening SE, with good clinical results [2–4]. However, conventional blowhole incisions are essentially methods using natural air drainage but not negative suction; therefore, it is doubtful whether they can effectively remove subcutaneous air when a faster and large amount of air drainage is required following positive-pressure mechanical ventilation. Additionally, blowhole incisions themselves are associated with nosocomial wound infection.

In this study, we examined the feasibility and effectiveness of negative pressure wound therapy (NPWT) for overcoming the above-mentioned disadvantages of conventional blowhole incisions in the treatment of severe SE in patients requiring mechanical ventilation.

PATIENTS AND METHODS

We retrospectively analysed the clinical characteristics and outcomes of 10 patients who developed severe SE during mechanical ventilation and were treated with modified blowhole incisions using NPWT from January 2009 to November 2013. The mean age of the patients was 61.5 ± 12.9 (range, 42–81) years, and the male : female ratio was 7 : 3.

Negative pressure wound therapy

The indication of NPWT for SE was when patients showed pneumomediastinum-induced cardiac tamponade and airway

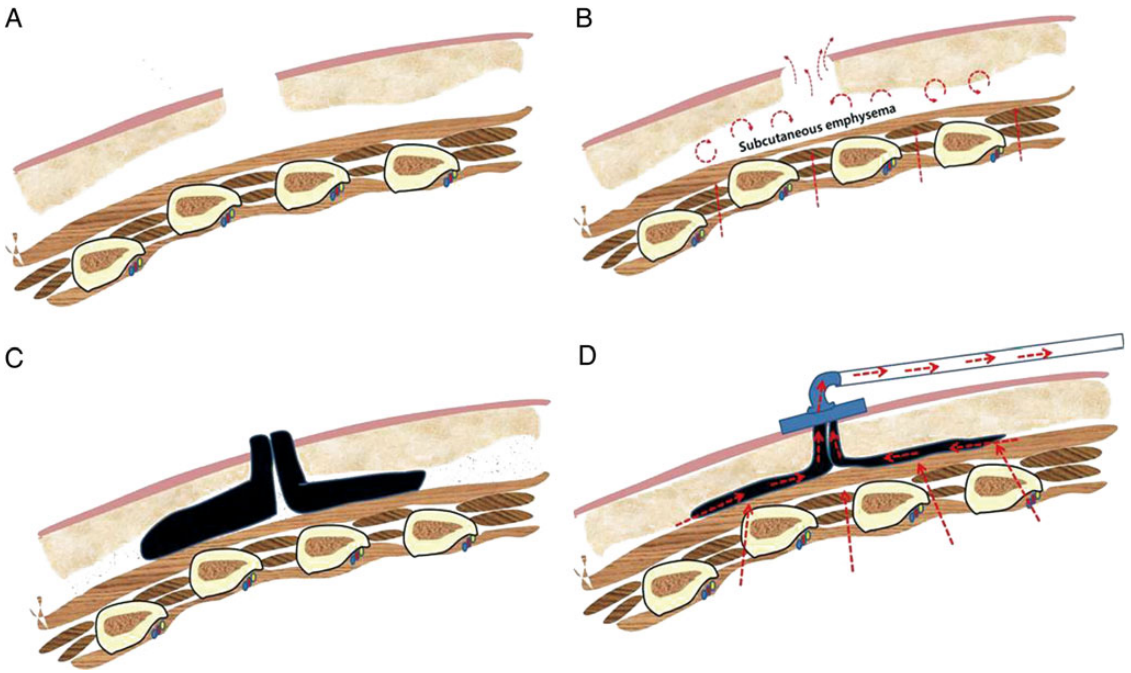

Figure 1: Process of application of negative pressure wound therapy. (**A** and **B**) The subcutaneous layer is dissected to where the air has accumulated. (**C**) A number of 2–3-cm-long block-shaped sponges are inserted into the subcutaneous space in different directions. (**D**) An opening is made through the sealing drape directly above the site of the skin incision, the suction plate is attached and a negative suction pump is connected.

obstruction symptoms. Depending on the severity and region of SE, a blowhole skin incision measuring 2–2.5 cm was made at the supraclavicular or infraclavicular area. For easy air drainage, the subcutaneous space was dissected to drain out the trapped air to the maximum possible extent (Fig. 1A and B). Then, 2–3-cm long block-shaped sponges were inserted into the subcutaneous space in different directions (Fig. 1C). The sponges protruding out of the skin incision were cut and levelled to the upper skin layer and sealed using an adhesive drape. An opening was created in this sealing drape directly above the site of the skin incision, and a suction plate was attached. A negative suction pump was connected (Fig. 1D) and 150 mmHg of suction pressure was maintained. The longer a sponge was maintained without change, the more adhered it was to the wound; patients usually complain of pain when detaching an applied sponge from the wound. The wound dressing was changed within 3–5 days. NPWT was performed until the air leakage subsided and SE disappeared. Skin closure was performed thereafter.

RESULTS

Among the 10 patients analysed in this study, mechanical ventilation support was required for the following causes: postoperative pneumonia, 4 patients; blunt lung injury, 1 patient; acute exacerbation of idiopathic pulmonary fibrosis (IPF), 1; pneumonia, 2 patients; status asthmaticus and bilateral pneumothorax with re-expansion pulmonary oedema, 1 patient each. Overall, 8 patients developed pneumothorax requiring the placement of a chest drain before the development of SE. The causes of air leakage and SE were as follows: lung surgery-related air leakage, 2 cases; blunt trauma-related lung laceration, 1 case; ventilator-associated barotrauma, 5 cases; post-lung transplantation bronchopleural fistula, and secondary pneumothorax, 1 case each. In 9 patients, it was possible to mitigate the air leakage by conservative treatment, but in 1 patient the air leakage caused by post-lung transplantation bronchopleural fistula was ameliorated by lung retransplantation. Veno-venous extracorporeal membrane oxygenation was performed in 2 patients (acute exacerbation of IPF and status asthmaticus), and interventional lung assist was performed in 1 patient, each with post-lung transplantation bronchopleural fistula and postoperative pneumonia following Ivor-Lewis oesophagectomy.

NPWT was initiated at a mean of 2.5 ± 1.7 (range, 1–7) days after SE symptoms were observed. In 7 patients, blowhole skin incisions were created on the side of the pneumothorax; in 1 patient, bilateral chest incisions were made due to severe SE affecting the whole body. A right-sided supraclavicular skin incision was made in 2 patients who suffered SE with life-threatening pneumomediastinum but without pneumothorax. All patients showed immediate improvement in SE after NPWT was started (Fig. 2) and no symptom aggravation occurred after NPWT. The mean duration of NPWT was 7.3 ± 4.8 (range, 3–14) days and the mean number of dressing changes was 1.4 ± 0.5 (range, 1–2). There were no blowhole-incision-related wound infections or any other complications (Table 1).

DISCUSSION

SE subsequent to mechanical ventilation can occur due to various causes. Typically, it occurs in two types of clinical scenarios. Firstly, mechanical ventilation may be applied for a patient with air leakage occurring after lung resection, thoracic trauma, pneumothorax and so on. In such cases, positive-pressure mechanical ventilation can accelerate air leakage and cause massive SE. Secondly, mechanical ventilation itself can cause SE subsequent to barotrauma of the lung parenchyma. Although the cause is different, the clinical course of SE is similar in both scenarios. Since mechanical-ventilation-related SE occurs under positive-pressure

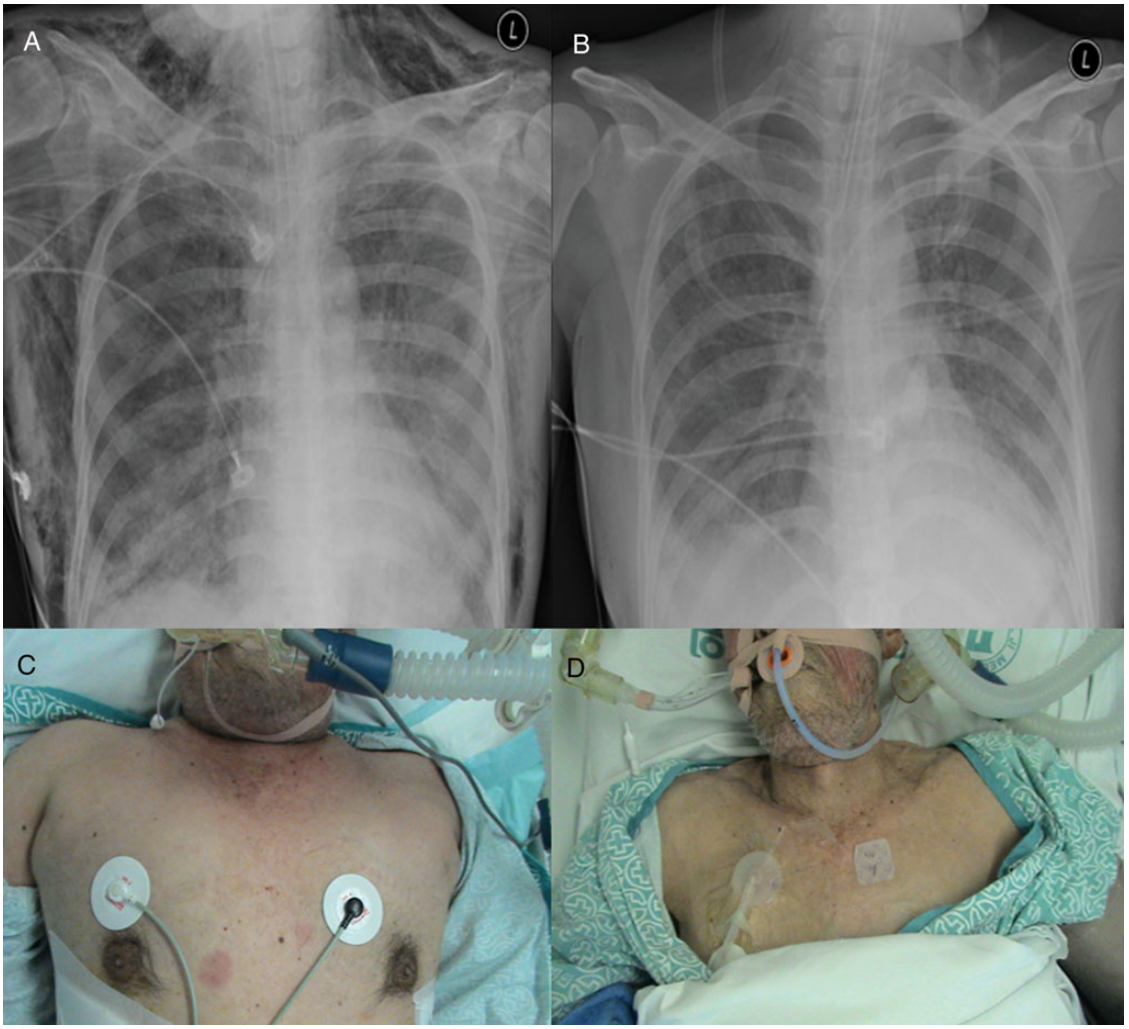

Figure 2: Outcomes of a modified blowhole skin incision using negative pressure wound therapy. (**A** and **C**) Radiographs showing the development of severe subcutaneous emphysema in a ventilator-supported patient. (**B** and **D**) After 3-day of application of negative pressure wound therapy, the subcutaneous emphysema was resolved.

Table 1: The outcomes of a modified blowhole incision using negative pressure wound therapy

Number of patients	Chest tube drain	From air leak to NPWT	Blowhole incision	Immediate response	Number of dressings	Duration of NPWT
1	Yes	3	Infraclavicular	Yes	1	3
2	Yes	7	Infraclavicular	Yes	1	3
3	Yes	2	Infraclavicular	Yes	1	4
4	Yes	3	Infraclavicular	Yes	2	14
5	Yes	3	Infraclavicular	Yes	2	14
6	Yes	2	Supraclavicular	Yes	1	4
7	Yes	1	Infraclavicular	Yes	1	5
8	Yes	2	Infraclavicular (both)	Yes	2	11
9	No	1	Supraclavicular	Yes	1	3
10	No	1	Supraclavicular	Yes	2	12

NPWT: negative pressure wound therapy.

ventilation and poor pathological lung status, such as acute respiratory distress syndrome, chronic obstructive pulmonary disease, pneumonia, status asthmaticus and so on, in most such patients, SE rapidly progresses to life-threatening status than in patients who are not ventilator supported. In particular, if hypotension or airway obstruction occurs despite maximal chest tube drainage, additional rapid subcutaneous air drainage is essential to prevent further life-threatening exacerbation.

Johnson *et al.* [5] reviewed 14 related articles out of >200 papers found using the reported search. They reported the possibility of various methods for the treatment of SE, such as additional chest tube insertion into the pleural cavity, microdrainage via a fenestrated angiocatheter, drainage via a Penrose or Jackson-Pratt drain and a supra or infraclavicular blowhole skin incision. The outcomes of all these methods were relatively good. Of these methods, the subcutaneous insertion of angiocatheters or small-sized catheter drainage devices is preferred for air drainage in SE because such procedures are simple with relatively good therapeutic effects. However, catheters are thin and are easily jammed by blood clot or discharge and so on; thus, effective air drainage using such devices is not easy in severe SE with massive intrathoracic air leaks. Thus, for more effective air drainage, perhaps blowhole incisions are preferred over drainage catheter insertion. However, these reports included patients under various clinical conditions, unlike those in our study, who were patients receiving positive-pressure mechanical ventilation. It is doubtful that blowhole incisions for treating SE would have identical effects in patients with severe SE supported by positive ventilation. For severe SE, a more powerful and rapid air drainage method than conventional blowhole incisions appears to be needed.

Furthermore, blowhole incisions have certain disadvantages. Since the wound needs to be kept open for effective air drainage, regular dressing changes, more than twice a day, are necessary to prevent wound infection. Therefore, conventional blowhole incisions are not appropriate in the intensive care unit where the risk of hospital-acquired infections is high. Moreover, since air drainage through a blowhole incision occurs by natural drainage without negative suction, rapid drainage is difficult and a long period of treatment is necessary for the complete resolution of SE. However, in mechanical ventilator-supported patients with a pathological lung status such as acute respiratory distress syndrome, pneumonia or other types of respiratory failure, the development of SE can lead to rapid life-threatening clinical deterioration since high-pressure ventilation can aggravate SE. Therefore, we consider conventional blowhole incisions inappropriate for treating SE occurring in ventilator-supported intensive care unit patients, and a new effective modality is needed. So, we applied NPWT directly for all patients without applying a conventional blowhole incision.

Sciortino *et al.* [6] first applied NPWT in the treatment of ventilator-related severe SE to overcome the disadvantages of blowhole incisions. The NPWT system is widely used in the treatment of complex wound problems, such as mediastinitis, fasciitis and open wound defects [7]; this technique can keep the wound clean without frequent wound dressing. Sciortino *et al.* considered that since the air leakage originates in the thoracic cavity and the thoracic cavity is connected to the subcutaneous site of air accumulation, life-threatening air leaks could be relieved by effective subcutaneous air drainage despite their origin in the thoracic cavity. Further, they also postulated that NPWT could be applied to conventional blowhole incision wounds with a subsequent decrease in the wound infection rate and the number of dressings.

We have previously reported the feasibility of NPWT for treating severe SE in patients with secondary pneumothorax admitted to the general ward [8]. All of the patients experienced a dramatic reduction in trapped air after 24 h of NPWT therapy, and all of the NPWT machines were withdrawn within 4 days. Subsequently, we aimed to extend the indications for NPWT to severe SE developed during ventilator care, with good clinical outcomes as reported in the present study. In all 10 patients, life-threatening SE was ameliorated rapidly after the initiation of NPWT and the blowhole incision wounds were clean and well maintained without frequent dressing until the time of wound closure. However, the mean duration of NPWT was longer than that in our previous report concerning NPWT for secondary pneumothorax-related SE [8]. We observed that the pathological lung status at the time of SE development and the presence of positive-pressure mechanical ventilation increased the treatment duration of NPWT. In particular, we observed that NPWT was considerably helpful in high-risk patients, such as those who underwent extracorporeal membrane oxygenation or interventional lung assist and transplantation, and also in post-lung transplantation patients.

In conclusion, we note that while it is not necessary to apply a blowhole incision with NPWT in all cases of SE, this therapy can be helpful for patients with severe SE associated with mechanical ventilation requiring rapid decompression.

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Conflict of interest: none declared.

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