REVIEW

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# Negative Pressure Wound Therapy (NPWT)-assisted blowhole incisions in treating extensive subcutaneous emphysema: a literature review

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## ABSTRACT

**Background:** Subcutaneous emphysema (SE) is defined as the generation or infiltration of air in the subcutaneous tissues (beneath the dermal layer) of skin, cause by various etiologies. Untreated extensive SE can lead to respiratory and cardiovascular collapse. There are various treatments for treating SE. Blowhole incisions are considered one of the minimally invasive methods, with their variation by combining the incision with the usage of negative wound pressure therapy (NPWT). This literature study aims to evaluate the NPWT blowhole incisions in treating extensive subcutaneous emphysema

**Methods:** Literature was sourced from PubMed, ProQuest, and Google Scholar databases. This review used case reports, case series, and systematic reviews, and each study underwent quality appraisal with the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. In this study, we will compare the various settings used in NPWT-assisted blowhole incisions in treating extensive SE and the outcomes from the method used. The final list for review consisted of 14 studies.

**Results:** Fourteen studies met the inclusion criteria. The most common causes of extensive subcutaneous emphysema were pneumothorax and rib fractures following chest trauma. The most frequently applied intervention was bilateral infraclavicular blowhole incisions measuring 3–5 cm, combined with NPWT at approximately −125 mmHg. Regression of subcutaneous emphysema, assessed clinically and/or with chest X-ray or CT, was typically observed within the first 24 hours, with NPWT removal possible after 96 hours. No complications or recurrences were reported across the included studies.

**Conclusion:** NPWT-assisted blowhole incisions are a minimally invasive, safe, and effective method for managing extensive SE. Bilateral infraclavicular incisions measuring 3–5 cm combined with NPWT at continuous −125 mmHg appear to be a practical approach, typically resulting in regression within 4–72 hours, with device removal often after 96 hours. No significant complications or deaths were reported. The technique's low cost, minimal infection risk, and practicality make it a viable alternative to more invasive interventions.

**Keywords:** Blowhole Incisions, Negative-Pressure Wound Therapy, NPWT, Subcutaneous Emphysema.
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## INTRODUCTION

Subcutaneous emphysema (SE) is defined as the generation or infiltration of air in the subcutaneous tissues (beneath the dermal layer) of skin.[1-3] SE has a varied incidence from 0.43% to 2.34%, with 71% of the patients being male.[1] In other literature, extensive SE complicates between 1 and 6% of elective thoracic procedures.[4] In one case-control study, the incidence rate of extensive SE was 2.05%, and approximately 75.58% of the cases occurred within 1 to 4 days after pulmonary resection through video-assisted thoracoscopic surgery (VATS).[5] Aetiologies of SE vary from surgical, traumatic, infectious, or spontaneous aetiologies.[1] Injury to the thoracic cavity, sinus cavities, facial bones, barotrauma, bowel perforation, or pulmonary blebs are some common causes [1,6] The etiopathogenesis of SE can be broadly categorized into mucosal disruption of an air-filled structure, soft tissue infection of gas-forming organisms, or lung alveolar rupture with visceral pleural tear.[2] Air expansion in SE can involve subcutaneous and deep tissues. Air extravasation in other body cavities and spaces can also cause pneumomediastinum, pneumoperitoneum, pneumoretroperitoneum, and pneumothorax, which can further contribute to the course of SE.[1-3] SE is one of the complications following chest tube insertion in managing pneumothorax.[1,6] The parietal pleura is breached during traumatic pneumothorax and chest tube insertion, which can lead to the formation of a direct pathway for air into the subcutaneous tissue.[3]

SE can manifest as sudden swelling, dysphonia, sore throat, and, in extensive cases, pain, dysphagia, dysphonia, palpebral closure, and even airway compromise.[2,3] SE is typically a benign condition that rarely requires urgent intervention.[1,7] In its course, air can travel to areas that have lower pressure gradients, such as between the intra-alveolar and perivascular interstitium, and air will spread to the head, neck, chest, and abdomen by connecting fascial and anatomic planes. Extensive SE can happen if air accumulates in subcutaneous areas with the least amount of tension, then the pressure increases and dissects along

the other planes. Untreated extensive SE can lead to respiratory and cardiovascular collapse.[1,6] It can also lead to difficult interpretation of chest radiographs, echocardiography, ultrasound, and electrocardiograms [8]

Although SE in controlled resources and environment will resolve within 10 days, extensive SE and poorly improving SE will require treatments.[4] Currently, there is no specific guideline for treating SE. The main objective of treating SE is to decrease the source of air insufflating into the subcutaneous space, allowing proper expansion of the lung and apposition of the pleura surfaces, which will enable the injured parenchyma to recover.[9] Treatments available are focused on the underlying cause or precipitating factors of SE.[1,4] SE can be conservatively managed in hemodynamically stable patients, observation including usage of analgesia and bed rest, avoiding Valsalva maneuver, tissue squeezing, and high oxygen concentration.[9,10] These managements can also be applied to pediatric patients.[10] Treatment modalities can resort to more invasive treatments if the patients turn unstable, with respiratory or hemodynamically compromise. A high oxygen concentration can relieve discomfort, as this treatment will allow nitrogen washout and diffusion of gas particles in a patient with pneumothorax and/or pneumomediastinum.[1] Meanwhile, the other more invasive treatments, such as increasing the suction of chest tubes, placement of additional chest tubes, placement of subcutaneous drains, blowhole incisions, VATS, or open thoracotomy with repair of parenchymal injury, can also be done.[4,11] Treatments like making bilateral 2 cm infraclavicular incisions ("blowholes" incisions) in extensive SE can reduce the expansion. Another case report mentioned that placing a subcutaneous drain superficial to the pectoral fascia on low suction delivers a satisfactory result. Invasive treatments are usually done in cases of increasing airway impairment or cardiovascular compromise.[11]

Blowhole incisions are among the choices of treatment that can be done in managing SE, as stated in various case reports. Blowhole incision provides decompression in SE directly by making incisions of between 2-4 cm in length deep to the external thoracic fascia, placed in the supraclavicular or infraclavicular region.[3] Blowhole incisions are considered one of the minimally invasive methods, and these methods would be preferable in a multiple-injured patient to avoid additional systemic burden.[12] Blowhole incision alone has its limitations in the application, such as limited effectiveness and increased risk of infection.[13] Another variation of blowhole incision is combining the incision with the usage of negative wound pressure therapy (NPWT).[3] Blowhole incision provides an opening in the epidermal barrier, allowing passive release of air from tissue contiguous to the incision. At the same time, NPWT will work as an extension of the 'blowhole' technique, with the sponge maintaining incisional patency and the continuous suction improving the release of trapped air.[14] The device will be applied on top of the blow hole incisions with various pressure settings.[3] This literature review will review the role of negative wound pressure therapy (NPWT) in assisting blowhole incisions in treating extensive subcutaneous emphysema, from the usage of various settings, durations of regression of signs and symptoms, and complications regarding the method.

## METHODS

### Study design

This study reviews related studies, using searches conducted from electronic databases from PubMed, ProQuest, and Google Scholar. The search was done in English using terms that indicated the role of NPWT in assisting blowhole incisions in treating extensive subcutaneous emphysema, as listed in **Table 1**. A combination of some or all of these keywords was used in the article's title and abstract to conduct the search.

### Study selection

This literature review included various studies such as case reports, case series, and systematic reviews with intervention and comparison to conventional treatments or pre-intervention measures.

The inclusion criteria for the selected studies were as follows:

1. Articles with patients diagnosed with extensive subcutaneous emphysema caused by spontaneous pneumothorax, either primary or secondary, unexplained SE in the chest area, chest trauma, or thoracic surgery.
2. Articles using blowhole incisions and negative-pressure wound therapy (NPWT) as treatment for SE
3. Articles written in English
4. Articles that provided free full-texts.
5. All related publications published between 2009 and 2024

The exclusion criteria for the selected studies were as follows:

1. Articles that did not mention negative-pressure wound therapy (NPWT) assisting blowhole incisions in treating SE
2. Articles from letters, notes, conference abstracts, and conference publications
3. Articles that do not provide full English texts
4. Articles that do not offer free full-texts

### Literature Searching Strategy

Articles that met the inclusion and exclusion criteria were extracted using the search terms. A total of 42 articles were screened. First, through the title

**Table 1. Electronic Databases Keywords**

| Electronic Database | Keywords |
|---|---|
| PubMed | ("subcutaneous emphysema" OR "surgical emphysema") AND (blowhole OR "blowhole" OR "blow hole" OR incision) AND ("negative pressure wound therapy" OR NPWT OR VAC OR "vacuum assisted closure") |
| ProQuest | NOFT("subcutaneous emphysema" OR "surgical emphysema") AND NOFT("negative pressure wound therapy" OR NPWT OR VAC OR "vacuum assisted closure") |
| Google Scholar | intitle:"subcutaneous emphysema" AND ("negative pressure wound therapy" OR NPWT OR VAC) |

and abstract review, articles unavailable and duplicates were excluded according to exclusion criteria. The abstract and full texts were further scrutinized using exclusion and inclusion criteria.

### Data extraction and quality assessments

The search was conducted on March 31st, 2025. The search strategy produced 111 records. Following the initial screening, 69 studies were excluded at the first exclusion. Subsequently, 42 studies were assessed for eligibility, with 10 removed after title review, and then 32 articles were screened based on abstract review, resulting in the exclusion of 18 studies. The final list for review consisted of 14 studies. The searching process from selecting studies from three electronic databases is depicted in **Figure 1**. The data collected included the study name, population, and interventions (author, year, country, study population, types of extensive SE patients, underlying conditions of SE, intervention characteristics, and outcome measurements). To further ensure the validity and reliability of the selected studies regarding the role of blowhole incisions and NPWT in treating extensive SE, the studies were appraised for their quality based on the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Case Reports, Case Series, and Systematic Reviews & Research Syntheses (**Figure 1**).

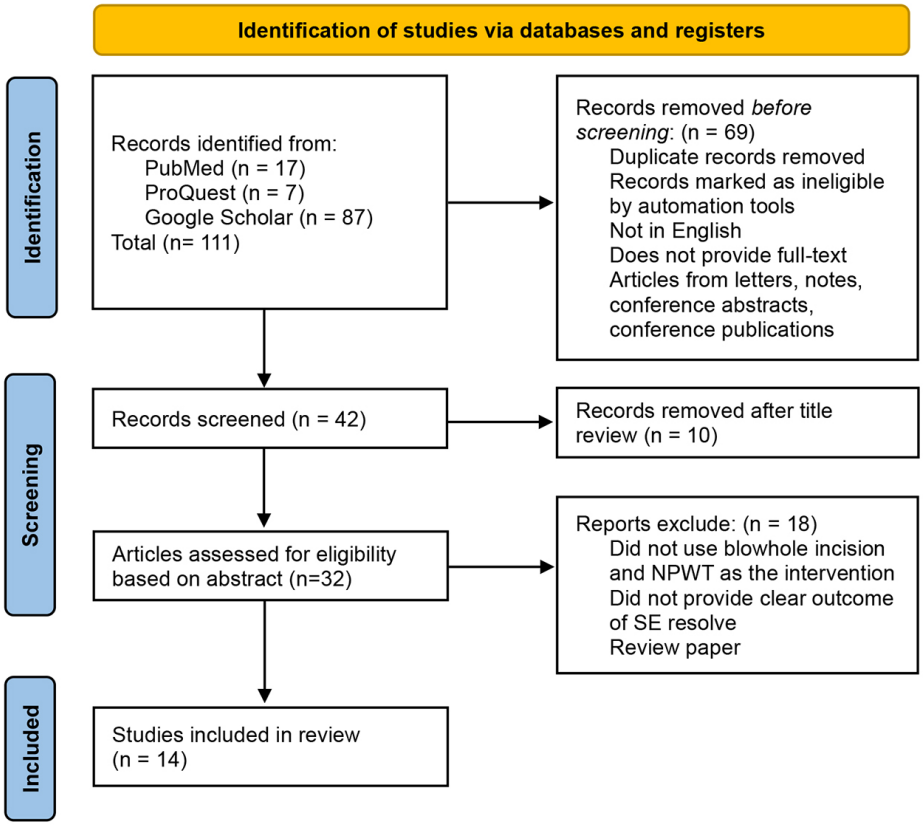


**Figure 1.** Searching Process Flowchart using PRISMA 2020 Flowchart

## RESULTS

The final list for review consisted of 14 studies, divided into 3 separated tables (**Table 2, 3,** and **4**). Each table contained data of the author details (name, year, country), study population, patients' history of illness (including related diagnosis and previous attempt of treating SE if stated), intervention characteristics, outcome measurement tools and results (including time needed from initial NPWT to initial improvement, NPWT removal time, complication after NPWT procedure and SE recurrence), and also the JBI critical appraisal score for the respective type of studies used. A study by Janssen *et al.* was extracted and assessed twice because the study had both a case series and a systematic review. Observed signs and symptoms of SE such as sudden swelling, dysphonia, sore throat, and, in extensive cases, pain, dysphagia, dysphonia, palpebral closure, and airway compromise. Chest X-Ray of SE shows striated lucencies in the soft tissues, which can show the ginkgo leaf sign if affecting the anterior chest wall. Chest CT-Scan shows pockets of gas in the subcutaneous space (**Table 2, 3, and 4**).

## DISCUSSION

Negative Wound Pressure Therapy (NPWT) or Vacuum-Assisted Closure (VAC) therapy is a system developed in the early 1990s that aids the optimization of wound healing by applying sub-atmospheric pressure to help reduce inflammatory exudate and promote granulation tissue.[23,24] The system consists of a sponge, a semiocclusive barrier, and a fluid collection system.[25] The mechanism of action comprises a range of pressure settings from -40mmHg to -200mmHg, which can be tailored for different types of wounds. The material from which the foam is derived is either polyurethane (PU) (black) or polyvinyl alcohol (PVA) (white).[24] NPWT placement can be indicated in respiratory and hemodynamically compromised patients, such as pneumomediastinum-induced cardiac tamponade and airway obstruction symptoms.[9] The first use of NPWT to treat subcutaneous emphysema was reported by Sciortino *et al.* in 2009. They applied NPWT to a blowhole incision after initial decompression failed, resulting in near-complete resolution of SE within 48 hours. Since this first case, NPWT has gained popularity as a minimally invasive, safe, and relatively simple method for aiding SE regression, although optimal incision sites and suction settings have yet to be standardized.[15]

Following a comprehensive literature search and critical appraisal, the author identified several noteworthy findings—the literature comprised of case reports, case series, and systematic reviews. The first finding was the most common underlying conditions associated with subcutaneous emphysema, namely pneumothorax and rib fractures following chest trauma, which were reported in 5 out of 14 included studies.[12,13,16,17,22] Other

**Table 2. Characteristics of the included case report studies**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Sciortino *et al*, 2009, USA[15] | A 70-year-old African American male | Right lung pneumothorax with history of bullous emphysema with left-sided chest pain → intubation and right needle thoracostomy failed → chest tube placement → developed SE on the right anterior chest | • A right infraclavicular 2-cm blowhole incision was made through the skin and prepectoral fascia<br>• NPWT dressing (VAC dressing, KCI International) was inserted into the incision and set at a continuous suction of -100 mmHg | Pre: signs and symptoms of trapped air (clinical + chest CT Scan and X-Ray)<br>Post: reduction of SE (clinical + chest CT Scan and X-Ray, after 48 h) | • Symptoms improvement: Near-complete within 96 h<br>• NPWT removal: N/A<br>• Complication: none<br>• Recurrence: none | 8/8 |
| Towe *et al*, 2014, USA[14] | 74-year-old East-Asian male | • Patient underwent elective bronchoscopy and thoracoscopic right middle lobe lobectomy, two 24Fr Blake drains were left to decompress the chest postoperatively<br>• On postoperative day (POD) 2 patient developed SE persisted to POD 4 → chest drains were removed → developed right pneumothorax → chest tube was replaced → extensive SE in POD 7 | Right 4 cm infraclavicular blowhole incision of 6 cm in length, NPWT dressing (VAC, Kinetic Concepts, Inc) was placed with continuous pressure of -125 mm Hg → NPWT dressing kept being obstructed → replacement of the dressings with additional contralateral incision | Pre: signs and symptoms of trapped air (clinical + chest X-Ray)<br>Post: reduction of SE (clinical + chest X-Ray, after 24 h) | • Symptoms improvement: partially resolved within 4 h of first NPWT initiation, complete resolve in 24 h after second NPWT attempt<br>• NPWT removal: after 6 days<br>• Complication: none<br>• Recurrence: none after the second attempt dressing | 8/8 |
| Mihanović, 2018, Croatia[16] | 60-year-old white male | • 4th-9th right side rib fractures with bilateral pneumothorax after a motor-vehicle collision<br>• Dependent on mechanical ventilator after a surgery → persistent (5 days) extensive SE and referred to current hospital → persistent bilateral pneumothorax, pneumomediastinum, pneumoperitoneum, and SE extending to the pelvis (CT scan)<br>• High inspired oxygen fraction (FiO2 100%) was required for sufficient oxygenation. | • Bilateral chest tube insertion failed<br>• Two infraclavicular blowhole incisions (3 cm in length) were made, and NPWT dressings were applied. The equipment used was the V.A.C.®GranuFoam Medium Dressing Kit from KCI Acelity, with continuous pressure of -100 mm Hg<br>• The procedure was done at the bedside in the ICU | Pre: signs and symptoms of trapped air (clinical + chest CT Scan)<br>Post: reduction of SE (clinical, after 12 h, radiograph N/A) | • Symptoms improvement: within 12 h<br>• NPWT removal: within 72 h<br>• Complication: none<br>• Recurrence: none | 6/8 |

**Table 2. Continued**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Lieb, 2018, Switzerland[17] | 79-year-old white male | • Blunt chest trauma after frontal collision<br>• Minimally dislocated fracture of the manubrium sterni, right 2nd-8th rib fractures. Developed SE in hour 6.<br>• Bilateral chest tubes failed to improve SE | A 5cm incision was applied over a large subcutaneous bulla in the right pectoral region under local anesthesia. NPWT device (brand N/A) was set at continuous -75 mmHg | Pre: signs and symptoms of trapped air (clinical + Chest CT Scan + Chest X-Ray)<br>Post: reduction of SE (clinical in 1st day) | • Symptoms improvement: rapidly improved (time N/A)<br>• NPWT removal: after 3 days<br>• Complication: none<br>• Recurrence: none | 7/8 |
| Sindi *et al*, 2019, Saudi Arabia[10] | 7-year-old child | • Right pneumothorax, pneumomediastinum, pneumopericardium, and extensive SE (neck-back-inguinal) after an unclear history of trauma.<br>• Bilateral intercostal chest tubes failed. | Infraclavicular bilateral blowhole incisions (lengths were not detailed) were made, connected to NPWT, with the pressure setting not detailed | Pre: signs and symptoms of trapped air (clinical + chest CT Scan)<br>Post: reduction of SE (clinical + repeated chest CT Scan with no remarkable improvement, showed viral infection, CT Scan time N/A) | • Symptoms improved: within 10 days<br>• NPWT removal: time N/A<br>• Complication: none<br>• Recurrence: none | 6/8 |
| Bouwmeester, 2020, the Netherlands[18] | 50-year-old white male | The patient was diagnosed with Pneumocystis jirovecii pneumonia and developed severe subcutaneous and mediastinal emphysema, which was progressive despite low-pressure mechanical ventilation. | Two infraclavicular skin incisions (incision sizes not listed) and placement of NPWT (ActiV.A.C., KCI Medical, –125 mm Hg). | Pre: signs and symptoms of trapped air (clinical + chest CT Scan)<br>Post: reduction of SE (clinical in 1st week + chest X-Ray, time N/A) | • Symptoms improvement: within 1 week<br>• NPWT removal: after 9 days<br>• Complication: none<br>• Recurrence: N/A | 6/8 |
| Huan *et al*, 2020, Malaysia[19] | 80-year-old East-Asian male | • Right spontaneous secondary pneumothorax → misplaced chest tube's tip → extensive SE<br>• Past medical history: COPD<br>• The patient was intubated<br>• Subcutaneous cannula insertions failed to treat SE | • Bilateral 5 cm below the clavicle level blowhole incisions with NPWT dressings, with pressure setting 10 mmHg, with sequential increment up to 50 mmHg<br>• External pressure and massage | Pre: signs and symptoms of trapped air (clinical + chest CT Scan)<br>Post: reduction of SE (clinical, within 24 h + radiograph N/A) | • Symptoms improvement: within 24 h<br>• NPWT removal: after 4 days<br>• Complication: none<br>• Recurrence: none | 6/8 |
| Taylor & McGowan, 2020, USA[12] | 52-year-old female | • Right 4th-7th rib fractures after a fall, bilateral pneumothoraces, pneumomediastinum, extensive SE<br>• Past medical history: COPD<br>• Bilateral chest tubes failed → SE persisted | Day 6 post-injury: bilateral infraclavicular blowhole incisions (3 cm in length) and placement of NPWT with setting of -125mmHg continuous pressure | Pre: signs and symptoms of trapped air (clinical + chest X-Ray) Post: reduction of SE (clinical + chest X-Ray, after 34 h) | • Symptoms improvement: within 72 h<br>• NPWT removal: after 5 days<br>• Complication: none<br>• Recurrence: none | 7/8 |

**Table 2. Continued**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Soler-Silva, 2022, Spain[20] | 82-year-old male | ASA grade III with COVID-19 and ARDS → invasive ventilation → developed moderate SE 24 hours after intubation → extensive SE in 24 hours. | Two infraclavicular blowhole incisions (lengths were not listed) and NPWT with pressure setting was -150 mmHg were applied. | Pre: signs and symptoms of trapped air (clinical + chest CT Scan and X-Ray)<br>Post: reduction of SE (clinical + chest X-Ray, after 5 days) | • Symptoms improvement: improvement onset N/A<br>• NPWT removal: after 5 days<br>• Complication: none<br>• Recurrence: none | 7/8 |

The selected papers had an average score of 6,8/8 (85%) on the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Case Reports, which was considered good quality for case reports. N/A=Not addressed.

**Table 3. Characteristics of the included case series studies**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Byun *et al*, 2013, South Korea[9] | 4 male patients, age 63-87 years (mean age 73.3 years) | • All patients had secondary pneumothorax with extensive SE<br>• All had a COPD emphysematous lung history<br>• Chest tube placement → SE did not resolve | • Right or left infraclavicular 2 cm blowhole incisions, and placement of NPWT dressings and equipment (CuraVAC™, Daewoong Pharm. Co.) was done, with continuous -150 mmHg pressure setting<br>• Mean time to NPWT was 1.5 days post-chest tube placement (range 0-3 days) | Pre: signs and symptoms from clinical physical examination + cutaneous trapped air on chest X-Ray<br>Post: signs of trapped air reduction observed both clinical and chest X-Ray (starting from 24 h post procedure, daily) | • Symptoms improvement: within 24 h<br>• NPWT removal: within median of 72 h (range 48-96 h)<br>• Complication: none<br>• Recurrence: none | 5/9 |
| Son *et al*, 2014, South Korea[21] | 10 patients, age 42-81 years old (mean age was 61.5 ± 12.9 years old), and the male: female ratio was 7:3 | • All 10 patients required mechanical ventilation support for the following causes: postoperative pneumonia (4 patients); blunt lung injury (1); acute exacerbation of idiopathic pulmonary fibrosis (1); pneumonia (2); status asthmaticus (1), and bilateral pneumothorax with re-expansion pulmonary oedema (1)<br>• 8 patients developed pneumothorax requiring a chest tube before the development of SE | • Blowhole skin incision (2–2.5 cm in length) was made supraclavicularly or infraclavicularly, then the subcutaneous space was dissected to the maximum possible extent to drain out the trapped air<br>• Then, 2–3-cm long block-shaped NPWT dressings and equipment were inserted into the incision, and the suction pressure setting was set at -150 mmHg | Pre: signs and symptoms from clinical physical examination + cutaneous trapped air on chest X-Ray<br>Post: signs of trapped air reduction observed both clinical and on chest X-Ray (72 h after insertion) | • Symptoms improvement: improved, duration N/A<br>• NPWT removal: within a mean duration of 7.3 ± 4.8 (range 3–14) days<br>• Complication: none<br>• Recurrence: none | 5/9 |

**Table 3. Continued**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Minarich, 2021, USA[4] | 5 post-operative patients (3 males, 2 females) | • 5 post-operative patients had worsening SE despite operatively placed chest tubes<br>• All have extensive smoking histories<br>• Surgical procedures prior to SE: wedge resection (n = 1), lobectomy (n = 1), combined wedge resection and lobectomy (n = 2), thymectomy (n = 1)<br>• Chest tubes were placed at continuous suction of -20 cm $H_2O$. Initial effort to treat SE by increasing the suction (range 25-40 cm $H_2O$ failed) | • A 5-cm incision was made 2 cm below the clavicle on the ipsilateral side of the thoracic procedure under local anesthesia at the bedside.<br>• A black wound VAC sponge was cut to size and placed within the wound, and suction was applied to −125 mm Hg (V.A.C.ULTA™ system while in-patient, then switched to the ACTIV.A.C.™ system at discharge, KCL/3M, 3M Center, USA).<br>• The VAC dressing was placed a median of 6 days after the initial operation (range 3–19 days). | Pre: signs and symptoms of trapped air (clinical + chest X-Ray)<br>Post: reduction of SE (clinical + chest X-Ray, after 72 h) | • Symptoms improvement: immediate (onset N/A)<br>• NPWT removal: Median was 10 days (range 4–15 days)<br>• Complication: none<br>• Recurrence: N/A | 5/9 |
| Janssen *et al*, 2022, the Netherlands[22] | Case series: 11 patients, median age was 69 years (range 65–72 years), and the male: female ratio was 7:4. | • Most patients (n=7/11) underwent a uniportal video-assisted thoracic surgery (uVATS) lobectomy<br>• One patient had a secondary spontaneous pneumothorax caused by COPD<br>• Patients had a history of COPD (n=5), emphysema (n=1), asthma (n=1), and post-COVID-19 pneumonia (n=1).<br>• Two patients required mechanical ventilation support<br>• Chest tubes were in situ and were on a no-suction water seal regime | Blowhole incisions were made, and NPWT was initiated at a median of 5 days (range 2–13 days) after SE symptoms were first observed. Continuous pressure range N/A | Pre: signs and symptoms from clinical physical examination + cutaneous trapped air on chest X-Ray.<br>Post: signs of trapped air reduction observed both clinical and chest X-Ray (started from 2 days post-procedure, another at day 5) | • In 9/11 patients, SE totally resolved during NPWT, duration N/A<br>• NPWT removal: median duration was 8 days (range 6–11 days)<br>• Complication: none<br>• Recurrence: none | 8/9 |

**Table 3. Continued**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Fernandez *et al*, 2024, USA[13] | 59-year-old female | • Two left rib fractures with pneumothorax<br>• Previous history: COPD<br>• Intubation and two attempts of chest tube thoracostomy → developed diffuse SE (Grade V) | Incisional NPWT (INPWT) was done, incisions and equipment, and their settings were not listed | Pre: signs and symptoms of trapped air (clinical + chest X-Ray)<br>Post: reduction of SE (clinical), radiograph N/A | • Symptoms improvement: within 6 h, full resolve in 24 h<br>• NPWT removal: after 4 days<br>• Complication: none<br>• Recurrence: none | 4/9 |
| | 39-year-old female | • Multiple pelvic, rib, and spinal fractures, and bilateral pneumothorax with SE caused by a motor vehicle collision<br>• Intubation and bilateral chest tubes failed → SE progressed to Grade V | | Pre: signs and symptoms of trapped air (clinical + chest X-Ray and CT Scan)<br>Post: reduction of SE (clinical), radiograph N/A | • Symptoms improvement: within 6 h, full resolve in 24 h<br>• NPWT removal: after 4 days<br>• Complication: N/A<br>• Recurrence: N/A | |
| | 60-year-old white male | • Patient with empyema underwent VATS and decortication → prolonged air leak requiring chest tube<br>• Eight weeks later developed hypoxemia and SE Grade V in 48 hours | | Pre: signs and symptoms of trapped air (clinical + chest CT Scan)<br>Post: reduction of SE (clinical), radiograph N/A | • Symptoms improvement: N/A<br>• NPWT removal: after hospital day 10<br>• Complication: none<br>• Recurrence: none | |
| | 72-year-old male | • Left rib fractures and left pneumothorax after falling 12 stairs<br>• Previous history: emphysema<br>• Developed SE on HD 5 (Grade IV) after the chest tube was misplaced into the pulmonary parenchyma | | Pre: Pre: signs and symptoms of trapped air (clinical + chest X-Ray)<br>Post: reduction of SE (clinical), radiograph N/A | • Symptoms improvement: within 24 h, and near total resolution at 48 h<br>• NPWT removal: N/A<br>• Complication: none<br>• Recurrence: none | |

The selected papers had an average score of 5.4/9 (60%) on the JBI Critical Appraisal Checklist for Case Series, which was considered a moderate quality case series. N/A=Not addressed.

common aetiologies included pre-existing pulmonary conditions predisposing to spontaneous subcutaneous emphysema, such as chronic obstructive pulmonary disease (COPD), which were reported in 3 of the 14 studies.[9,19,22] Less frequently, SE was associated with conditions such as Pneumocystis jirovecii pneumonia and COVID-19.[18,20,22] In addition to underlying pulmonary disease, iatrogenic factors were also identified. SE was reported following medical interventions such as mechanical ventilation, as well as surgical procedures including video-assisted thoracic surgery (VATS) and open thoracotomy.[4,13,14,21,22]

The aetiologies mentioned above, ranging from trauma-related pneumothorax to chronic pulmonary disease, infection, and iatrogenic causes, are frequently encountered in daily practice. Conventional strategies such as subcutaneous drains, high-flow oxygen, or additional chest tubes or increasing their suction pressure, remain the mainstay of management and are typically attempted first.[4,9-11] Ipsilateral chest tubes are most often used as the

**Table 4. Characteristics of the included systematic review study**

| Author, Year, Country | Study Population | Patients' History of Illness | Intervention Characteristics | Measurements | Treatment Outcome | JBI Critical Appraisal |
|---|---|---|---|---|---|---|
| Janssen *et al*, 2022, the Netherlands[22] | Systematic review: 10 studies and 23 patients; age varied from 42-87 years | SE occurred following secondary spontaneous pneumothorax (n=9/23), traumatic pneumothorax (n=5/23 patients), ventilator-associated barotrauma (n=5/23 patients), or lung surgery (n=4/23 patients) | • The infraclavicular blowhole incisions of 2-6 cm in length create a prepectoral pocket for the NPWT foam insertion. Three patients received a supraclavicular incision. In five cases, the blowhole incisions were not only on the affected side.<br>• Different NPWT techniques were applied. The studies used closed incision NPWT (ciNPWT) and PICO©. Continuous suction pressure range N/A | Pre: signs and symptoms observed with clinical physical examination, radiographs examination N/A<br>Post: signs and symptoms of trapped air reduction observed by clinical physical examination | • Symptoms improvement: 7/10 articles and 20/23 patients reported within 48 h<br>• NPWT removal: median of 4 days (range 3–7.5 days)<br>• Complication: non<br>• Recurrence: none<br>• No relation with the used technique, nor between the duration prior to NPWT placement and duration of the NPWT, due to lack of data | 9/11 |

The selected paper score 9/11 (82%) on the JBI Critical Appraisal Checklist for Systematic Reviews & Research Syntheses was considered good quality for systematic reviews. N/A=Not addressed.

initial measure to evacuate subcutaneous air and to prevent further progression that could compromise hemodynamic stability. [9,13,14,22] In some cases, bilateral chest tube placement was performed as a modification of the standard ipsilateral approach, representing the majority of first-line interventions across the included studies.[10,12,13,16,17] Minarich *et al*. also described increasing the negative suction pressure setting as an attempt to accelerate the extensive SE relieve.[4] Placement of subcutaneous catheter was also explored by Huan *et al*.[19] Usage of high inspired oxygen fraction (FiO2 100%) was also used to help maintain the oxygen supply of patients with extensive SE.[16] But the procedures mentioned in the included studies faced challenges and did not yield satisfactory results, thus authors alternated to blowhole incisions and NPWT procedure, as SE remained or progressed to extensive SE. Conventional methods, including subcutaneous drains, high-flow oxygen, and additional chest tubes, often showed limited efficacy in extensive SE, requiring longer intervention or increased monitoring. In contrast, NPWT-assisted blowhole incisions provide more rapid regression, minimal complications, and can be performed at the bedside, making it a practical alternative. An additional advantage highlighted in the literature is that this technique can be performed safely at the bedside in the intensive care unit (ICU), particularly in patients whose condition is too unstable to undergo definitive surgical repair of persistent air leaks.[16] It is essential that these procedures are carried out while ensuring a sterile field and the correct handling of instruments. In such scenarios, NPWT-assisted blowhole incisions not only provide rapid relief of massive SE but also serve as a practical, minimally invasive, and adaptable intervention that bridges the gap until definitive management becomes feasible.

With regard to the technical aspects, the number, length, and location of blowhole incisions varied across studies. Incisions were performed either supraclavicularly or infraclavicularly, with the latter was more frequently reported; only one study specifically described the supraclavicular approach.[21] Nevertheless, both techniques appeared to yield comparable outcomes. Among infraclavicular approaches, bilateral incisions were reported with lengths ranging from 3-5 cm.[12,16,19] Single ipsilateral infraclavicular incisions were also described, typically measuring 2–5 cm.[4,9,14,15,17,21] In addition to variation in incision size and number, the negative pressure settings applied to NPWT also differed among studies. Huan *et al.* reported the lowest continuous suction pressure, up to 50 mmHg. Intermediate pressures between 51–100 mmHg were described in several studies, while higher settings of 101–150 mmHg were most frequently applied, with –125 mmHg being the most commonly used.[4,9,12-21] In clinical

practice, bilateral infraclavicular blowhole incisions measuring approximately 3–5 cm, combined with NPWT set at around −125 mmHg, appear to represent the most reproducible and effective approach for extensive subcutaneous emphysema. In contrast, single ipsilateral incisions may remain a reasonable alternative in selected or fragile patients.

Outcome assessment across the included studies was heterogeneous, both at baseline and during follow-up. Clinical evaluation relied on observed signs and symptoms of SE, such as sudden swelling, dysphonia, sore throat, and, in more extensive cases, pain, dysphagia, palpebral closure, or airway compromise. Some studies relied solely on clinical physical examination.[16,19] Several reports combined clinical assessment with chest X-Ray, which typically revealed striated lucencies in the soft tissues and, in some cases, the characteristic 'ginkgo leaf sign' when the anterior chest wall was affected.[4,12,14,20,21] Only Sciortino *et al.* incorporated both chest X-Ray and CT imaging, with CT demonstrating pockets of gas within the subcutaneous tissues.[15] Follow-up imaging was performed at variable intervals, ranging from within 24 hours, 24–48 hours, 48–72 hours, to beyond 72 hours.[12-21] Taken together, these findings underscore the lack of standardized outcome definitions and highlight the descriptive nature of current evidence.

In terms of clinical outcomes, symptomatic improvement following NPWT-assisted blowhole incisions was generally rapid. The majority of patients demonstrated regression of subcutaneous emphysema within the first 24 hours.[9,13,14,16,19] Improvement within 24–72 hours was described in two case reports, whereas delayed responses beyond 72 hours were also noted.[10,12,15,18] Taken together, these findings suggest that NPWT-assisted blowhole incisions typically result in substantial clinical improvement within the first 1–3 days, underscoring the effectiveness of this intervention for extensive SE. The duration of NPWT application also varied among the included reports. Device removal within 96 hours was documented in 4 out of 14 studies.[9,16,17,22] In contrast, most other studies reported longer durations, with NPWT maintained beyond 96 hours.[4,12-15,18-20] Overall, these findings indicate that while early removal within 4 days is feasible in selected cases, the majority of patients required a longer treatment period before complete regression of subcutaneous emphysema was achieved. This variability may also reflect differences in patients' underlying pulmonary conditions, as impaired alveolar integrity and persistent air leaks could delay the resolution process.

Importantly, none of the included studies explicitly reported complications or recurrence following the use of NPWT-assisted blowhole incisions. This consistent absence of adverse events across heterogeneous case reports, case series, and systematic reviews supports the safety of this technique and reinforces its role as a minimally invasive and reliable intervention for managing extensive subcutaneous emphysema. However, the strength of this conclusion is limited by several factors. Outcome definitions were not standardized, with some studies relying solely on clinical regression while others incorporated chest X-ray or CT imaging. Follow-up intervals were also inconsistent, ranging from within 24 hours to beyond 72 hours, and several studies did not specify the schedule or modality used. Moreover, long-term outcomes such as recurrence or late complications were rarely evaluated, as most reports restricted follow-up to the inpatient period. Taken together, these limitations constrain comparability and highlight the need for future studies to establish standardized criteria for outcome measurement and follow-up. Although most reported patients were adults, NPWT-assisted blowhole incisions have also been applied successfully in a pediatric patient (7 years old), suggesting potential applicability across age groups. Future research could explore the incidence and characteristics of extensive subcutaneous emphysema in children and evaluate the safety and efficacy of NPWT-assisted blowhole incisions in pediatric populations.

## CONCLUSION

Extensive subcutaneous emphysema can lead to serious respiratory and cardiovascular compromise, requiring timely intervention. NPWT-assisted blowhole incisions have emerged as a minimally invasive, safe, and effective method to relieve extensive SE. The technique combines blowhole incisions, which provide openings for passive air release, with NPWT to maintain incision patency and enhance evacuation of trapped air. Since the first reported case by Sciortino *et al.* in 2009, NPWT has been applied with varying incision sites, lengths, and pressure settings. In clinical practice, bilateral infraclavicular blowhole incisions measuring approximately 3–5 cm, combined with NPWT set at around −125 mmHg, appear to represent the most reproducible and effective approach for extensive SE, typically resulting in regression within 4–72 hours, with NPWT removal often performed after 96 hours. No significant complications or deaths were reported, supporting the safety of this approach. Although most patients were adults, successful application in a pediatric patient (7 years old) highlights the potential for use across age groups. Overall, the minimally invasive nature, low cost, and minimal infection risk make NPWT-assisted blowhole incisions a practical alternative to more invasive interventions for managing extensive SE. At the same time, future studies should aim to standardize outcome definitions and further explore their use in pediatric populations.

## CONFLICT OF INTEREST

The author declares no conflict of interest regarding this study publication.

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## ETHICAL CLEARANCE

Not applicable.

## AUTHOR CONTRIBUTION

The author conducted the study independently.

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