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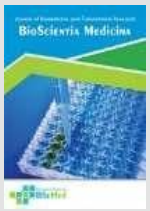

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Pathogenesis and Minimally Invasive Management of Subcutaneous Emphysema: A Narrative Literature Review

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A B S T R A C T

Subcutaneous emphysema is the result of air infiltrating the subcutaneous and soft tissues. The prevalence of subcutaneous emphysema varies between 0.43% and 2.34%. Subcutaneous emphysema typically results in mild symptoms, poses no significant risk, and does not necessitate specific medical intervention. Pathologies affecting underlying tissues can exhibit greater severity and pose a risk to life. Subcutaneous emphysema is a challenge in terms of how to handle it. The treatment should initiate a focused endeavor to determine the underlying etiology of subcutaneous air dissection. This literature review focuses on subcutaneous emphysema, specifically exploring its pathogenesis and therapy strategies for people with this condition.

1. Introduction

Subcutaneous emphysema (ES) is the infiltration of air into the subcutaneous and soft tissues. Typically, this phenomenon manifests in the pliable tissue of the chest wall or neck; however, it can also manifest in other regions of the body.[1] The prevalence of ES varies from 0.43% to 2.34%.[2-4] A study conducted by Aghajanzadeh et al. over a period of 10 years revealed that the mean age of those diagnosed with ES ranges from 25 to 53 years, with males accounting for 71% of the patient population.

Epidural space (ES) can be caused by various factors, including severe or sharp trauma, barotrauma, infection, cancer, and surgical operations. It can also occur without any apparent cause. Subcutaneous emphysema is the result of air entering the layer of tissue beneath the skin, known as the subcutaneous layer.[4,5] Air expansion may affect both the subcutaneous tissue and deeper tissue, with the spread of air beneath the skin leading to a deterioration in clinical condition.[6,7] The emergence of ES can suggest the presence of air in other internal regions of the body that are not easily visible during a basic examination. Accurate evaluation of emphysema in anatomically challenging regions necessitates meticulousness and targeted diagnostic procedures.[8]

Typical indications of ES include noticeable swelling in the neck along with chest discomfort. Additional indications and manifestations encompass a tender throat, discomfort in the neck region, challenges in swallowing, limited breath capacity, audible breathing difficulties, and an expansion of the abdomen. Subcutaneous emphysema typically presents with mild symptoms, poses no significant risk, and does not necessitate specific medical intervention. Subcutaneous emphysema that affects

deeper tissue is a more serious and potentially life-threatening condition. This can be worsened by limiting the expansion of the lungs and can result in elevated airway pressures, severe respiratory acidosis, failure of ventilation, malfunction of pacemakers in patients who use them, and obstruction of the airway.[3,4]

The diagnosis is established through a comprehensive and precise assessment, which includes a detailed medical history, a thorough physical examination, and the identification of crepitus through palpation. Additionally, radiological examination reveals the presence of air in the affected area. The process of management involves the initial step of identifying the underlying cause of subcutaneous air dissection.[1,4] Management strategies encompass the utilization of subcutaneous incisions, needles, and diverse drainage procedures. The presence of air in the chest cavity and other bodily cavities, which is not natural, can lead to disorders such as pneumomediastinum, pneumoperitoneum, and pneumothorax.[5-7]

The movement of air from the region between the alveoli and the surrounding blood vessels, driven by the pressure difference, leads to its accumulation in the subcutaneous area. This accumulation occurs from areas of lower pressure to areas of higher pressure, causing a widespread spread under the skin. This can ultimately lead to the collapse of the lungs and heart.[2,8] ES can occur in some circumstances, even in the absence of an underlying disease. For example, women in the second stage of labor may experience ES due to the intense pressure, leading to an increase in intrathoracic pressure. The worldwide prevalence of this syndrome is approximately 1 in 2,000 occurrences.[1,9]

Tracheal damage resulting from endotracheal intubation can lead to esophageal stenosis (ES) and is more prevalent among women and those aged 50 and above. The incidence rate of tracheal damage during endotracheal intubation is approximately 0.05%. The incidence of harm related to single lumen endotracheal intubation varies from 1 in 20,000 to 1 in 75,000, while for double lumen endotracheal intubation tubes, it ranges from 0.05% to 0.19%. Tracheal tears are also associated with the risk of emergency intubation.[4,6] This literature review will examine the topic of ES, with a particular focus on the causes and treatment methods for patients with subcutaneous emphysema.

Pathogenesis

Subcutaneous emphysema can be caused by trauma, both iatrogenic and infectious. Injuries to the chest cavity, sinus cavity, facial bones, barotrauma, intestinal perforation, or lung bleb are some of the common causes that often occur. Iatrogenic causes can occur due to malfunction or interruption of the ventilator circuit, improper closure of the pop-off valve, or the Valsalva maneuver, which increases thoracic pressure and trauma to the airway.[1,3] Air can enter the subcutaneous space through small mucosal injuries in the trachea or pharynx. during traumatic intubation, balloon overload of the endotracheal intubation tube, or increased airway pressure in the presence of a closed glottis. Injury to the esophagus during the placement of a nasogastric tube can also provide an entry point for air.[2,7] Because fascial planes connect the mediastinum and retroperitoneum, air normally flows from these areas. The condition of trauma or the condition of a punctured lung causes rupture of the alveoli so that air escapes through the alveoli and causes air to move up the perivascular envelope and then into the subcutaneous tissue of the mediastinum, neck, head, and other parts of the body. Increased pressure in the lungs can also cause rupture of the alveoli, resulting in ES (Figure 1).[1,3,10,11]

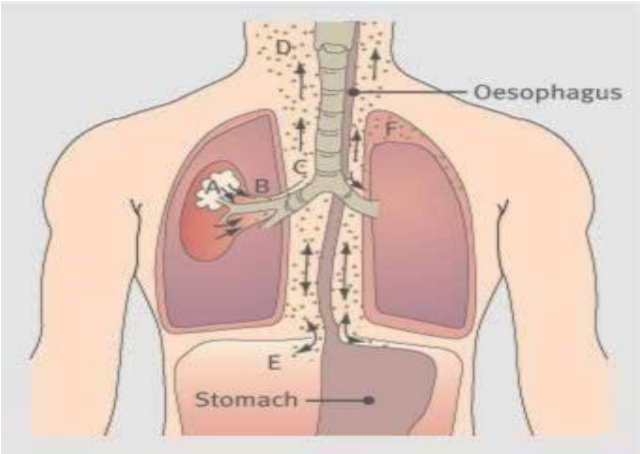

Figure 1. Overview of air flow in the pathogenesis of subcutaneous emphysema.

Air can enter the subcutaneous tissue through soft tissue during a tracheotomy, through the chest wall during arthroscopic shoulder surgery, through an extremity due to trauma, through intestinal or esophageal perforation without lung injury, through a thoracostomy route, or during a central venous access procedure or percutaneous or transbronchial lung biopsy. Subcutaneous emphysema has also been observed to occur following air insufflation during modern laparoscopy, through the female genital tract during pelvic examination, postpartum exercise, and during pregnancy.[7,8] The positive pressure exerted by ventilator inspiration can increase air expansion through fascial planes associated with a reduced gradient of partial pressure. The risk of barotrauma when using non-invasive ventilation is lower, so ES complications are less common. Massive bilateral subcutaneous emphysema can occur in some cases without evidence of pneumothorax, with postoperative nausea and vomiting.[1,4]

Spontaneous pneumomediastinum can also result in ES and is an emergency condition that must be treated. Spontaneous pneumomediastinum is often referred to as Hamman's syndrome, which can be the Macklin effect, namely that there is free air in the mediastinum spontaneously without any cause such as trauma or previous infection.[11] Macklin described the pathophysiology of Hamman's syndrome as barotrauma due to rupture of the alveolar membrane, causing a positive pressure gradient of air from the lungs. to the mediastinum increases and results in pneumomediastinum.[11,12]

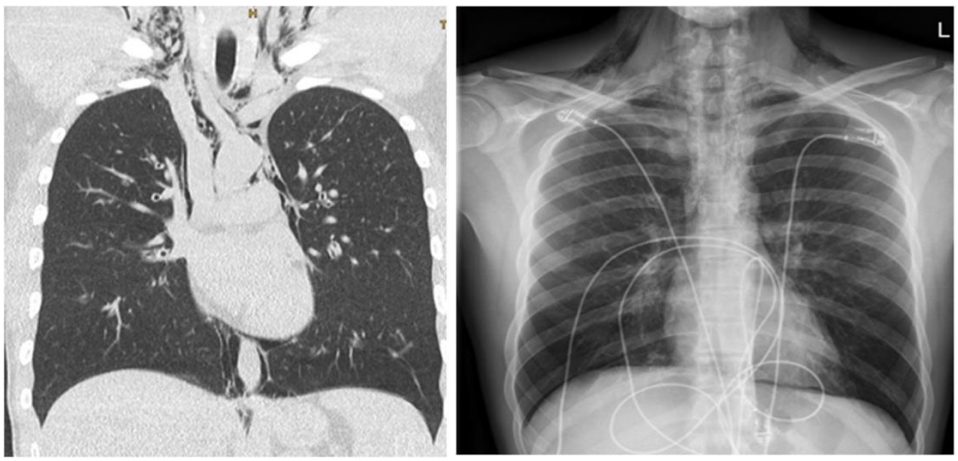

Figure 2. Computed tomography (CT) scan of the chest and chest X-ray show a picture of emphysema without any lung abnormalities

Injuries

Subcutaneous emphysema can result from blunt and sharp trauma, frequently from stab wounds or gunshot wounds. Chest trauma is the main cause of ES, which can cause air to enter the skin of the chest wall from the neck or lungs. When the pleural membrane is punctured, as occurs in stab trauma to the chest area, air will flow from the lungs to the muscles and subcutaneous tissue of the chest wall. Lung laceration can cause the alveoli to rupture so that air can flow under the visceral pleura to the hilus of the lung, up the trachea, then the neck, and then to the chest wall. This condition can also occur when a broken rib punctures the lung. Rib fractures can tear the parietal pleura, allowing air to escape into the subcutaneous tissue.[8,13] Subcutaneous emphysema is most often found in cases of pneumothorax and can also occur due to air in the mediastinum or air in the pericardial cavity around the heart (pneumopericardium). The condition of tension pneumothorax is characterized by air accumulating in the pleural cavity and putting pressure on the organs in the chest, causing air to enter the subcutaneous tissue through the pleura, which is torn by the broken ribs. Subcutaneous emphysema originating from the pneumothorax will cause air to enter the tissue of the face, neck, chest, armpits, or stomach.[13,14]

Barotrauma results in damage caused by excessive pressure, with ES as the initial clinical symptom that will appear. This condition can occur in injuries resulting from diving and is an indication that the lungs have experienced significant barotrauma.[1,4] Trauma to the respiratory system other than the lungs, such as rupture of the bronchial tubes, can also cause ES. Air can flow towards the neck area from pneumomediastinum caused by rupture of the bronchial tubes or down from a tear in the trachea or larynx into the soft tissues of the chest. This condition often occurs in cases of facial bone fractures, neoplasms, asthma attacks, Heimlich maneuvers, and during childbirth.[3,8,9]

Iatrogenic

Medical procedures can cause ES, especially in operations in the chest area, but they can also occur in operations in other areas, such as operations in the area around the esophagus, and are very likely to occur in long-term operations. Other potential causes are anesthesia, laparoscopy, and cricothyrotomy procedures. A pneumonectomy that removes the entire lung can cause the remaining bronchi to release air. This condition is rare but can be very serious as it causes progressive subcutaneous emphysema.[2,3,5] Air can leak out of the pleural cavity through the incision made for thoracotomy, causing ES. This condition can cause a variety of clinical symptoms, and the most common is swelling of the face and neck, which is usually painless, with immediate onset, palpable crepitus on palpation, and often with subcutaneous air visible on a chest x-ray. One of the causes of iatrogenic ES other than surgery is a chest drainage tube that is not functioning properly.[1,3] Patients who have a chest drainage tube installed and ES occurs is often a sign that there is something wrong with the chest drainage tube, such as a blockage that can be caused by fluid. lumpy, pinched, or out of place. Patients with pneumothorax who use a ventilator may experience ES because the pressure of mechanical ventilation forces air into the tissue.[5-8] Another cause that can cause ES is the trachea being injured during a tracheostomy or endotracheal intubation. Most cases of injury to the trachea cause air to enter the subcutaneous space, resulting in ES. Besides that, the endotracheal tube can puncture the trachea or bronchus and cause ES.

Infection

Necrotizing infections such as gangrene and ES can cause air to become trapped under the skin and are a sign of further clinical deterioration. Subcutaneous emphysema is also considered a feature of Fournier's gangrene. Subcutaneous emphysema can occur when the microorganisms that cause infection produce gas through a fermentation process. Subcutaneous emphysema occurs due to an infectious process,

which is a sign of progression towards a systemic infection, namely the spread of infection beyond the initial location so that ES can occur in uninfected places or elsewhere.[4,6,10]

Diagnosis

The diagnosis of ES is made based on anamnesis, physical examination, and supporting examinations. In history, patients most often complain of shortness of breath, chest tightness, hoarseness, pain, and swelling in the ES area. Physical examination revealed crepitation in the thorax, cervix and abdomen which indicated that there was air in the soft tissue. The most common supporting examinations performed are chest x-rays and thoracic CT scans. A typical appearance on a chest x-ray is the Gingko leaf image, namely an image of air around the neck and axilla with a radiolucent line around the pectoralis muscle, thus forming an image of a Gingko leaf as in Figure 3.[16,17]

Figure 3. Gingko leaf imaging on chest x-ray

A thoracic CT scan shows a dark image in the subcutaneous area of the thorax, which, if extensive, will put pressure on the thorax. Aghajandazeh et al.'s research classified the severity of ES based on anatomical extension into five classes, namely: (1) base of the neck; (2) entire neck area; (3) subpectoralis major area; (4) chest wall and entire neck area; and (5) chest wall, neck, orbital, scalp, abdominal wall, upper limbs, and scrotum.[16,17] The clinical classification of the severity of subcutaneous emphysema can be seen in Figure 4.

Treatment

Management of ES cases is based on the cause and severity. Observation can be performed in mild cases that do not cause significant patient discomfort. ES patients present with peritonitis without visible compartment or deep tissue involvement at exploratory laparotomy. The use of an abdominal binder can be used for patient comfort. A radiological examination can be carried out to monitor the progress of therapy.[2,3] Generally, ES improves and resolves spontaneously without intervention; however, in cases of grade 3 ES and above, which extend beyond the trunk to the neck and head, it must be treated to prevent complications.[2,3]

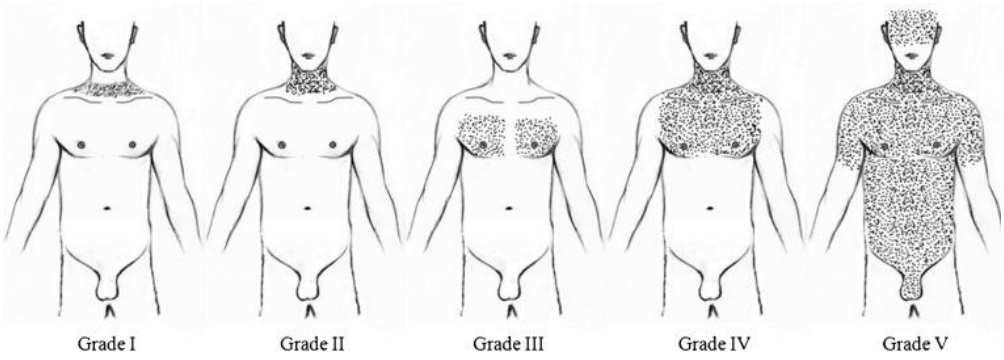

Figure 4. Classification of the severity of subcutaneous emphysema based on clinical conditions

Initial Management

Initial management begins with an assessment of the patient's condition. Any possible airway obstruction should be treated first, and the patient may require oxygen management. Providing oxygen is useful in the air resorption process in cases of ongoing air leaks, but not much research has been done on oxygen. The British Thoracic Society (BTS) recommends that management of ES should begin with a concerted effort to identify the cause. The most reliable supporting examination for this is a chest CT examination, which can be seen in Figure 5.[13,14]

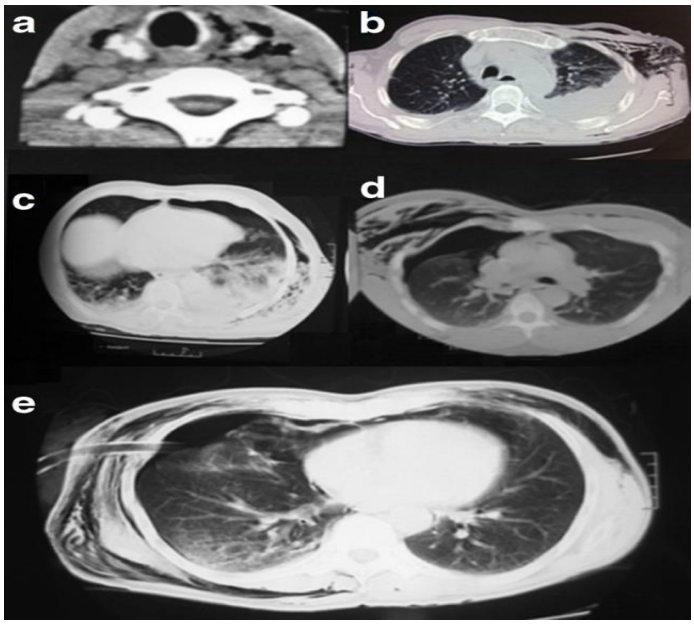

Figure 5. Classification of the severity of subcutaneous emphysema based on CT-scan

Patients with ES caused by pneumothorax must be managed appropriately and correctly, especially patients with extensive pneumothorax. The most common treatment is intercostal drainage. In trauma settings, larger bore drains of more than 28F are generally recommended due to the potential need for air and blood evacuation, although recent evidence suggests that 14F drains are sufficient if smaller drains are well tolerated by the patient and minimize injury to the patient.[13,14] For patients who have had water seal drainage (WSD) installed, it is important to ensure that the WSD is in the correct position and is not bent, blocked, or pinched. If there is any doubt about WSD, a normal, sterile saline rinse can be performed. Treating ES alone is an option for doctors treating patients with ES originating from a

pneumothorax that cannot be drained safely, for example, because of its very small size, if the patient refuses intercostal drainage, or if the ultimate goal of treatment is symptom relief alone.[12,17]

Subcutaneous emphysema drainage via blow hole

Subcutaneous emphysema that cannot be treated with oxygen can be decompressed directly through an incision in the skin, which is called a blow hole. There are several reports in the literature about ES that have been successfully drained massively. Massive unilateral and bilateral incisions ranging from 2-4 cm to the external thoracic fascia are not too deep and are carried out using a sterile scalpel. This procedure can be performed on ES in both supraclavicular, infraclavicular, and often midclavicular positions.[15,16] The study by Herlan et al. found results in four ICU patients, three patients after thoracic surgery, and one patient with ARDS. Bilateral 3 cm infraclavicular incisions into the pectoralis fascia successfully resolved ES in all four patients within 2 to 4 days. These results show success in patients because each patient had a massive degree of ES. Three patients showed tension phenomena from ES, and one patient was on positive pressure ventilation. Massage of the blowhole incision is often performed to manually decompress air from the hole and has been reported to significantly speed up the resolution of ES (Figure 6).[13,16,20]

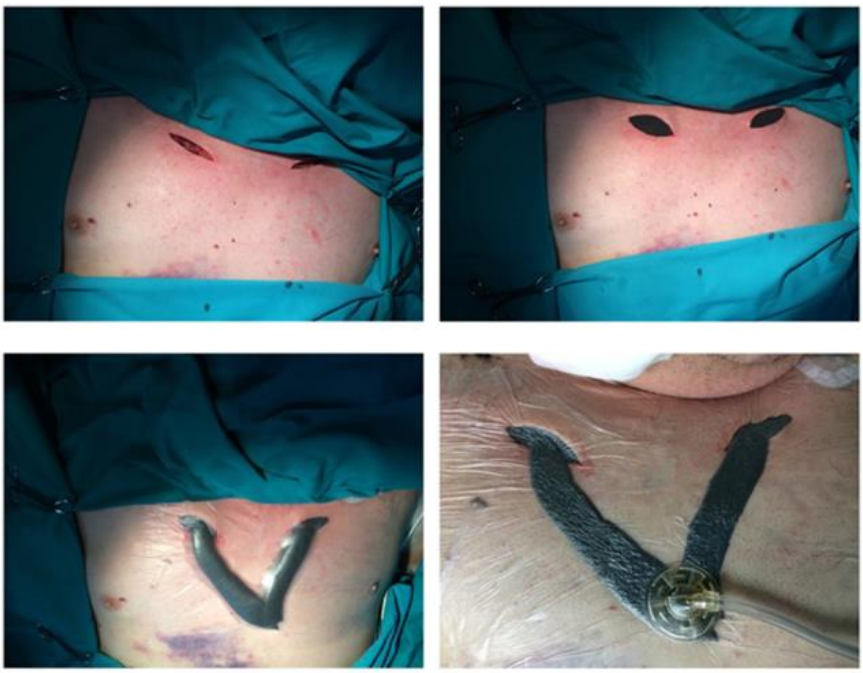

Figure 6. Blow hole incision with drain

Drainage with subcutaneous angio-catheter

The non-invasive treatment of choice is to place an angiocatheter into the lining of the chest wall. A 14G catheter was placed into the patient's subcutaneous tissue with ES under local anesthesia, then 2-3 cm lateral to the midclavicular line. The angiocatheter is inserted subcutaneously medially at a 45° angle so that the tip ends approximately 1 to 1.5 cm from the skin.[16,20] Variations in this technique are determined based on the number of angiocatheters used, the position of the catheter, and the depth and angle of placement in the subcutaneous tissue (Figure 7).[16,21]

Figure 7. The use of subcutaneous angio-catheter

Drainage with subcutaneous drain

Another technique in the management of ES is the use of a subcutaneous drain because it is safer than using an angio-catheter, which has the potential to bend or become blocked relatively often, so complications occur less frequently. This technique involves creating a superficial subcutaneous drain into the chest fascia using blunt dissection, then connecting it to a chest drainage bottle and then to a seal tube. It can be accompanied by the application of low to high pressure, depending on the severity of ES.[19,21] There are two case reports of patients with ES. who were successfully treated using subcutaneous drainage after failure of treatment with wide-bore drainage with high negative pressure suction. Some of these patients had bilateral insertions with a mean time to healing of 3 to 7 days.[16,18,24]

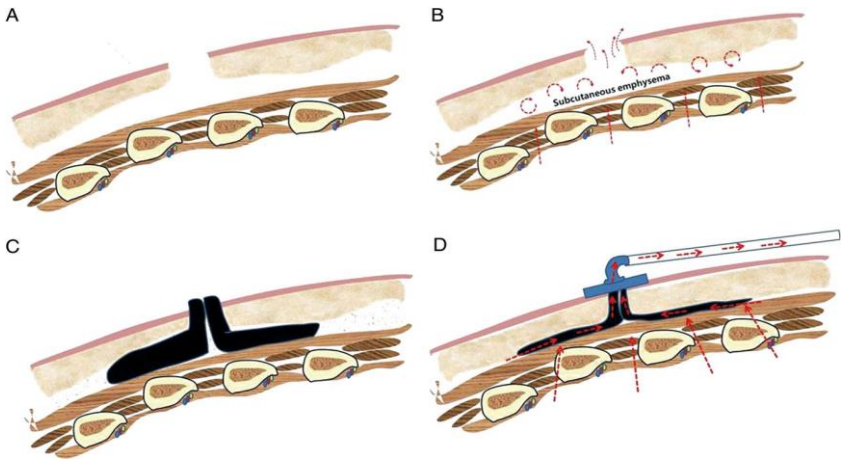

Figure 8. Subcutaneous drain

The use of a larger drain to allow a greater total air flow rate is recommended by experts because this procedure hypothetically has a better effect because, based on the Fanning equation, the flow rate is proportional to the fifth power of the tube radius. Wider 26F and 28F drains have also been reported to be successful in aiding the recovery of ES.[15,18,20] A case report of a patient with resistant ES reported improvement after the placement of a larger bore drain.[16,19] A cohort study by Chen et al. evaluated 255 patients with ES after elective surgery for lung resection. All of these patients were treated with 28F

intercostal drains with suction, and some of these patients had drainage in both intercostals. In the group with two intercostals, the majority of 170 patients (67%) experienced improvement in their ES condition.[16] There are reports of successful use of a customized 12F drain, inserted unilaterally in the axilla and connected to a drain with suction, with improvement on day 5 and in the infraclavicular area. bilateral with the application of suction and manual decompression, leading to improvement on day 5.

The one-bottle chest drainage system and the digital chest drainage system allow the application of negative pressure suction to the pleural cavity. The height of the water column in the suction control room controls this one-bottle system so that air can escape from the subcutaneous tissue.[16,24] The principle of management in ES is to increase flow to the chest drainage and thereby reduce flow to the subcutaneous tissue. There is no consensus regarding the suction pressure that should be applied to drains in the context of ES.[13] A meta-analysis A study conducted by Ahmde et al. in 2010 could not draw definitive conclusions about the effectiveness of post-surgical suction and found no statistically significant difference in the duration of air leaks. post-operatively between suction and non-suction patient groups.[16,18]

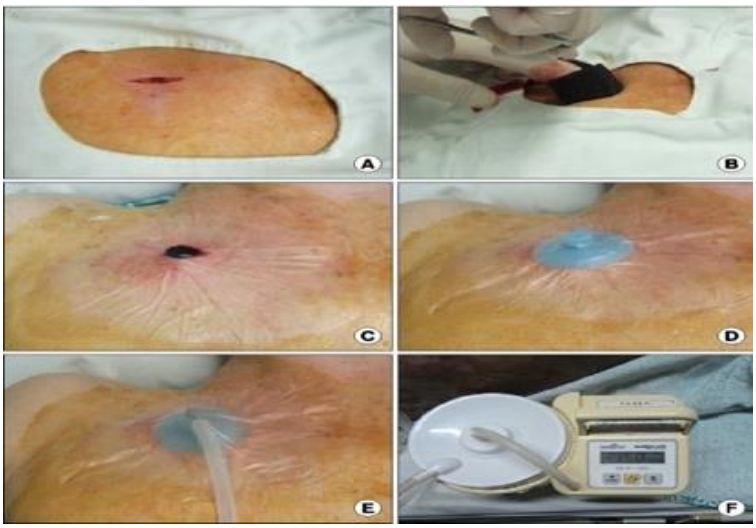

Figure 9. Intercostal drain with suction

Surgery

Surgery is a potential definitive solution for ES, such as in cases of bronchopleural fistulas. The application of this surgical procedure is clearly invasive and limited to the group of patients who are fit to undergo general anesthesia. This surgical treatment can often be used in cases of ES due to spontaneous pneumothorax secondary to underlying chronic lung disease and in cases of ES that do not improve after non-surgical treatment. Other definitive management strategies for patients with ES with persistent air leaks include endobronchial valve placement and pleurodesis.[13]

Complications

Extensive air leaks in the subcutaneous tissue can prevent expansion of the chest cavity, preventing the lungs from reaching the appropriate tidal volume, resulting in desaturation, respiratory distress, and cardiac arrest. The spread of air to the neck area can cause dysphagia and compression or closure of the airway. In the ventilation mechanism, if it cannot achieve an appropriate tidal volume, it can cause high peak pressure and trigger widespread barotrauma or pneumothorax, which can become a life-threatening condition.[22] Subcutaneous emphysema that presses on the thoracic area can prevent adequate air flow, reduce cardiac preload, and result in poor cerebral

perfusion. Expansion of subcutaneous air into the genitals can disrupt the delicate blood vessels that supply this area, causing necrosis of the skin and testicles, which can lead to infertility. Subcutaneous emphysema in patients using pacemakers can cause dysfunction in the device due to trapped air in the pulsation generator, causing the pacemaker to be compressed and damaged.[1,2]

Prognosis

The prognosis of ES depends on the severity and underlying disease. Because the body can absorb air, even in cases of positive pressure mechanical ventilation when using a ventilator, mild ES can typically heal without the need for special treatment. ES caused by other conditions such as trauma, extensive iatrogenic infections, and severe infections must be of special concern and must be treated appropriately and quickly because it can cause respiratory and cardiac arrest, which can lead to death.[25]

2. Conclusion

Subcutaneous emphysema is a medical condition characterized by a buildup of air in the subcutaneous layer of the skin, which can be caused by trauma, iatrogenic factors, or infection. Mild degrees of subcutaneous emphysema can experience spontaneous resolution, while more severe degrees require treatment such as drainage using various techniques and surgery. Severe subcutaneous emphysema that cannot be resolved can cause serious complications, up to death.

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