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A study of subcutaneous emphysema, factors contributing to its development, resolution and management with different modalities

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ABSTRACT

Subcutaneous emphysema is defined as an escape of air in subcutaneous tissue. It is one of the most common complications after inter-costal chest tube drainage. Subcutaneous emphysema is usually benign requiring no specific treatment, but extensive subcutaneous emphysema can be uncomfortable and alarming for the patient. It can rarely lead to airway compromise, respiratory failure and death. Factors leading to its development, following chest tube insertion and methods of management, have not been extensively studied and published. This was an analytical study done over a period of two years, on indoor patients who developed subcutaneous emphysema. These cases were managed using four different modalities and were analyzed for various factors contributing to the development, severity, and resolution of subcutaneous emphysema. Results of this study highlight that the cases of hydropneumothorax and secondary pneumothorax were significantly more predisposed to the development of severe subcutaneous emphysema (following intercostal chest tube insertion) and large air leak as compared to others. Larger air leak develops higher grades of subcutaneous emphysema. The average time for resolution of subcutaneous emphysema was similar among the different modalities of management compared in the study.

Key words: Subcutaneous emphysema, intercostal chest tube drainage, pneumothorax.

INTRODUCTION

Subcutaneous emphysema (SE) refers to gas in the subcutaneous tissues. It is a common condition occurring after a chest injury. It occurs after blunt or penetrating trauma to laryngeal, tracheal, or bronchial tree. Injury to sinus cavities, facial bones, barotrauma, and bowel perforation are some common causes [1]. Iatrogenic cases may occur due to tube thoracostomy, tracheal intubation, malfunction or disruption of the ventilator circuit, inappropriate closure of the pop-off valve, Valsalva maneuver that increases thoracic pressure, and trauma to the airway. Infrequently, SE and pneumo-mediastinum have been reported spontaneously in tubercular cavities, silicosis cavitating malignancies, sarcoidosis and infections such as COVID-19 [2-4]. SE is characterized by swelling of tissues under the skin, commonly seen over the chest wall, neck, face, around drain or wound sites, but may be found at any place of the body. Chest pain, sore throat, dysphagia,

neck pain, breathlessness and wheezing may be found. SE appears as a radiolucent area over soft tissues on a radiograph. Sometimes, striations are noticed in a pattern, due to gas outlining the fibers of pectoralis major muscle group, called 'ginkgo leaf sign' of the chest. Air trapped in subcutaneous tissue appears as dark spots on computed tomography (CT) scan, and is easier to see than on the skiagram [5].

SE is usually a benign, self-limiting condition and managed conservatively [4] but extensive cases are disfiguring, uncomfortable and alarming for the patient, and can rarely be associated with airway compromise, respiratory failure and death, especially in those having tension pneumothorax or pneumomediastinum [5]. Massive accumulation of air in deeper tissue spaces, at the level of the thoracic outlet has the capability of compressing the trachea and great vessels, thereby severely compromising the airway, venous return, and blood flow to head and neck [6].

Various approaches have been described for the management of SE like use of subcutaneous incisions, needles and drains. In severe cases, catheters can be placed in subcutaneous tissue to release air. Small cuts, or "blow holes," may also be made in the skin [7]. When SE occurs due to pneumothorax, an inter-costal chest tube (ICT) is frequently used, which controls and eliminates the source of air entering subcutaneous space. If the volume of air increases and ICT cannot remove air completely, then the tube should be replaced by a larger one. Suction may also be applied at ICT to remove air faster [8]. Since treatment usually involves dealing with underlying condition, cases of spontaneous SE may require nothing more than bed rest, control of pain, and supplemental oxygen. Breathing oxygen help body to absorb the subcutaneous air more quickly [9]. Reassurance and observation are also part of treatment in mild form of SE.

Factors leading to development of SE following ICT and various methods for its management have not been studied thoroughly till date. So this study was attempted to explore different aspects of development and management of subcutaneous emphysema.

MATERIALS AND METHODS

This was an analytical study, conducted among the patients admitted at the department of Respiratory Medicine, Jawaharlal Nehru Medical College, Ajmer, over a period of last two years, who developed subcutaneous emphysema.

The aims of this study were to compare various methods used for the management of surgical emphysema and to identify and analyze various underlying factors contributing to its severity and resolution.

Convenience sampling method was used with a sample size of 68 subjects. The diagnosis of SE was made by detection of thoracic, cervical and abdominal crepitus on physical examination and presence of subcutaneous air detected by chest x-ray and/or thoracic computed tomography among patients presented in the department of Respiratory Medicine of our institute. Administrative restrictions (a separate wing, distinct from the respiratory department, for COVID-19 and post COVID patients) debarred from including cases from those wings/department in the study. Grading of SE was done as proposed by Aghajanzadeh *et al*. [10] into five categories depending on the extent and area of distribution. Grade 1 was SE at base of the neck, grade 2 in all of the neck area, grade3 in subpectoralis major area, grade 4 in chest wall and all of neck area, grade5 in chest wall, neck, orbit, scalp, abdominal wall, upper and lower limbs and scrotum.

Subjects with grade 1 SE were considered as mild subcutaneous emphysema, subjects with grade 2 and 3 as moderate and grade 4 and 5 were considered as severe subcutaneous emphysema.

All patients were assessed by detailed clinical history, examination, for resolution of SE, air leak in ICT and complications, if any. Air- leak was graded using the classification proposed by Sang *et al.* [11] into grade 0: no air bubble on three serial volitional coughs, grade 1: more than one air bubble present on three serial volitional coughs, grade 2: persistent air bubbles on volitional coughs, grade 3: persistent, small amount of air bubbles on spontaneous respiration and grade 4: persistent large amount of air bubbles on spontaneous respiration. Digital anemometers can precisely quantify the air leak but were not used in the study due to financial and administrative constraints.

The patients were managed by the following four methods:

1. Conservative management by continuous inhalation of high concentration oxygen.
2. Management by blow hole skin incisions.
3. Management by insertion of subcutaneous drain connected to vacuum system.
4. Management by insertion of a second intercostal chest tube.

Patients requiring surgical treatment of underlying pulmonary pathology were not included in the study due to non-availability of thoracic surgeon at our institute. Patients were given continuous high concentration oxygen inhalation through non re-breathing

mask or a Venturi mask. Blow hole skin incision was made deep to external thoracic fascia, thereafter compressive massage was done towards the site of incision to aid drainage. Subcutaneous drainage was done by inserting an 18 Fr Ryles tube, in subcutaneous space, in the anterior chest wall. After making a skin incision just above the nipple, a tract was created by blunt dissection with a hemostat forceps; subcutaneous tube was inserted in this tract and connected to a negative pressure apparatus. The second ICT was usually inserted one or two intercostal spaces below or above the first ICT, within the 'safe triangle' for ICT placement, although depending upon the locule, it may be inserted more posteriorly or anteriorly in the second intercostal space midclavicular line, as per BTS guidelines [12]. Both ICTs were connected to an underwater seal system separately. Written informed consent was obtained from all the subjects. The subjects also received medical management for underlying pulmonary disease apart from pleurodesis, when indicated .

Statistical analysis was done using Epi Info (CDC, Atlanta, GA, USA) version 7.2.1.0 software. Categorical variables were expressed as frequency and percentage and were analysed using chi-square test. Continuous variables were expressed as mean and standard deviation and were analyzed using Independent sample *t*-test for comparison between two groups and one-way analysis of variance (ANOVA) test for comparison between more than two groups. A p-value of less than 0.05 was taken as significant.

RESULTS

A total of 68 patients who developed SE within the age range 22 to 77 years participated in this study, mean age of subjects was 51.27 $\pm$ 15.7 years**,** males (n=60, 88.2%) outnumbered females (n=8, 11). Majority were underweight (n=42, 61.8%), 25 cases (36.8%) had normal body mass index and one case was overweight**.** Majority were current smokers (45.5%), 17.6% were ex-smoker and 25% non-smokers. The most frequent pulmonary co-morbidity was pulmonary tuberculosis constituting 27 cases (39.7%), followed by chronic obstructive pulmonary disease 21 cases (30.9%), carcinoma lung 6 cases (8.8%), occupational lung disease 3 cases (4.4%), bronchial asthma 2 cases (2.9%) and interstitial lung disease 1 case (1.5%). It was observed that patients with pulmonary co-morbidities had a higher grade (4 & 5) of SE (n=46, 80.7%) as compared to patients with no pulmonary co-morbidities (n=4, 36.36%). Patients with no co-morbidity were more likely to develop moderate SE (n=7, 63.6%).

Majority of subjects (n=63, 92.6%) developed subcutaneous emphysema following ICT insertion whereas five cases (7.3%) developed spontaneous subcutaneous emphysema. In subjects developing SE following ICT insertion, most had secondary pneumothorax (n=30, 44.1%) as the underlying condition. This was followed by 24 cases (35.3%) of hydro-pneumothorax, 7 cases (8.8%) of pleural effusion, and 2 cases (2.9%) of primary pneumothorax. Among the cases of (hydro)pneumothorax, 48 cases (85.7%) had large and 8 cases (14.2%) had small pneumothorax.

Grade 5 SE was seen in 29 cases (42.6%), 18 cases (26.5%) had grade 4, 19 cases (27.9%) had grade 3, and 2 cases (2.9%) had grade 2 subcutaneous emphysema.

The subjects with an underlying lung disease [(hydro) pneumothorax or pleural effusion], developed severe SE significantly more than the subjects with spontaneous SE, who had greater chance of developing moderate SE (Table 1). Larger air leak of grade ≥2 (in ICT) was significantly more in cases of secondary pneumothorax and hydro-pneumothorax as compared to other cases (Table 2), Chi-square: 21.437 with degrees of freedom: 9, (p=0.011).

A significant correlation between the grade of air leak (in ICT) and the grade of subcutaneous emphysema was observed with higher chances of developing severe SE in higher grades of air leak (grade 2 or more). Among the 29 subjects who had grade 5 SE, 67.9% had air leak of grade ≥3 and the rest of 32.1% had air leak of grade 2 (Table 3).

Out of total study subjects, 42.6% (n=29) were managed by high-flow oxygen inhalation followed by subcutaneous tube insertion in 21 cases (30.9%), skin incision in 13 cases (19.1%) and second ICT in 5 cases (7.4%) (Figure 1).

Average time taken for the resolution of SE was 6.75 ± 2.61 days, 7.07 ± 2.25 days, 7.61 ± 2.76 days and 5.60 ± 3.64 days respectively in cases of SE managed by high flow oxygen, skin incision, subcutaneous tube and insertion of a second ICT (Table 4). There was no significant difference in the time of resolution of SE among the different methods used (p=0.440), but mean time taken for resolution of SE increased with the increase in grade of air leak, a statistically significant finding with p-value of 0.019. The mean duration of resolution was 5.60 ± 2.70 days in grade 0, 4.50 ± 1.29 days in grade 1, 6.71 ± 2.06 days in grade 2 and 8.12 ± 3.16 days in cases of air leak of grade ≥ 3 (Table 4).

Discussion

Severe subcutaneous emphysema is associated with co-morbidities and probably has a higher mortality. Apart from the distressing cosmetic deformity, SE can lead to upper

airway obstruction, acute respiratory failure and circulatory collapse due to tension pneumo-mediastinum or pacemaker malfunction. It can also lead to difficult interpretation of chest radiographs, echocardiography, ultrasound, and electrocardiograms. This study has identified several important factors associated with SE and its management.

Patients with pulmonary co-morbidities had a higher grade of SE compared to patients with no pulmonary co-morbidities. There are several individual reports of the occurrence of spontaneous SE in patients with underlying tuberculosis, silicosis, lung cancer, etc. with multiple mechanisms. Dixit *et al.* [13] described a case of acute silicosis complicating as spontaneous pneumomediastinum, bilateral pneumothorax and subcutaneous emphysema in a 35-year-old male engaged in stone crusher unit. Dixit and George [14] described a case of subcutaneous emphysema in cavitary pulmonary tuberculosis without pneumothorax or pneumo-mediastinum. Das *et al.* [15] described a case of a 5-year-old girl with miliary tuberculosis complicated by pneumo-mediastinum and SE**.**

We observed that cases who had large pneumothorax (even after chest tube insertion) developed subcutaneous emphysema, an observation consistent with the study by Jones *et al*. [16] where 167 patients were studied and SE was associated more with cases of moderate or large pneumothorax.

Severe subcutaneous emphysema developed more in cases of hydro-pneumothorax and secondary pneumothorax as compared to pleural effusion and primary pneumothorax, when managed with intercostal chest tube drainage. This may be due to larger, longer air leaks in an underlying damaged lung. We observed that hydro-pneumothorax and secondary pneumothorax cases had larger air leak (grade>3) than other cases. A large air leak (grade ≥3) results in a higher percentage of patients with grade 5 subcutaneous emphysema.

Average time taken for the resolution of SE was different for the different methods of management used in this study but there was no significant difference among them. Although, it was observed that insertion of a second chest tube resulted in fastest resolution of subcutaneous emphysema.

In our study, the mean time for resolution of SE on subcutaneous tube insertion was 7.61 ± 2.76 days. There are different reports showing different resolution time. Lloyd *et al*. [17] reported two cases of life-threatening SE with blunt traumatic pneumothorax,

managed by fenestrated 28F catheters inserted subcutaneously and connected to suction. Both patients experienced dramatic relief in one hour. Beck *et al*. [18] described a case report of inserting bilateral fenestrated 14-gauge angio-catheter subcutaneously in a patient with severe SE which resolved by day three. Kelly *et al*. [19] described a case of severe SE in a patient of bilateral pneumothorax. They managed SE with 28-F subcutaneous catheter and showed rapid resolution in one day. Leo *et al*. [20] reviewed 12 patients who developed SE requiring microdrainage. Fenestrated angio-catheters aided by compressive massage (three to four times daily) were used. In 11 of the 12 cases, SE resolved within 3 days. Cesario *et al*. [21] reviewed 21 cases of post lung resection SE, where they used Penrose-type rubber drains subcutaneously through supraclavicular incisions for a mean of 3.5 days, aided by compressive massage. Sherif and Ott [22] described a case where they used a Jackson-Pratt drain, a closed suction drain with bulb reservoir, providing decompression of head and neck area in three hours, and drain removed on day seven without complications.

Management methods of subcutaneous emphysema and its influencing factors are under studied till date. Only case reports, series and review articles are available in the literature. This study is one of the first ever study, done on cases of subcutaneous emphysema that developed following chest tube drainage, and comparing various modalities used in its management. It throws light on the significant differences between, the pulmonary conditions and grade of air leak following chest tube insertion, grade of air leak with severity of subcutaneous emphysema and time taken for its resolution. Despite these strengths, the study had few limitations: small sample size, lack of availability of thoracic surgeon, non inclusion of COVID-19 pneumonia and post COVID patients due to administrative restrictions, lack of randomization and control group (so the chances of selection bias cannot be ruled out). More studies need to be done in the future with larger sample size, proper randomization and preferably with a control group.

Conclusions

Subcutaneous emphysema is usually considered a benign, self-limiting condition only requiring conservative management. The interventional modalities are useful in severe cases with patient discomfort and respiratory distress. The four techniques described in this study have been shown to provide effective relief of severe subcutaneous emphysema with no significant difference in time resolution between different methods. A significant

observed finding of the study is that pulmonary conditions like hydro-pneumothorax and secondary pneumothorax were found to develop a higher grade of subcutaneous emphysema and a higher grade of air leak following chest tube insertion. A larger air leak was found to be causing a higher grade of SE with a longer time for its resolution. So, the cases of higher grades of subcutaneous emphysema, associated with pulmonary co-morbidities, should be managed promptly, with the choice of the method depending on its availability, relevance and expertise of the treating physician. This is a novel study, the first of its kind, highlighting important aspects of intercostal tube drainage and associated subcutaneous emphysema.

References

1. Maunder RJ, Pierson DJ, Hudson LD. Subcutaneous and mediastinal emphysema. Pathophysiology, diagnosis, and management. Arch Intern Med 1984;144:1447-53.
2. Agrawal A, Sen KK, Satapathy G, et al. Spontaneous pneumomediastinum, pneumothorax and subcutaneous emphysema in COVID-19 patients—a case series. Egypt J Radiol Nucl Med 2021;52:27.
3. Raykar PS, Banur A, Mahanthappa G, et al. J. Characteristics and outcome of pneumothorax, pneumomediastinum, and subcutaneous emphysema in COVID-19 patients: A case series. J Assoc Chest Physicians 2023;11:28-35.
4. Macklin MT, Macklin CC. Malignant interstitial emphysema of the lungs and mediastinum as an important occult complication in many respiratory diseases and other conditions. Medicine (Baltimore) 1944;23:281-358.
5. Chan L, Reilly KM, Henderson C, Kahn F, Salluzzo RF. Complication rates of tube thoracostomy. Am J Emerg Med 1997;15:368-70.
6. Fidrocki DM, Greenbaum NR, Diaz GC. Severe pneumomediastinum and subcutaneous emphysema subsequent to prolonged mechanical ventilation. IDCases 2021;24:e01090.
7. Johnson CH, Lang SA, Bilal H, Rammohan KS. In patients with extensive subcutaneous emphysema, which technique achieves maximal clinical resolution: infraclavicular incisions, subcutaneous drain insertion or suction on in situ chest drain? Interact Cardiovasc Thorac Surg 2014;18:825-9.
8. Ruan G, Edquist C, Pagali S. Extensive subcutaneous emphysema: a complication of traumatic pneumothorax. JAAPA 2021;34:52-4.
9. Ali RK, Kakamad FH, Hama Ali Abdalla S, et al. Management of post lobectomy subcutaneous emphysema: a case report with literature review. Ann Med Surg (Lond) 2021; 69:102610.
10. Aghajanzadeh M, Dehnadi A, Ebrahimi H, et al. Classification and management of subcutaneous emphysema: a 10-year experience Indian J Surg 2015;77:673-7.
11. Oh SG, Jung Y, Jheon S et al. Postoperative air leak grading is useful to predict prolonged air leak after pulmonary lobectomy. J Cardiothorac Surg. 2017;12:1.

12. Laws D, Neville E, Duffy J. BTS guidelines for the insertion of a chest drain. Thorax 2003;58:ii53-9.
13. Dixit R, Meena M, Patil CB. Pneumomediastinum, bilateral pneumothorax and subcutaneous emphysema complicating acute silicosis. Int J Occup Med Environ Health 2015;28:635-8.
14. Dixit R, George J. Subcutaneous emphysema in cavitary pulmonary tuberculosis without pneumothorax or pneumomediastinum. Lung India 2012;29:70-2.
15. Das M, Chandra U, Natchu M et al. Pneumomediastinum and subcutaneous emphysema in acute miliary tuberculosis. Indian J Pediatr 2004;71:553-4.
16. Jones PM, Hewer RD, Wolfenden HD, Thomas PS. Subcutaneous emphysema associated with chest tube drainage. Respirology 2001;6:87-9.
17. Lloyd MS, Jankowksi MP. Treatment of life-threatening surgical emphysema with liposuction. Plast Reconstr Surg 2009;123:77e-8e.
18. Beck PL, Heitman SJ, Mody CH. Simple construction of a subcutaneous catheter for treatment of severe subcutaneous emphysema. Chest 2002;121:647-9.
19. Kelly MC, McGuigan JA, Allen RW. Relief of tension subcutaneous emphysema using a large bore subcutaneous drain. Anaesthesia 1995;50:1077-9.
20. Chari M R, Leo S, Priya A R. Simple micro drainage system for palliation of severe subcutaneous emphysema. Trop Doct 2022;52:408-10.
21. Cesario A, Margaritora S, Porziella V, Granone P. Microdrainage via open technique in severe subcutaneous emphysema. Chest. 2003;123:2161-2.
22. Sherif HM, Ott DA. The use of subcutaneous drains to manage subcutaneous emphysema. Tex Heart Inst J 1999;26:129-31.

Table 1. Relation between grade of subcutaneous emphysema and the underlying condition.

Underlying condition	**Grades of subcutaneous emphysema initially**							
	Grade 2		Grade 3		Grade 4		Grade 5	
	n	%	n	%	n	%	n	%
Primary pneumothorax	0	0	1	5.3	1	5.6	0	0.0
Secondary pneumothorax	1	50	8	42.1	9	50.0	12	41.4
Hydropneumothorax	1	50	2	10.5	5	27.8	16	55.2
Pleural effusion	0	0	4	21.1	3	16.7	0	0.0
Spontaneous subcutaneous Emphysema	0	0	4	21.1	0	0.0	1	3.4
Total	2	100	19	100	18	100	29	100

Chi-square = 21.821 with 12 degrees of freedom; (p=0.040, Significant)

Table 2. Relation between underlying disease and grade of air leak.

Underlying disease	**Grade of air leak**								**Total**
	Grade 0		**Grade 1**		**Grade 2**		**Grade ⩾3**		
	n	%	n	%	n	%	n	%	
Primary pneumothorax	0	0.0	0	0.0	2	100.0	0	0.0	2
Secondary pneumothorax	0	0.0	1	3.3	19	63.3	10	33.3	30
Hydropneumothorax	0	0.0	1	4.2	11	45.8	12	50.0	24
Pleural effusion	1	14.2	2	28.5	3	42.8	1	14.2	7

Chi-square = 21.437 with 9 degrees of freedom; (p= .011, S).

Table 3. Relation between grade of surgical emphysema and grade of air leak.

Grade of air leak	**Grades of subcutaneous emphysema initially**							
	Grade 2		Grade 3		Grade 4		Grade 5	
	n	%	n	%	n	%	n	%
Grade 0	0	0	1	6.7	0	0.0	0	0.0
Grade 1	0	0	3	20.0	1	5.6	0	0.0
Grade 2	1	50	10	66.7	15	83.3	9	32.1
Grade 3 and more	1	50	1	6.7	2	11.1	19	67.9
Total	2	100	15	100	18	100	28	100

Chi-square = 24.372, degree of freedom 6, ($p<0.001$, Significant)

Table 4. Comparison of time of resolution of subcutaneous emphysema among various management methods and grade of air leak.

Management method / **Grade of air leak**	**Time of resolution mean (days ± SD)**	**p-value**
High flow oxygen / **Grade 0**	6.75 ± 2.61 / 5.60 ± 5.60	0.440 (NS)
Skin incision / **Grade 1**	7.07 ± 2.25 / 4.50 ± 1.29	
Subcutaneous tube / **Grade 2**	7.61 ± 2.76 / 6.71 ± 2.06	0.019 (S)
Second ICD / **Grade 3 and more**	5.60 ± 3.64 / 8.12 ± 3.16	

ICD, intercostal drain; S, significant; NS, not significant.

Figure 1. Distribution of study subjects according to modality of management.