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Imaging Analysis of the Visceral Pleura for Area Calculation and Therapeutic Approach in Primary Spontaneous Pneumothorax

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ABSTRACT
Introduction: the pleura is the bilamine serous membrane that lines the thoracic wall (parietal layer) and the lung parenchyma (visceral layer), forming a space between its layers known as the pleural cavity. Under physiological conditions, the pleura prevents lung collapse through intra- and extrapulmonary pressure equilibrium. Pneumothorax is the entry of air into the pleural cavity due to a rupture of the visceral or parietal pleura. It can be classified as primary spontaneous (unrelated to underlying lung disease) or secondary (associated with lung pathologies). Calculating the pneumothorax area can facilitate prognostic evaluation as well as therapeutic decision-making; however, there is no consensus in imaging analysis regarding the disease magnitude for standardized treatment decisions.
Objectives: this study aims to identify the visceral pleura on chest radiographs to measure the Primary Spontaneous Pneumothorax (PSP) area and to correlate the therapeutic approach with the pneumothorax area percentage.
Materials and Methods: medical records of 40 patients diagnosed with PSP treated at an emergency hospital unit from January 2012 to January 2022 were reviewed. Variables considered were age, gender, occupation, smoking history, ethnicity, and type of treatment (medical or surgical), which were investigated for correlations using combinatorial analysis. The Light's index was used to calculate the percentage area of PSP on chest radiographs (posteroanterior view) based on visualization of the visceral pleura.
Results: patients with PSP were predominantly male (75%), Caucasian (87.5%), with a mean age of 26 years, mostly students, and approximately one-third were smokers. Closed pleural drainage was the predominant treatment (62.5%), followed by surgical approaches (15%), and conservative treatment in 5% of cases. No statistically significant correlation among epidemiological variables was observed. The Light Index estimated on each chest X-ray identified a value of ⅓ (or 33.33%) of the affected lung area to indicate closed pleural drainage in PEP since 80% of the cases (20 cases out of 25) of water-seal drainage were performed with pneumothorax area values above 33.33%.
Conclusion: a Light Index calculated on anteroposterior chest radiographs of patients with PEP, based on clear visualization of the visceral pleura, can be used as a method for determining both the area of lung collapse and the therapeutic treatment.
Keywords: Pleura; Primary Spontaneous Pneumothorax; Light Index; Treatment.

Introduction

The pleura is a delicate, serous membrane that lines the chest wall and extends from the mediastinum towards the lungs.

The layer that covers the chest wall is called the parietal pleura, while the layer that covers the lungs and goes deeper into their fissures is called the visceral pleura, which adheres to the lung parenchyma. Between these two layers, there is a potential space; the pleural cavity, filled with liquid[1,2].

Under normal conditions, the pressure in the interpleural space is negative concerning the alveolar and atmospheric pressures, as a direct result of the elastic retraction of the lungs[3]. In this way, the pleural fluid, together with the negative pressure of the cavity, keeps the pleural leaflets stabilized and adherent to prevent lung collapse, ensure gas exchanges, and avoid friction injuries[4].

Pneumothorax is the extravasation of air from inside the lungs or from the environment itself into the pleural cavity, causing the lungs to collapse. As a result, there is a reduction in vital capacity due to a reduction in the partial pressure of arterial oxygen, chest pain and dyspnea[2].

The main causes of pneumothorax include wounds from white weapons or firearms, rib fractures or ruptures of subpleural emphysematous bullae. In most cases, the latter describes Primary Spontaneous

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Pneumothorax (SPP). SPP is not linked to prior lung diseases, and it is associated with smoking, age of nearly 20, male gender, lower body mass index, and family history[5,9]. Secondary Spontaneous Pneumothorax (SSP), on the other hand, is more serious because it usually develops in patients with chronic obstructive pulmonary disease. However, it can occur due to other clinical conditions[3,10].

The prevalence of spontaneous pneumothorax (primary or secondary) is approximately 24 cases per 100,000 inhabitants per year for men and 9.8 cases per 100,000 for women, equally distributed between PSP and SSP[11]. However, recurrence rates are higher in patients with SSP (45%) when compared to those with PSP (30%)[3].

Spontaneous pneumothorax usually occurs when the patient is at rest and is accompanied by chest pain (acute and ipsilateral) and dyspnea, which is proportional to the size and speed of accumulation of the pneumothorax and the patient's cardiopulmonary reserve. Physical examinations can show a reduction in the vesicular murmur, a local reduction in chest expansion with an increase in the volume of the hemithorax involved, and tympanism on percussion[12].

Diagnosis of pneumothorax is based on a detailed clinical history and physical examination and confirmation by imaging methods. In cases of PEP, diagnostic confirmation is usually carried out in emergency rooms using chest X-rays, based on the identification of the presence of a strip of air between the chest wall or the diaphragm muscle and the visceral pleura[12,13].

In isolation, the quantitative value of pneumothorax is not a defining factor of symptoms or prognosis, but it is important in determining the therapeutic approach to be undertaken, even by calculating the area of pneumothorax to estimate prognosis[14,15]. However, it is difficult to do this, due to the irregular and random collapse that occurs during a pneumothorax[12,15], and so the empirical assessment of the trained professional tends to predominate, which can delay the necessary therapeutic intervention[15]. Treatment of pneumothorax can range from a conservative (expectant) approach such as home monitoring to more invasive procedures such as lung resection or pleurectomy[12,14].

For cases of large PEP or PEP associated with dyspnea, it is recommended to reduce the size by pleural aspiration or by closed chest drainage or water seal[12], and after 48 hours control chest X-rays should be taken to check for re-expansion of the affected lung. If this does not occur, surgical intervention may be necessary[14].

Determining the most appropriate approach for each pneumothorax case is crucial to minimize deleterious effects, recurrence, or unnecessary invasive procedures with increased risk of complications[14]. In this context, measuring pneumothorax size from chest radiographs could help to optimize decisions regarding the most effective treatment[15,16]. Given the lack of absolute consensus for managing PSP in emergency settings[14,15]; the objective of this study is to identify the visceral pleura on chest radiographs to measure PSP area, aiming to correlate the therapeutic approach with pneumothorax area percentage.

Materials and Methods

Initially, following ethical approval: 1,440 medical records of patients diagnosed with pneumothorax, treated from January 2012 to January 2022 at Hospital de Base de São José do Rio Preto – SP, were reviewed.

Inclusion criteria comprised patients aged 15 to 30 years treated in the emergency department. Exclusion criteria encompassed patients with other types of pneumothorax (secondary spontaneous, tension, or traumatic), prior thoracic surgery, or the presence of lung diseases.

Variables were age, gender, occupation, smoking history, ethnicity, and type of treatment for Primary Spontaneous Pneumothorax (PSP) (expectant or conservative management, closed or water-seal chest drainage, or surgery, either open or via video-assisted thoracoscopy).

To select patients´ records affected by PSP, the following ICD-10 codes were used: ICD-10 – J93.0, ICD-10 – J93.1, ICD-10 – J93.8, and ICD-10 – J93.9.

Forty chest radiographs in posteroanterior (PA) view were selected for calculation of the percentage area of PSP according to the Light's index. Subtracting from 100 the cube of the collapsed lung diameter over the cube of the affected hemithorax diameter recommended[17]. The diameters were obtained from imaginary lines drawn conventionally from the midpoint of the eighth thoracic vertebra. For this purpose, it was necessary to identify the visceral pleura on each chest radiograph , which delineates the remaining lung parenchyma visible after pneumothorax occurrence. After calculation, the size of the collapsed lung area was correlated with the chosen therapeutic approach.

Descriptive statistical analysis[18] included frequency of occurrence, and inferential statistics used combinatorial analysis[19], with a significance level set at 5%.

Results

The epidemiological data showed that 75% of the 40 patient records with PEP were male, with an average age of about 26 years. This group was mostly Caucasian, followed by mixed race (10%) and other races (2.5%). Tobacco use was prevalent in 32.5% of the patients. Student activity was the most common occupation (27.5%), followed by service auxiliaries (12.5%), general helpers and domestic work (5% each), and various other occupations (35%), with an additional 15% of cases lacking occupational information.

Table 01 points out the therapeutic options adopted based on the Light index in patients with PEP treated in an emergency unit. Figures 01 and 02 illustrate pneumothorax with a Light index higher than and less than 33%, respectively.

Discussion

The development of pneumothorax (PEP) is considered a medical emergency due to the potential for pleural collapse[5], which needs an urgent assessment to determine whether more invasive treatment—such as pleural drainage-is required[12]. Since pneumothorax reduces lung volume, compliance, and diffusion capacity, the chosen treatment depends on the extent of lung volume reduction[5,6].

To optimize the selection of the most appropriate therapeutic approach for each PEP case; this study aimed to correlate pneumothorax area with therapeutic choices, thereby attempting to standardize PEP management[15]. The Light Index was employed for this purpose, providing a pragmatic calculation of the pneumothorax area based on the visual identification of the visceral pleura in chest radiographs[12].

Defining pneumothorax volume is crucial for objective quantification, which aids in treatment decision-making[16]. The Light Index suggests that the size of the pneumothorax can be calculated by subtracting the cube of the collapsed lung diameter from 100 and dividing it by the cube of the affected hemithorax diameter[17]. The Light Index can be useful for quickly estimating the percentage of lung area affected by PEP and for recommending either conservative or interventional treatment[12,14] Therefore, to prevent recurrences, minimize adverse effects from unnecessary invasive procedures[14], reduce hospital stay, and improve prognosis[15]. This study also aimed

Table 01. Therapeutic Approaches for Pneumothorax (PEP) and Corresponding Percentages according to the Light Index (n=40)

Treatment Adopted in Emergency Setting	**Frequency of Occurrence**	**Light Index**	**Number of Cases with an Area Above** 33.3% by Light Index	**Number of Cases with Area Below** 33.3% by Light Index
Conservative or Expectant (n=2)	5%	30,5%	1	1
Closed Pleural Drainage or Water-Seal (n=25)	62,5%	57,1%	5	20
Open or Video-Assisted Thoracoscopic Surgery (n=13)	22,5%	64,79%	-	-

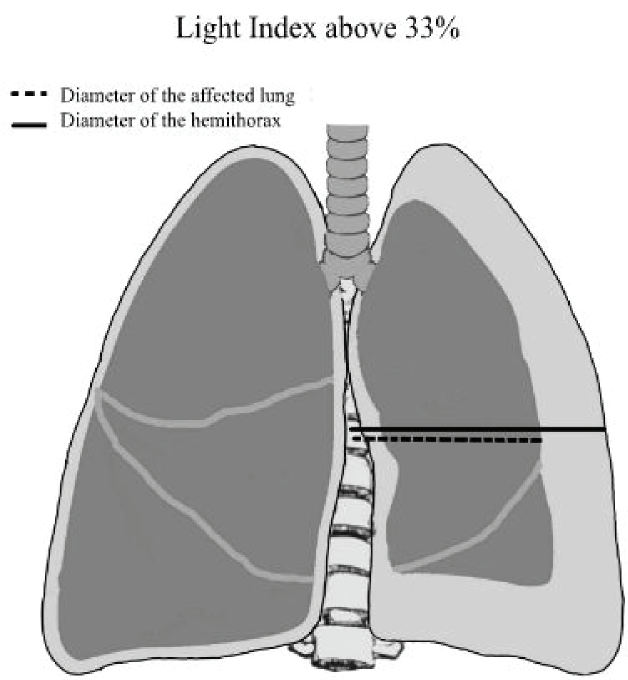

Figure 01. Pneumothorax with a Light Index greater than 33%. The presence of a larger area of lung parenchyma collapse suggests the need for pleural drainage.

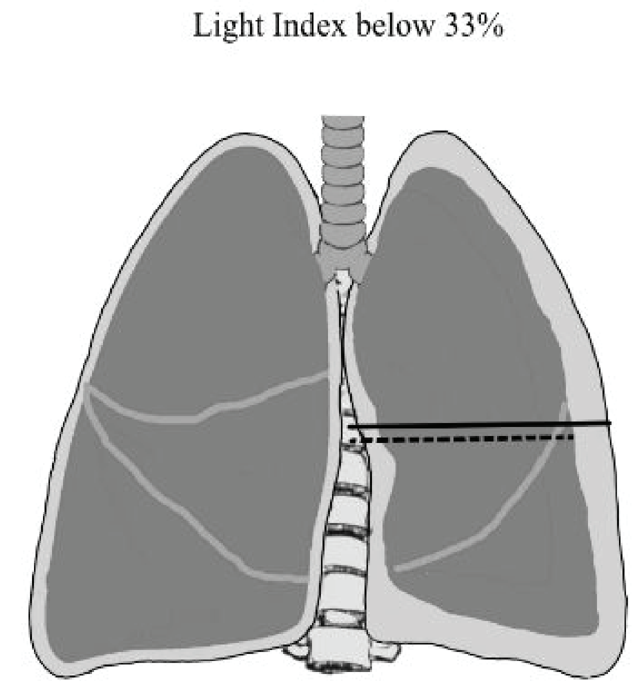

Figure 02. Pneumothorax with a Light Index of less than 33%. A pneumothorax of lesser extent has suggested conservative treatment.

to correlate larger or smaller pneumothorax areas determined by the Light Index with the epidemiological profile of patients with PEP.

Regarding the epidemiology of patients with PEP; 75% were male; the majority were Caucasian (87.5%), and approximately one-third were smokers, aligning with related literature[7-9]. The higher prevalence of PEP in males may be attributed to different smoking habits between genders[8].

Additionally, young adult smokers with a family history are more likely to develop PEP[7]. However, the small sample size precluded significant statistical inferences in this study.

Although 1,044 records suggestive of PEP were identified, the application of diagnostic coding and the rigor applied to therapeutic follow-up data and radiographic examinations reduced the sample to 40 strictly selected cases.

According to the analysis of 40 patient records with PEP; closed pleural drainage was predominant (62.5%), followed by surgical approaches (15%) and conservative treatment in 5% of cases (Table 01). This prevalence is consistent with literature data, which generally recommends closed pleural drainage or water-seal drainage for PEP cases[16].

Based on the Light Index estimated from each chest radiograph, this study identified a threshold of ⅓ (or 33.33%) of the lung area affected to indicate closed pleural drainage for PEP. This is supported by the finding that 80% of water-seal pleural drainage cases were performed with pneumothorax areas exceeding 33.33% (Table 01). Literature has not shown a direct correlation between pneumothorax area and surgical interventions, although estimates of pneumothorax area in such situations have varied from 15% to 35%[14,20-22].

These findings align with the results of this study and reinforce the justification for recommending closed pleural drainage for PEP when the Light Index is near 33%; suggesting conservative treatment below this threshold.

Surgical indications for patients with PEP generally comprise clinical data (intensity of dyspnea), epidemiological factors (recurrence and risk factors), and imaging data (empirical size of pleural collapse)[20]. In this study, no records mentioned any imaging or surgical decision-making, either.

The Light Index proved practical and swift in application, allowing for rapid estimation of pneumothorax area from digital chest radiographs by measuring one line to determine the diameter of the affected hemithorax and another for the collapsed lung diameter (Figure 01). Using a calculator, values could be applied to the equation[17] to estimate the pneumothorax area quickly. Additionally, the Light Index was executed on chest radiographs; a technique characterized by simplicity, rapid execution, and wide availability[13], which enhances cost-effectiveness. Another advantage of the Light Index in PEP cases is its ability to provide a reliable percentage value even considering prevalent thoracic shapes in the population[12,15].

It is important to point out that the Light Index had limitations in this study, as the visceral pleura was distinctly visible in all 40 chest radiographs. Moreover, pneumothorax area calculation is an estimate, given that lung collapse occurs irregularly and randomly[14,15]. A significant point is the reliance on high-quality radiographic exams, with good penetration and patient cooperation[13].

While the Light Index is a valuable approach for estimating pneumothorax area in various situations[13,17]; it is necessary to emphasize that in select cases, additional high-resolution computed tomography may be indicated. This imaging modality can identify apical emphysematous lesions present in up to 80% of PEP patients and is useful in intensive care unit settings where chest radiographs in the anteroposterior view might not show air in the pleural cavity due to septation or anterior positioning relative to the affected lung[12,13].

Furthermore, the Light Index does not account for pneumothorax localized in the lung apices, as it considers diameter rather than organ length[17]. For such cases, an attempt to measure apical lung collapse involves assessing the distance between the lung apex and the pleural dome, with measurements exceeding 3 cm indicative of significant pneumothorax. However, this approach is disadvantageous as it does not express percentage and is thus applicable only to mediolateral thoraxes[12]. An alternative method involves summing interpleural distances at the apex and midpoints of the upper and lower parts of the affected lung to estimate pneumothorax area using the formula $A=4.2+[4.7x(sum)]$, although this requires more time for definitive calculation and is less advantageous in emergencies[23].

This study suggests using the Light Index as a method for interpreting pneumothorax area in PEP cases, particularly, in emergency units, even though current therapeutic approaches for PEP generally rely on prior experience[15]. This is to avoid patients with PEP receiving invasive treatment disproportionate to the extent of pulmonary collapse[14].

Conclusion

The Light index, calculated from chest radiographs in the anteroposterior projection of patients with pleural effusion, provides a measure of the extent of lung involvement. By assessing the visibility of the visceral pleura, it was determined that a threshold of ⅓ (or 33.33%) of the lung area affected indicates the need for closed pleural drainage. For pleural effusions affecting less than this percentage, conservative treatment is recommended.

This study recommends employing the Light Index, since this can determine clear identification of the visceral pleura. It should be considered a method for interpreting lung collapse areas as well as providing effective therapeutic decision-making to estimate PEP cases.

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