Comparison of methods to quantitate spontaneous pneumothorax - A study from a tertiary care hospital

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Background Pneumothorax can present as a respiratory emergency and has varied etiology. However, literature available on assessment and management of primary spontaneous pneumothorax (PSP) based on radiological quantitation is scarce. This study was undertaken to compare two different methods of quantitating pneumothorax size with that recommended in American Thoracic Society (ATS) guideline on chest radiogram with respect to possible change in management practices.

Patients and methods A prospective cohort of adults presenting with spontaneous pneumothorax (SP) over 3 years to Emergency and Pulmonology Department, St John's Medical College Hospital, Bangalore, was included. Demographic characteristics and clinical presentation were compiled. Management of SP was based on ATS guidelines. PSP size on chest radiogram was requantitated in the included patients using Light's index and Collin's method and was compared with that proposed by the ATS guideline.

Results Seventy-six participants with SP were studied; their mean age was 43.7 years, with a preponderance of male patients (84.2%). Twenty-four (31.6%) patients had PSP and 52 (68.4%) patients had secondary spontaneous pneumothorax. In PSP, there was poor agreement between various methods of estimating size of pneumothorax on chest radiogram (Kappa statistic=0.23; ICC of 0.263). Three (12.5%) of the 24 incidences of PSP, which were treated conservatively as per ATS guidelines, would have required invasive intervention if Light's index or the Collin's formula were taken into consideration.

Conclusion There was poor agreement of radiological pneumothorax size estimation by Collin's, Light's, and that proposed in the ATS guidelines. Thus, a unified, standardized method of radiological assessment of PSP is required.

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Introduction

Pneumothorax is a common condition presenting as a respiratory emergency [1]. Although most secondary pneumothoraces require some form of drainage owing to the underlying diseased lung parenchyma, the initial management of primary spontaneous pneumothorax (PSP) is based on the size at presentation. Various guidelines such as American Thoracic Society (ATS) guideline, British Thoracic Society (BTS) guideline, Light's index, Rhea method, and Collin's method suggest a different methods of evaluation for estimating the size of pneumothorax on chest radiology with different cut-off points for intervention [2–6]. The effect of using any of the aforementioned methods on the immediate management and final outcome has not been studied thus far.

Some of the suggested methods for evaluation of pneumothorax size are based on measuring the distance from the lung margin and the chest wall (BTS) and that from apex to cupola (ATS). Based on the aforementioned methods, conservative management is recommended for small pneumothoraces [defined as <2 cm between the lung margin and the chest wall at the level of the hilum (BTS) or <3 cm from apex to cupola (ATS) or <25% by Light's index], whereas intercostal drainage is recommended for large pneumothoraces.

Despite the availability of assessment methods, it has been reported that there is variability in the actual management of pneumothorax from documented guidelines. This may be owing to the fact that management is based on clinical scenario and the level of respiratory distress at presentation which overrides standard recommendations mentioned in guidelines [6].

In addition, the diversity in various recommendations with respect to radiological quantitation methods may result in inappropriate management of pneumothoraces with either aggressive treatment when not indicated and vice versa.

Limited literature is available on comparing the various methods of quantitating pneumothorax and the effect on management. Thus, the purpose of the present study was to compare the agreement between various radiological pneumothorax indices in relation to the immediate management of spontaneous pneumothorax (SP).

Aims and objectives

The aim was to estimate the size of pneumothorax by the Light's index and Collin's method followed by comparison of these indices with the ATS guideline.

Patients and methods

This prospective study was conducted in our hospital between January 2013 and January 2017, after obtaining ethics review board approval. Participants were included in the study after obtaining written informed consent. All adult patients presenting with a diagnosis of SP in Emergency and Pulmonary Medicine Department were included in the study (Fig. 1).

The treatment decision for pneumothorax (observation/ needle aspiration/pigtail insertion/intercostal tube drainage) was made by the emergency medicine or pulmonary physician, who were blinded to the outcome of the study. The physicians adhered to ATS guidelines for making a decision on the management of PSP. All secondary pneumothoraces were drained with either a pigtail or intercostal tube insertion. When indicated, 9 or 10 size pigtail catheters or 20–28 F Portex chest tube was used to drain the pneumothoraces, according to the physician's decision.

A predesigned structured proforma was used to collect data, after obtaining informed consent from patients.
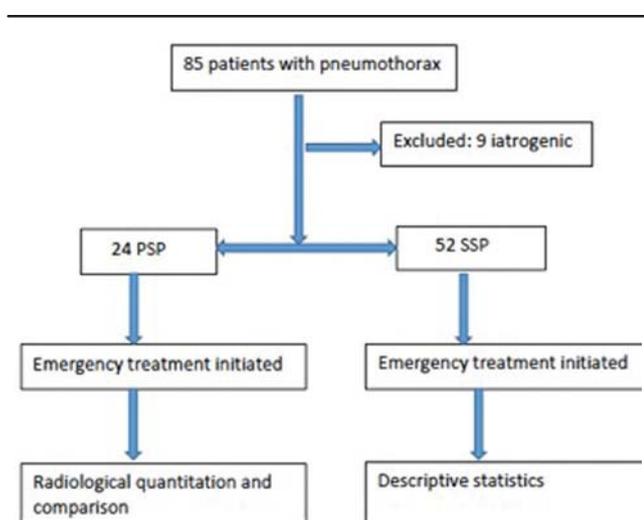
Demographic details, anthropometry, and clinical presentation (pre-existing cardiopulmonary disease or other comorbid condition, findings on examination) were noted.

Radiologic imaging by digital chest radiological was assessed by a radiologist (N.S.) and an author (U.D.) individually. The pneumothorax size was calculated by Light's index and Collin's method (Figs 2 and 3, Table 1) and compared with ATS guideline [1,2]. The radiologist ascertained PSP as absence of any underlying radiologic

Figure 1

Study flow.
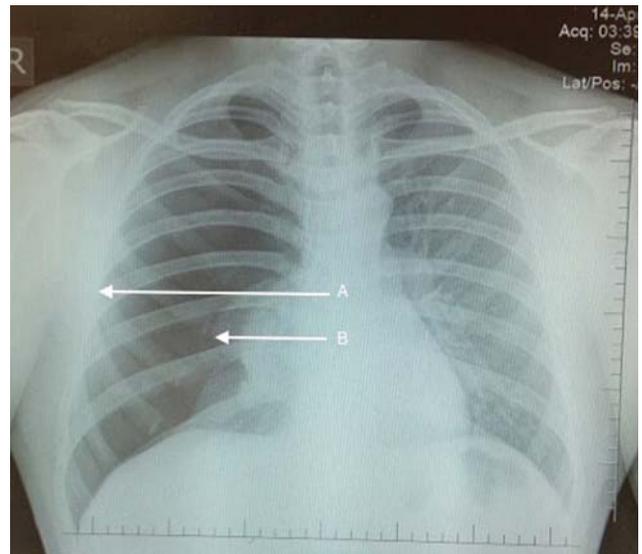
Figure 2

Light index calculated as $100[1-(\text{lung diameter (A)}^3/\text{hemithorax diameter(B)}^3)]$.

Figure 3
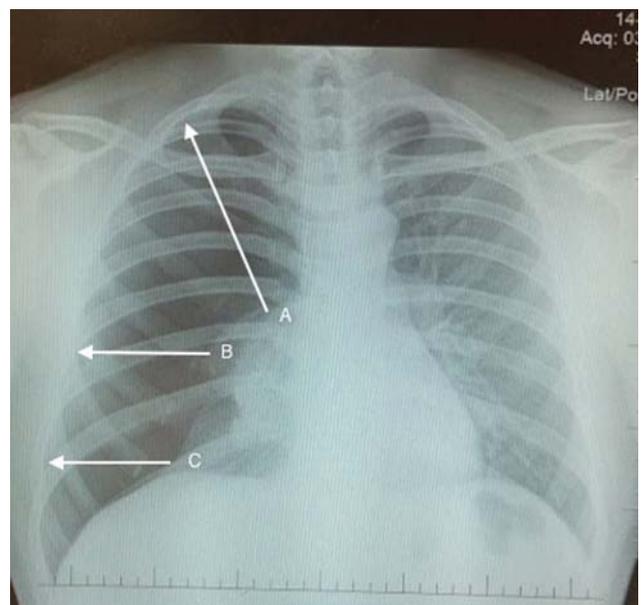
Collin's method is given by % PNX=4.2+[4.7×(A+B+C)].

Table 1 Comparison of guidelines of size estimation of pneumothorax

Pneumothorax size estimation methods	Formula	Indication for intervention (ICD)
Light's index	$100\left[1-\left(\frac{\text{lung diameter}^3}{\text{hemithorax diameter}^3}\right)\right]$	>25%
Collin method	$\%\text{PNX} = 4.2 + [4.7 \times (A + B + C)]^a$	>25%
ATS guideline	3 cm apical cupola cut-off (interpleural distance)	>3 cm cupola

A, apex to apical lung; ATS, American Thoracic Society; B, interpleural distance at mid-point of upper half of hemithorax; C, interpleural distance at mid-point of lower half of hemithorax.

abnormality in the lung parenchyma and secondary spontaneous pneumothorax (SSP) as the presence of visible radiologic parenchymal abnormalities suggesting the underlying etiology. A chest CT scan was done when categorization was challenging.

Sputum for acid-fast bacillus and HIV testing were done. The time taken from presentation to hospital to initiation of definitive intervention for the pneumothorax (needle aspiration/pigtail insertion/intercostal tube drainage) was noted. The participants were followed up until discharge from hospital. The treatment received, outcome, any complications (persistent air leak, secondary infection), and number days spent in hospital were noted.

Statistical analysis

Descriptive statistics, mean, range, and percentages were used to analyze demographic data. Agreement between the Lights index and Collins formula with ATS guideline in patients with PSP was analyzed by Kappa statistics, bias plot analysis, and paired t test. χ^2 test (for categorical variables) and unpaired t test (for continuous variables) were applied to compare risk factors between PSP and SSP. Mann–Whitney U test was used for variables with skewed distribution. Spearman rho correlation coefficient was used to analyze any effect of the methods of quantitation on the time to intervention for definitive treatment. P value less than 0.05 was considered significant.

Results

There were 85 participants with pneumothorax during the study period. Nine patients had iatrogenic pneumothorax and were excluded from analysis. The annual incidence of SP was 61.7 per 100 000 hospital admissions. The annual incidence of PSP was 16.6 per lakh hospital admissions.

Clinical presentation of spontaneous pneumothorax

The mean age was 43.7±18.4 years (range, 18–86 years) (Table 2). Males constituted 84.2% of the patients.

Table 2 Clinical profile of patients with pneumothorax

Characteristics	SP (N=76)	PSP (N=24)	SSP (N=52)	P value
Age (years) (mean±SD)	43.7 ±18.4	28.6 ±9.7	48.2 ±17.8	0.0001
Males [n (%)]	64 (84.2)	19	45	0.001
Male : female	5.2 : 1	8 : 1	6 : 1	0.001
Smoking status [n (%)]	41 (53.9)	8 (33.3)	33 (63.4)	0.06
Residence (urban)	39	14	25	0.23
Height (mean in cm)	166.08 ±8.2	169.35 ±8.2	164.43 ±7.5	0.049
Weight (kg)	52.65 ±14.4	57.9 ±15.3	50.58 ±14.2	0.047
BMI (kg/m²)	19.05	20.4	18.6	0.22
US/LS ratio	0.85	0.86	0.84	0.8
Side of PNX (right) [n (%)]	39 (51.3)	13 (54.1)	26 (50)	–
Duration of ICD/pigtail (mean number of days)	8.6	4.9 ±3.5	10.1 ±5.8	0.04

PSP, primary spontaneous pneumothorax; SP, spontaneous pneumothorax; SSP, secondary spontaneous pneumothorax; US/LS ratio, upper segment to lower segment ratio.

Table 3 Etiology of spontaneous pneumothorax

Etiology	N=76 [n (%)]
Primary spontaneous pneumothorax	24 (31.6)
Tuberculosis	28 (36.8)
COPD	18 (23.6)
Interstitial lung disease	3 (4.2)
Pneumonia	2 (2.6)
Empyema	1 (1.3)

Twenty-four (31.6%) patients had PSP, whereas 52 (68.4%) had secondary pneumothorax. Right-sided pneumothorax was more common (51.3%); two patients had bilateral pneumothorax. Patients with PSP were taller and heavier than patients with SSP (P=0.04) (95% confidence interval of differences 0.03, 9.8, 0.08, 14.61, respectively). Smoking was more common in patients with SSP than in PSP, though not statistically significant (P=0.06). The clinical features of both sub-groups are depicted in Table 2.

The average duration of symptoms before presentation with pneumothorax was 1–3 days. The time to definitive intervention from the time of presentation did not differ between PSP and SSP (mean, 6.5 vs. 5.4 h; P=0.6).

The most common cause of secondary pneumothorax was tuberculosis, which was seen in 28 (53.8%) of the 52 patients with SSP, of whom 18 had active pulmonary tuberculosis (Table 3). Three (5.8%) patients with SSP were HIV positive and their pneumothorax was secondary to tuberculosis.

The duration of intercostal drainage was longer in SSP (10.1 vs. 4.9 days) than in PSP ($P=0.04$). There was no significant difference in the usage of pigtail or intercostal drainage tube or between large and small bore intercostal drainage tube ($P=0.10$) [7]. Persistent air leak (air leak of >5 days duration after intervention) [8] was more common in SSP as compared with PSP (15/52 vs. 2/24, respectively), with a likelihood ratio of 3.36. Two patients with PSP and persistent air leak were subjected to surgical intervention and closure. Other complications seen included re-expansion pulmonary edema, empyema, and wound infection in one patient each. There was no significant difference noted in the percentage of patients subjected to pleurodesis between PSP and SSP ($P=0.29$).

Comparison of the pneumothorax size estimation methods in primary spontaneous pneumothorax

The various methods for size estimation were applied and compared only in patients with PSP ($n=24$), and the results of the same are discussed in the following paragraphs.

There was wide difference in the estimation of pneumothorax in patients with PSP by Lights index and Collins formula compared with ATS guideline (Kappa statistic=0.23; intra-class correlation coefficient of 0.263).

The ATS guideline categorizes PSP based on less than 3 cm and more than 3 cm cupola as small and large, respectively. Both the small and large pneumothoraces of the ATS were categorized as 'large' by the Light's index, with the median size being 65.9 and 76.3%, respectively. The Collin's method fared better, with median size estimated being 37.5 and 60.3%, respectively (Table 4). Bland–Altman analysis could not be performed as the distribution of the size of pneumothoraxes was scattered widely from the mean. There were remarkable differences in the pneumothorax sizes by the Light's index and Collin's method on evaluation by paired sample *t* test (mean difference of –4.32, 95% confidence interval of differences –14.46, 5.81).

Table 4 Comparison of guidelines in estimating size of pneumothorax in primary spontaneous pneumothorax

ATS	<3 cm cupola	>3 cm cupola
	Median, IQR, range of pneumothorax %	Median, IQR, range of pneumothorax %
Light's index	65.96, 38–91%, 0.04–99.9%	76.3, 42.4–89.9%, 62.3–98.5%
Collin's method	37.5, 22.4–60.3%, 6–70%	77, 54–120.4%, 21–220%

ATS, American Thoracic Society; IQR, interquartile range.

ATS recommends intercostal tube drainage if the PSP cupola exceeds a size of 3 cm, whereas Light's and Collins's method uses a cutoff of 25% pneumothorax. In our study, the physicians adhered to ATS guidelines for making a decision as to the management of PSP. Three (12.5%) of the 24 incidences of PSP, which were treated conservatively as per ATS guidelines, would have required invasive intervention if Light's index or the Collin's formula were taken into consideration.

The time to definitive intervention or the outcome (resolution) did not differ between the pneumothoraxes assessed by the three methods when analyzed by Spearman's rho correlation ($P=0.16$), which brings to fore the discrepancies in the three methods.

Discussion
Pneumothorax descriptors
Pneumothorax is a common respiratory condition, which has not been extensively studied in India. Our study reveals that the descriptors of pneumothorax (risk factors and clinical profile) except a few are not very different from previous reports from the Indian subcontinent [9–11].

In the present study, the incidence of pneumothoraces was lesser, whereas the male preponderance (male : female=5.2 : 1) was similar, when compared with a previous study by Gupta *et al.* [10]. Patients with PSP were significantly younger than those in the SSP group.

Our study also revealed that male preponderance was even more evident in PSP as compared with SSP (male : female ratio 8 : 1 and 6 : 1, respectively). Patients with PSP were significantly taller than those with SSP ($P=0.04$) [1].

Patients presenting with SSP comprised higher percentage of smokers than those patients diagnosed with PSP, though this was not statistically significant (63.4 vs. 33.3%; $P=0.06$).

Being a country endemic for tuberculosis, the most common etiology for SSP was pulmonary tuberculosis (36.8%) which surpassed COPD (23.6%). In contrast, western literature has cited COPD as the most common cause of SSP [1,12].

Primary spontaneous pneumothorax radiological quantification
Initial management of PSP is guided by recommendations, which are based on expert opinion and consensus. This is owing to nonavailability of a

unified standardized guideline. There is a lack of high-quality randomized control trials or metadata clinical research for this condition. As noted before, multiple guidelines and formulae exist, each with different cutoff points for management. There are few studies that compare the pneumothorax guidelines/indices on a head-to-head basis [13,14].

The ATS and BTS determine the cutoff points on the chest radiograph arbitrarily, based on expert opinion and consensus. Poor correlation was seen when these estimated measurements were compared with each other [15].

The treatment of pneumothorax depends on clinical presentation and extent of pneumothorax and ranges from simple observation, oxygen supplementation, manual needle aspiration, pigtail, or intercostal tube drainage to surgical interventions [1,16–18]. Although pneumothorax is widely prevalent in India, limited data are available to enable development of a guideline for management, the assessment of the size classification of the pneumothorax, and its influence on treatment outcomes.

Our study shows that there is poor agreement in size of the pneumothorax in PSP as measured by the Light's index, Collin's formula, and the ATS guideline (Kappa=0.23). None of the previous studies have shown good agreement of the pneumothoraces size estimation by various methods [13–15].

In PSP, observation and needle aspiration were the preferred line of management in two patients and one patient, respectively. The rest of the patients with PSP were treated by intercostal tube drainage. There were challenges in deciding the line of management, given the lack of consensus between the pneumothorax size estimation methods.

Management of secondary spontaneous pneumothorax

As patients with SSP have an underlying pulmonary disorder, they might not tolerate even a small pneumothorax. When radiological quantitation is considered for deciding management options, the additional factor of physiological compromise owing to pneumothorax is not factored in, while deciding the need for intercostal drainage. Intercostal tube drainage was the preferred first line of management in patients with SSP in our center. There are no firm recommendations available as yet on the management for SSP and thus each condition leading to SSP warrants individualized approach [19].

This is the first prospective study comparing the different size estimation methods and its implication on the management, from India. Previous studies have compared Collin's and Rhea method [13], BTS, American College of Chest Physicians, and Belgian Society of Pulmonology guidelines [20]. All these studies were retrospective studies, which compared the pneumothoraxes on the radiographs. They have also concluded that there is a lack of agreement between the different methods of size estimation of pneumothorax and have reiterated the need for a consensus guideline for the same.

The observational nature of the study is a limitation to draw definitive conclusions. However, this primes us to the fact that a randomized controlled trial in which a head-to-head comparison of outcomes resulting from management options based on comparison of the different pneumothorax measurement methods is needed.

Conclusion

Younger age, male sex, and smoking are risk factors for PSP. Most common etiology associated with SSP was pulmonary TB. Patients with SSP require longer duration of intercostal drainage. There is poor agreement of the measures of pneumothoraxes sizes as defined by the Light's index, Collin's formula, and the ATS guideline. There is a need for a unified guideline for management of SP.

Conflicts of interest

There is no conflict of interest.

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