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Original Article

Air leak grading in primary spontaneous pneumothorax is useful to predict prolonged air leak

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ABSTRACT

Background: Results of studies to predict prolonged air leak (PAL) after chest tube administration in primary spontaneous pneumothorax (PSP) have been inconsistent and have limited use. In this study, in which we used a scale grading the amount of air leak, we investigated the correlation between the scale and the duration of air leak and its potential to be a predictor of PAL.

Materials and Methods: PSP cases (n = 140) requiring chest tube insertion between April 2017 and December 2021 were prospectively studied. We graded the air leak in these patients using a 5-grade scale. We designed eight 'SUM' variants using air leak grades within the first five days after chest tube administration. In this study, PAL was defined as an air leak lasting more than five days.

Results: Total PAL occurrence was 29 (20.7%) in this cohort with a mean age of 26.6±8.14 years. Correlation analyses showed that each SUM variable correlated highly with the duration of the air leak, and SUM7to8, the sum of two consecutive values of air leak grades on the fourth day, was proved to be the most powerful predictor. When SUM7to8 ≥ 1, PAL can be predicted with a positive and negative predictive value of 69% and 100%, respectively. The sensitivity and specificity are 100% and 88.3%, respectively.

Conclusions: This simple new method of predicting PAL using SUM7to8 has shown that the amount of air leak is a powerful independent predictor of PAL. Therefore, grading air leakage in PSP is a useful method to predict PAL.

Keywords: prolonged air leak, primary spontaneous pneumothorax, air leak grade, chest tubes

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Introduction

Primary spontaneous pneumothorax (PSP) is defined as the abnormal accumulation of air in the pleural space without apparent underlying lung disease. The global incidence is 7.4 -18/1,000,000 men and 1.2 - 6/1,000,000 women per year [1]. It is usually observed in young adults who are tall and thin, and who smoke. PSP has a high recurrence rate that goes up to 55% with conservative treatment [2]. Treatment methods have been discussed many times from past to present. Treatment may vary from only monitoring the patient to performing an operation in the first pneumothorax attack. Although most pneumothorax cases can be resolved with a chest tube, some of them persist even days later. The duration of persistent air leak (PAL) and the timing of surgery are not clear. It is generally called PAL if the air leak after chest tube insertion lasts more than 5 or 7 days. PAL requires further surgical treatment as it increases other pulmonary risks such as pneumonia and empyema [3,4]. PAL is usually caused by spontaneous pneumothorax arising from underlying lung disease (secondary spontaneous pneumothorax), pulmonary infections, and complications of mechanical ventilation, chest trauma, or pulmonary surgery [4]. In PSP, air leakage is mostly expected to cease in a shorter time. Should we also wait for 5-7 days in PSP to decide on surgery, or can the grade of air bubbling observed with chest tube drainage be a guide to deciding earlier? The results of previous studies to predict PAL have been inconsistent and have limited use. In this study, we investigated the importance of the air leak grading scale, used by Oh et al [5] to predict PAL following pulmonary lobectomy, in predicting PAL in patients who underwent chest tube insertion due to PSP.

Materials and Methods

A total of 585 pneumothorax patients were admitted to our hospital between April 2017 and December 2021 and were treated by the same surgical team. Of these patients, 445 were excluded from the study. The data of 140 patients who underwent chest tube insertion after being diagnosed with PSP and met the study inclusion criteria were prospectively collected by the researchers.

Exclusion criteria were underlying lung disease (e.g., malignancy, interstitial lung disease, chronic obstructive pulmonary disease), traumatic or iatrogenic pneumothorax, age over 50 years, surgery within the first 72 hours due to ipsilateral or contralateral recurrence or bilateral pneumothorax despite chest tube insertion (even though there is no air drainage after chest tube administration, the presence of patients who underwent early surgical treatment does not overlap with the main objective of the study), recurrence (even though the same patient underwent a second chest tube insertion for recurrence during the study period, only the first chest tube administration was included in the study), re-administration of chest tube due to recurrence in the early postoperative period following treatment with VATS.

To diagnose PSP, we used chest radiography, the most common and accessible method. We preferred computed tomography to examine the lung parenchyma in terms of etiology after an emergency intervention, mainly with a chest tube.

For the treatment, a single 28 French (Fr) chest tube was used in all 140 patients under local anesthesia. A skin incision of approximately 15 mm width was usually performed at the intersection of the fifth or sixth intercostal space and the mid-axillary line. Using curved Metzenbaum scissors, the subcutaneous tissues and intercostal muscles were dissected, making a tunnel to the pleural space. After the tunnel was created, drain fixation suture was placed into both corners of the skin incision with atraumatic sharp number 1 silk suture. During chest tube removal, to close the incision, another suture was placed in the middle of the incision, the ends of which were left unknotted. With the help of a clamp, a chest tube was inserted into the chest cavity and advanced towards the apex. After air drainage was observed in the closed underwater drainage system, the tube was fixed to the patient's skin using fixation sutures. The suture in the middle was left unknotted and wrapped around the drain. The procedure was terminated by dressing the wound. Suction was not applied to closed underwater drainage in any of the patients. This study was approved by the designated Ethics Committee of our hospital. The approval number is 49109414-604.02-7018.

Air leak grading and definition of 'P' time period

In the days following chest tube administration, the semi-quantitative evaluation of air leakage was scored using a 5-grade scale (Table 1) every 12 hours, morning and evening periodically (P), for five days. Air leak grading based on the evaluation of volitional coughing by the patient was performed by the residents. To facilitate data collection, each visit period was defined as a 'P' time scale, and the visit periods were expressed as P1, P2, P3, P4, etc., respectively (Table 2).

Table 1. Air leak grading.	
Grade	Definition
0	No air bubbles on cough
1	Only a few air bubbles on cough
2	Persistent air bubbles on cough
3	Persistent, small amount of air bubbles on spontaneous respiration
4	Persistent, large amount of air bubbles on spontaneous respiration

Definition of PAL

We did not remove the chest tube until air drainage had stopped completely in the previous 24 hours. The cessation of air leakage was defined as the degree of air leakage being 0 points for at least two periods. In this study, PAL was defined as an air leak lasting longer than 5 days (>10 P).

"SUM" variables as predictors of PAL

For semi-quantitative comparison of air leakage following chest tube administration, we designed eight "SUM" variables, where we evaluated the degree of air leakage from P1 to P10 (Table 2). We studied the eight SUM variables, respectively, representing the amount of air leak to find out whether they were associated with PAL. The most appropriate variable among the variables that correlate with PAL and the threshold value for PAL prediction were obtained. We tested other predictors derived from variables such as age, gender, pneumothorax side, smoking, and pneumothorax recurrence to see if they had any additional effect on optimizing the PAL prediction.

Statistical Analysis

Pearson's $\chi 2$ test analysis was performed by creating crosstabs for the comparison of categorical variables between PAL (+) and PAL (-).Student's t-test analysis was performed for numerical variables. Categorical data were presented as numbers and percentages. Numerical variables were summarized as mean ± SD and median (min – max). Eight variations, SUM1to2, SUM3to4, SUM5to6, SUM7to8, SUM1to4, SUM3to6, SUM1to6, SUM1to8, were created for daily air leak scores. Receiver operating characteristic (ROC) curve analysis was performed for each variation of PAL status, and the areas under the ROC curve (AUC) were compared to select the best predictive SUM variable. In ROC analyses, the cutoff was calculated according to the Youden index. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were determined according to the calculated cutoff values. The statistical significance level was determined as $p < 0.05$. Statistical tests were performed using SPSS software (IBM SPSS Statistics Version 25, IBM Corporation, Armonk, NT, United States).

Results

One hundred and forty patients with a mean age of 26.6 ± 8.14 were included in the study. One hundred twenty-eight of the cases (91.4%) were male. Pneumothorax was on the right in 81 (57.9%) patients and on the left in 59 (42.1%) patients. Of the patients, 123 (87.9%) had a first pneumothorax attack, 14 (10%) had a second, and 3 (2.1%) had a third attack. Five (29.4%) of the recurrences were contralateral. According to the leukocyte values measured on the first day after the drain was inserted, 66 (47.1%) patients had leukocytosis. The mean time the chest tubes were in place was 4.3 ± 2.6 (2-17) days. The median leak score was recorded as 2.0 (0-39). Total

Table 2. Definitions of 8 "SUM" variable.										
Days[a]	1		2		3		4		5	
Periods[b]	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Air leak grade[c]	0-4 (n1)	0-4 (n2)	0-4 (n3)	0-4 (n4)	0-4 (n5)	0-4 (n6)	0-4 (n7)	0-4 (n8)	0-4 (n9)	0-4 (n10)
Variables	Definitions									
SUM^{1to2}	n1 + n2									
SUM^{3to4}	n3 + n4									
$SUM5^{to6}$	n5 + n6									
SUM^{7to8}	n7 + n8									
SUM^{1to4}	n1 + n2 + n3 + n4									
SUM^{3to6}	n3 + n4 + n5 + n6									
SUM^{1to6}	n1 + n2 + n3 + n4 + n5 + n6									
SUM^{1to8}	n1 + n2 + n3 + n4 + n5 + n6 + n7 + n8									

[a] Days after chest tube insertion; [b] morning and evening visit periods (P); [c] 'n' represents the air leak grade, from 0 to 4.

PAL occurrence in this cohort was 29 (20.7%). Thirty-four (24.3%) patients underwent video-assisted thoracoscopic surgery (VATS) for PAL and other indications. Three patients who could not be operated on for PAL due to various reasons were discharged by switching to the Heimlich valve system. Wedge resection and apical pleurectomy were performed via VATS in the other 26 patients with PAL.

Univariate analysis did not reveal a significant difference between PAL (+) and PAL (-) in terms of age, gender, pneumothorax side, leukocytosis at the time of diagnosis, smoking, and recurrent pneumothorax (Table 3).

Based on the 140 patients who were treated with a chest tube, correlation analyses showed that each SUM variable was strongly associated with PAL. In the analysis of the SUM variables (SUM1to4) of the first two days following the chest tube insertion, according to the Youden index, the cutoff for total air drainage score was regarded as ≥ 4, while it was ≥ 5 in the analysis of the SUM variables (SUM1to6) of the first three days, and ≥ 6 for the SUM variables (SUM1to8) of the first four days. The cutoff was calculated as ≥ 4 when the SUM variables (SUM3to6) of only the second and third day were considered. In all day-based evaluations, the cutoff was calculated as ≥ 1. ROC curves were generated for the SUM variables (Figure 1). In the ROC analyses, the AUC value ranged from the lowest of 75.8% for SUM1to2 to the highest of 94.1% for SUM7to8 (Table 4). The calculated AUC revealed that SUM7to8 was the most powerful predictor of PAL, and when SUM7to8 ≥ 1, PAL could be predicted with 100% sensitivity and 88.3% specificity, with 69% PPV and 100% NPV.

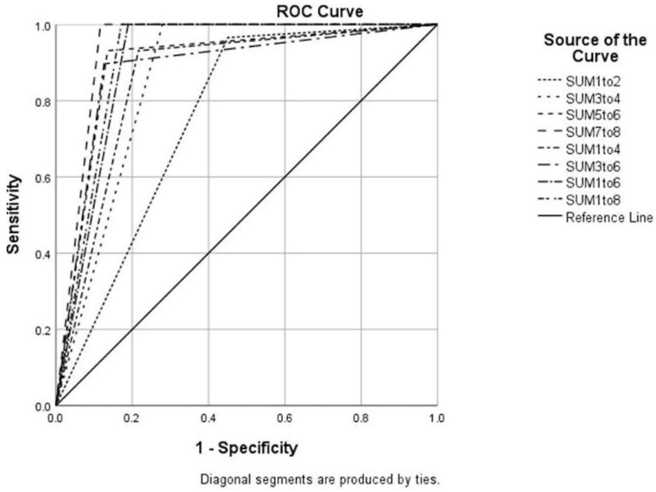

Figure 1. Comparison of the SUM variables. The dashed line represents the ROC curve, the highest AUC derived from only SUM7to8.

Table 3. Baseline characteristics and results of univariable analyses.

Variables	No. of cases (%)			P value[a]
	All (n=140)	PAL (-)(n=111)	PAL (+) (n=29)	
Ageb (years)	26.6±8.1	26.2±7.9	28.1±8.8	0.28c
Male	128 (91.4%)	103 (92.8%)	25 (86.2%)	0.25
Right side	81 (57.9%)	64 (57.7%)	17 (58.6%)	0.92
Leukocyte (>103)	66 (47.1%)	54 (48.6%)	12 (41.4%)	0.48
Smoker	106 (75.7%)	85 (77.3%)	21 (72.4)	0.58
Recurrent pneumothorax	18 (12.9%)	15 (13.5%)	3 (10.3%)	0.65

[a]P values are for comparison between PAL (-) and PAL (+), [b] Exceptionally, ages are expressed as "mean±SD" , [c] Student's t-test was performed. In other cases, Pearson's χ^2 test was performed.

Table 4. Statistical values of SUM variables.

c	Calculated AUCa (%)	Sensitivity (%)	Specificity (%)	PPVb (%)	NPVc (%)
SUM_{1To2}	75.8	96.6	55	35.9	98.4
SUM_{3to4}	86	100	72	48.3	100
SUM_{5to6}	89.8	93.1	86.5	64.3	98
SUM_{7to8}	94.1	100	88.3	69	100
SUM_{1to4}	85.7	93.1	78.4	52.9	97.8
SUM_{3to6}	88.5	89.7	87.4	65	97
SUM_{1to6}	90.5	100	81	58	100
SUM_{1to8}	91.4	100	82	60.4	100

[a]AUC denotes area under the ROC curve, [b]PPV, positive predictive value, [c]NPV, negative predictive value, the bold data show that SUM-7to8 is the most powerful predictor of PAL (i.e. the largest AUC).

Discussion

PAL is one of the most common problems in thoracic surgery and a significant cause of morbidity. It suggests that the fistula on the pleural surface is large, and the probability of spontaneous closure of the fistula is low. It causes failure of lung re-expansion in most patients and requires more advanced surgical methods. Prediction of PAL and early surgical intervention reduce morbidity and shorten hospital stay. We thought that the amount and duration of air leak could be a marker for PAL in patients with PSP who had required chest tube treatment. In a conventional closed underwater drainage system, we tracked the amount of leakage using an observational grading method.

There is no clear consensus on the definition of PAL, and it usually defines leakage that lasts more than 5-7 days [3,4]. In a report, the median time for spontaneous cessation of air leak was 7 days for primary spontaneous pneumothorax and 11 days for secondary spontaneous pneumothorax [6]. Since the underlying cause is different in primary and secondary pneumothorax, the duration of PAL and the surgical approach may differ in these two entities. While treatment with a chest tube can continue for a longer time and conservative methods and pleurodesis can be applied in secondary spontaneous pneumothorax, the next step after chest tube insertion is mostly a surgical treatment with VATS in PSP patients. However, the optimum time for surgical intervention remains unclear. Considering this situation, we decided to analyze only those who underwent chest tube insertion for PSP when planning our study. In this way, we thought we could conduct a more specific study for PAL in patients with similar primary lung pathology.

Although there are many studies on predicting PAL, most of them are retrospective analyses with heterogeneous patient groups that aim to identify predictive risk factors by comparing PAL groups with other groups. In addition, since there is no consensus on the duration of PAL, each study has discussed this period differently. On the other hand, our study includes a homogeneous population of selected patients treated with a chest tube for PSP, and it is based on a prospectively collected single-center database. Other studies have reported various risk factors, such as interpleural distance, pneumothorax size, time from symptom onset to hospital admission, poor lung function, and malnutrition, as predictors of PAL [1,2,5]. However, study results are mostly inconsistent and have limited clinical utility. With the semi-quantitative tracking of the amount of air leak in patients who had chest tube insertion, the prediction of PAL is much more practical and significant compared to other studies.

Patients who have undergone chest tube insertion and have not achieved the desired result due to PAL are easily treated with VATS in a short operating time. Considering that PSP is a disease with a high probability of recurrence and VATS is an extremely comfortable surgical method for the patient, it is of great significance to identify patients, who will be operated on for PAL, in less than 5-7 days. There will be, thus, some advantages such as shorter hospital stay, lower risk of pleural and parenchymal infection, and shorter chest tube duration.

In recent years, studies have been carried out using digital measuring devices to predict the probability of failure of chest tube treatment [7,8]. However, these studies have been conducted with a much smaller number of patients when compared to our study and consist of comparisons of heterogeneous patient groups. Furthermore, these devices are not widely used in daily practice and bring additional costs. However, as in our study, visual assessment of the size of the air leak does not require any special techniques, extra financial costs, or time. Moreover, the sensitivity, specificity, PPV, or NPV rates obtained with these studies are lower than in this study. Therefore, the scales based on air bubbles observed in the closed underwater drainage bottle after the patient's respiratory movements and coughing are much more practical and meaningful. In the past, such studies had been performed to identify PAL after lobectomy (5,9,10). There are several classifications aiming to quantify the severity of PAL in the postoperative setting, including the most cited classification by Cerfolio [9], which grades PAL according to whether the leak is expiratory or continuous and the amount of air leak. One of these is the 5-grade scale in which Oh et al [5] grade postoperative air leak after pulmonary lobectomy (Table 1). In our study, we preferred using this scale, which is very practical. Due to its potential to be a predictor of PAL in PSP patients, we used the scale prospectively, which Oh et al [5] used retrospectively for pulmonary lobectomy.

Studies define PAL differently and analyze heterogeneous patient groups. The overall incidence of PAL is therefore unknown [11]. The incidence of PAL after lobectomy ranges from 5.6% to 26% in various reports [5,12-16]. In the study where Chee et al [17] determined

PAL as 7 days, the rate of PAL was 25% in 31 patients with PSP and 39% in 73 patients with secondary spontaneous pneumothorax. In this cohort, on the other hand, PAL was defined as an air leak exceeding 5 days, and the PAL rate was 20.7% in 140 PSP patients. Our results revealed that SUM7to8 is the most powerful predictor of PAL and that PAL can be predicted with a PPV of 69% and NPV of 100% when SUM7to8 ≥ 1. In only one of our 29 patients with PAL, the score obtained on the fourth day was zero, and air leak started again in this patient the next day. In the other 28 patients, the score on the fourth day was ≥ 1. In simple terms, the detection of air leakage on the fourth day after chest tube insertion in PSP is an invaluable criterion for PAL. In this case, a longer waiting period may not be required for surgical intervention due to air leak in patients who are suitable for surgery.

In our study, we compared patients with and without PAL in terms of some basic characteristics as well. We found accordingly that age, gender, pneumothorax side, leukocytosis, smoking, and recurrent pneumothorax did not represent a significant difference between the two groups. Akamine T et al [2] reported in their study that there was no difference between the two groups in terms of age, gender, smoking, and pneumothorax side. Comparing these two groups, they reported that PAL was significantly higher only in those admitted to the hospital within the first 24 hours after symptom onset.

This study has the following potential limitations. The major limitation is the semi-quantitative evaluation of air leakage by more than one person. Our air leak grading is based on a subjective assessment despite being performed by our residents. There may be those who question its reliability on that account. However, we can assume that there is a high consistency among observers because of the simplicity of the evaluation method. Other limitations include the single-center nature of the study and sample size. We tried to overcome both limitations by including enough patients and using proper statistical methods.

In conclusion, the presence of air leakage on the fourth day following chest tube in PSP is a significant marker for PAL. Despite being a semi-quantitative method, visual assessment of air leaks is a simple and robust independent variable predicting the development of PAL. Data from larger and multicenter patient series may provide a consensus on the prediction of PAL. In this way, we believe that we can decide on earlier surgical intervention and prevent problems such as pneumonia, empyema, and prolonged hospital stay.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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Ethics approval

This study was approved by the designated Ethics Committee of University of Health Sciences, Dr. Suat Seren Chest Diseases and Chest Surgery Training and Research Hospital. The approval number is 49109414-604.02-7018.

Authors' contributions

SY, BY: made substantial contributions to the design of the work, BAŞ,AÜ: made the analysis of data, AÜ,SY: made the creation of new software used in the work, BAŞ,SY: have drafted the work, AÜ,SG: revised it.

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