Risk Factors for Severity of Pneumothorax after CT-Guided Percutaneous Lung Biopsy using the Single-Needle Method

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ABSTRACT

The purpose of this study is to evaluate the risk factors for the severity of pneumothorax after computed tomography (CT)-guided percutaneous lung biopsy using the single-needle method. We reviewed 91 biopsy procedures for 90 intrapulmonary lesions in 89 patients. Patient factors were age, sex, history of ipsilateral lung surgery and grade of emphysema. Lesion factors were size, location and pleural contact. Procedure factors were position, needle type, needle size, number of pleural punctures, pleural angle, length of needle passes in the aerated lung and number of harvesting samples. The severity of pneumothorax after biopsy was classified into 4 groups: "none", "mild", "moderate" and "severe". The risk factors for the severity of pneumothorax were determined by multivariate analyzing of the factors derived from univariate analysis. Pneumothorax occurred in 39 (43%) of the 91 procedures. Mild, moderate, and severe pneumothorax occurred in 24 (26%), 8 (9%) and 7 (8%) of all procedures, respectively. Multivariate analysis showed that location, pleural contact, number of pleural punctures and number of harvesting samples were significantly associated with the severity of pneumothorax (p<0.05). In conclusion, lower locations and non-pleural contact lesions, increased number of pleural punctures and increased number of harvesting samples presented a higher severity of pneumothorax.

Key words: Complication, Computed tomography (CT), Biopsy, Lung

CT-guided percutaneous lung biopsy is a well-established procedure that is safe and well-tolerated for diagnosing lung lesions[2, 4, 7, 8, 11, 14, 15]. However, pneumothorax occurs frequently as a complication of the procedure, of which the reported rate is from 8 to 45%[2-4, 6, 8-13, 15]. Although, in the majority of cases, pneumothorax is asymptomatic and resolves spontaneously, a small number of patients with a large pneumothorax require chest tube placement. The rate of pneumothorax requiring chest tube placement varies widely from 0 to 33%[1-6, 8-14]. There are many reports investigating the risk factors that influence any pneumothorax[2-5, 8, 9, 11, 13-15] and the requirement of chest tube placement[2, 3, 5, 7-10]. The reported risk factors for requiring chest tube placement are longer length of needle passes in the aerated lung, wider pleural angle, severe emphysema, obstructive lung disease and hyperinflation[3, 5, 7-10]. Unfortunately, these risk analyse of pneumothorax and chest

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tube placement are variable and often times contradictory. Indications of the need for chest tube placement, such as signs of respiratory distress, shortness of breath, large pneumothorax or markedly enlarging pneumothorax[2, 4, 5, 8-11, 13, 15], are necessarily subjective depending on the observer.

In this study, we evaluated objectively the risk factors that influence the severity of pneumothorax after lung biopsy. This evaluation may be useful for risk management in CT-guided percutaneous lung biopsy.

MATERIALS AND METHODS

Patient Population

From August 2000 to May 2006, ninety-five consecutive CT-guided percutaneous lung biopsies for 95 lung lesions in 91 patients were performed at Hiroshima University Hospital. Two biopsies were performed for 2 coexistent lesions in 2 patients in one session. These procedures were excluded from evaluation in this study. Repeat biopsy for one lesion in one patient and two biopsies for two different lesions in one patient, in another session, were performed, respectively. Each procedure was calculated as a new procedure. As a result, this study included 91 lung biopsy procedures for 90 lung lesions in 89 patients.

The medical charts, radiologic data and pathologic reports for all the procedures were reviewed retrospectively. This study selected only intrapulmonary lesions. Core biopsy, aspiration biopsy, or combinations of these, were used as biopsy techniques, according to the object of histological or cytological diagnoses, and lesion characteristics.

Biopsy Procedures

Written informed consent was obtained before lung biopsy from patients and family members. No institutional review board approval was required. All procedures were performed with hospital admission. A lung function test was not required as our biopsy protocol. As a general rule, biopsy was not refused due to severe emphysema. Our exclusion criteria were: the lesion diameter was less than 5 mm; if the patient had bleeding diathesis, or if the patients could not follow verbal or visual instructions or tolerate recumbent positions. Procedures were performed by one of six interventional radiologists who had over five years experience performing lung biopsy, with direct supervision by one of three experienced interventional radiologists.

All procedures were performed under local anesthesia with CT guidance (SOMATOM Plus4 Volume Zoom; Siemens, Erlangen, Germany) with patients in a prone, supine, or oblique position, depending on the lesion location. 18-21 gauge, half-automated cutting needles (Temno II; Allegiance, McGaw Park, IL) for core biopsy and sonopsy needles (PTC needle; Hakko, Chikuma, Japan) for aspiration biopsy were used, respectively. All procedures were prepared by an on-site cytotechnologist, who immediately evaluated the adequacy of harvesting samples.

CT images were obtained using 3-mm section thickness throughout the region of interest. A biopsy needle trajectory was selected to give a short needle path and avoid bullae, fissures and visible vessels whenever possible. By scanning intermittent CT using 2-mm section thickness, the needle was inserted and advanced to an adequate position for the target lesion. The cutting needle for core biopsy was manually pushed into the lung lesion and a fixed 1.0-cm (lesion size < 1.5 cm) or 2.0-cm (lesion size > 1.5 cm) long tissue core was obtained by triggering the spring-loading. The sonopsy needle for aspiration biopsy was inserted into and withdrawn from the lung lesion using a 20 ml syringe for aspiration. Immediately after harvesting a sample, the needle was withdrawn from the pleura. Then, the cytotechnologist visually examined the samples and prepared rapid toluidine blue-stained specimens. When it was considered that the sample was of insufficient quality or the specimen was inadequate (e.g. normal lung cell, blood clot or necrosis) for diagnosis, an additional biopsy was performed, occasionally changing the biopsy types or the needle sizes, if deemed safely feasible for patients. Harvested samples were submitted in 10% formalin for pathologic examination. When clinical or imaging features suggested infection, a section of the sample was also cultured.

Immediately after biopsy, the whole lung CT was examined to check for complications. If CT revealed large pneumothorax, it was aspirated by inserting an 18-gauge intravenous catheter (Surflo; Termo, Tokyo, Japan), regardless of the patient's symptoms (the criteria of severity of pneumothorax for air aspiration was indefinite). After the procedure, all patients were transferred to the clinical department, where they were kept under observation for at least overnight. Asymptomatic patients with no pneumothorax on postbiopsy CT were given bed rest for 2 hr. Patients with any pneumothorax on postbiopsy CT had been given bed rest until the following morning conservatively, and if required, given oxygen inhalation. Routine initial follow-up chest radiographs in the upright position were obtained to evaluate the appearance or enlargement of the pneumothorax the following morning. In some patients with a large pneumothorax on postbiopsy CT, a follow-up chest radiograph or CT was obtained from 2, 4 or 6 hr after the procedure. A chest tube was placed for patients with signs of moderate or severe respiratory symptoms or with a markedly enlarging pneumothorax during observation after procedures on the decision

of the pulmonary physicians (the criteria of chest tube placement was also indefinite). Patients with slight respiratory symptoms, or slight or no enlarging pneumothorax on chest radiographs were conservatively treated continuously, and further follow-up chest radiographs were obtained every 1 to 2 days if needed.

Definition and Data Collection

Table 1-3 shows evaluation factors that influence the severity of pneumothorax.

Patient factors (Table 1) were age, sex, history of ipsilateral lung surgery and grade of emphysema in the needle tract. Age categories were divided into two groups: > 60 y (64 patients: 70%) and > 70 y (36 patients: 40%). There were 65 male patients (71%). There was a history of lung surgery in 7 patients (8%). Grade of emphysema was assessed in the needle tract on CT of 3 mm thickness at the biopsy according to a three-level scale as grade 0-2 by modifying the criteria of Topal, U. et al[11] as follows: "grade 0" if no emphysema (42 patients: 46%), "grade 1" if emphysema affected less than 25% of the lung surrounding the lesion (21 patients: 23%) and "grade 2" if over 25% was affected (28 patients: 31%).

Lesion factors (Table 2) were lesion size, location and pleural contact. Lesion size categories were divided into three groups: $\leqq$ 20 mm (41 lesions: 45%), 21- 40 mm (36 lesions: 40%) and 40 mm < (14 lesions: 15%). Location categories were divided into three groups by trisecting the whole lung field in a cranio-caudal axis by diagnostic CT before biopsy: "upper" (36 lesions: 40%), "middle" (35 lesions: 38%) and "lower" (20 lesions: 28%). Pleural contact was defined as where the length of pleural abutting was over 1 cm. Pleural contact was seen in 58 patients (64%).

Procedure factors (Table 3) were position, needle type, needle size, number of pleural punctures, pleural angle, length of needle passes in the aerated lung and number of harvesting samples. Position categories were divided into two groups: spine (28 procedures: 31%) and prone (63 procedures: 69%), including each oblique position. Needle type categories were 2 different techniques: core biopsy (78/86 procedures: 91%) and aspiration biopsy (8/86 procedures: 9%). A combination of both techniques (5 procedures) was excluded from the analysis. Needle size categories were divided into two groups as 18-19 gauge (26/86 procedures: 30%) and 20-21 gauge (60/86 procedures: 70%), which excluded the combination of these two groups (5 procedures). Number of pleural puncture categories were one (60 procedures: 66%), two (22 procedures: 24%) and above three times (9 procedures: 10%). Pleural angle was measured as the smallest angle formed by a

Table 1. Patient Factors of Severity of Pneumothorax and Univariate Analysis

Patient factors	Severity of pneumothorax				p value
	None (n = 52)	Mild (n = 24)	Moderate (n = 8)	Severe (n = 7)	
Age (y) : Mean 64.6 ± 13.0					
$\leqq$ 60 (n = 27)	15 (56)	7 (26)	3 (11)	2 (7)	0.81*
> 60 (n = 64)	37 (58)	17 (26)	5 (8)	5 (8)	
$\leqq$ 70 (n = 56)	34 (61)	12 (21)	4 (7)	6 (11)	0.64*
> 70 (n = 35)	18 (52)	12 (34)	4 (11)	1 (3)	
Sex					
Male (n = 65)	34 (52)	19 (29)	7 (11)	5 (8)	0.17*
Female (n = 26)	18 (69)	5 (19)	1 (4)	2 (8)	
Prior surgery					
Yes (n = 7)	5 (72)	1 (14)	1 (14)	0 (0)	0.46*
No (n = 84)	47 (56)	23 (28)	7 (8)	7 (8)	
Grade of emphysema					
Grade 0 (n = 42)	22 (52)	13 (31)	3 (7)	4 (10)	0.39**
Grade 1 (n = 21)	12 (57)	5 (24)	3 (14)	1 (5)	
Grade 2 (n = 28)	18 (64)	6 (22)	2 (7)	2 (7)	

Note– Data of factors are presented as mean ± SD.

Severity of pneumothorax is classified into four groups: "none", "mild"; $\leqq$ 1 cm "moderate"; 1-3 cm and "severe"; $\geqq$ 3 cm, by lung surface retraction from the chest wall.

Numbers in parentheses in severity of pneumothorax are presented percentages (%).

* Mann-Whitney's U test. ** Spearman's correlation coefficient by rank test.

Table 2. Lesion Factors of Severity of Pneumothorax and Univariate Analysis

Lesion factors	Severity of pneumothorax				p value
	None (n = 52)	Mild (n = 24)	Moderate (n = 8)	Severe (n = 7)	
Size (mm): Mean 26.6± 15.2					
≦20 (n = 41)	15 (37)	16 (39)	5 (12)	5 (12)	< 0.05**
21 - 40 (n = 36)	25 (69)	6 (17)	3 (8)	2 (6)	
> 40 (n = 14)	12 (86)	2 (14)	0 (0)	0 (0)	
Location					
Upper (n = 36)	26 (72)	5 (14)	5 (14)	0 (0)	< 0.05**
Middle (n = 35)	20 (57)	10 (29)	1 (3)	4 (11)	
Lower (n = 20)	6 (30)	9 (45)	2 (10)	3 (15)	
Pleural contact					
Yes (n = 58)	41 (70)	12 (21)	4 (7)	1 (2)	< 0.05*
No (n = 33)	11 (33)	12 (37)	4 (12)	6 (18)	

Note – * Mann-Whitney's U test. ** Spearman's correlation coefficient by rank test.

Table 3. Procedure Factors of Severity of Pneumothorax and Univariate Analysis

Procedure factors	Severity of pneumothorax				p value
	None (n = 52)	Mild (n = 24)	Moderate (n = 8)	Severe (n = 7)	
Position					
Supine (n = 28)	14 (50)	8 (28)	4 (14)	2 (7)	0.35*
Prone (n = 63)	38 (60)	16 (26)	4 (6)	5 (8)	
Needle type***					
Cutting (n = 78)	44 (56)	20 (26)	7 (9)	7 (9)	0.89*
Aspiration (n = 8)	4 (50)	4 (50)	0	0	
Needle size***					
18 - 19 gauge (n = 26)	17 (65)	6 (23)	1 (4)	2 (8)	0.24*
20 - 21 gauge (n = 60)	31 (52)	17 (28)	7 (12)	5 (8)	
Number of pleural puncture Mean 1.48 ± 0.81					
1 (n = 60)	38 (63)	14 (23)	4 (7)	4 (7)	< 0.05**
2 (n = 22)	11 (50)	8 (36)	2 (9)	1 (5)	
≧ 3 (n = 9)	3 (34)	2 (22)	2 (22)	2 (22)	
Pleuralangle***: Mean 64.5 ± 20.3					
0 – 50° (n = 22)	15 (68)	6 (27)	1 (5)	0 (0)	0.28**
51-70° (n = 20)	11 (55)	5 (25)	2 (10)	2 (10)	
>70° (n = 40)	22 (55)	11 (28)	4 (10)	3 (7)	
Length of needle passes in the aerated lung (mm): Mean 15.3 ± 20.9					
0 (n = 26)	20 (77)	3 (12)	1 (4)	2 (7)	< 0.05**
1 – 20 (n = 37)	22 (60)	11 (30)	2 (5)	2 (5)	
21 - 40 (n = 21)	9 (43)	7 (33)	3 (14)	2 (10)	
> 40 (n = 7)	1 (14)	3 (43)	2 (29)	1 (14)	
Number of harvesting samples: Mean 1.40 ± 0.63					
1 (n = 62)	36 (58)	15 (24)	5 (8)	6 (10)	< 0.05**
2 (n = 22)	12 (55)	8 (36)	2 (9)	0 (0)	
3 (n = 7)	4 (58)	1 (14)	1 (14)	1 (14)	

Note – *Mann-Whitney's U test. **Spearman's correlation coefficient by rank test. ***Procedures belonging to multi-groups are excluded from the analysis.

line drawn along the needle and a straight line drawn tangential to the pleura at the point of needle puncture. Pleural angle categories were divided into 3 groups: 0-50°(22/82 procedures: 27%), 51-70°(20/82 procedures: 24%) and > 70°(40/82 procedures: 49%), which excluded 9 procedures belonging to the multi-groups. Length of needle passes in the aerated lung was defined as calculation of total distance of the aerated lung traversed by the needle during each procedure (i.e. calculation of total distance of needle passes in one session). The length categories were divided into four groups: 0 mm (26 procedures: 28%), 1- 20 mm (37 lesions: 41%), 21-40 mm (21 procedures: 23%) and > 40mm (7 procedures: 8%). Number of harvesting sample categories were one (62 procedures: 68%), two (22 procedures: 24%) and three (7 procedures: 8%).

Clinical examination, postbiopsy CT, follow-up chest radiographs or CT and any management including air aspiration and chest tube placement were recorded during and after all procedures. The severity of pneumothorax during and after procedures was classified into four groups by the criteria of Ko, J.P. et al[8],: "none", "mild"; ≤ 1 cm "moderate"; 1-3 cm and "severe"; ≥ 3 cm, by lung surface retraction from the chest wall on postbiopsy CT and follow-up chest radiograph or CT. The largest lung surface retraction length between parallel lines to the parietal and visceral pleura was measured in the axial CT and chest radiograph of the whole lung and appropriated to the severity of pneumothorax. The largest length in the most severe status of pneumothorax during clinical examination was selected and used in the analysis.

The type and frequency of all complications, except pneumothorax, associated with the 91 procedures were also recorded during clinical examination.

Diagnostic yield was deemed a failure if adequate specimens could not be obtained to make a decision about benignity. Diagnostic accuracy, sensitivity and specificity were evaluated by comparing the results of biopsy and a confirmed diagnosis obtained by subsequent surgery or clinical follow-up course.

Statistical Analysis of Factors for Pneumothorax

Data analyses were performed with the use of computer software (Statcel2; OMS publishing, Tokorozawa, Japan). Univariate analysis was performed to evaluate the association between patient factors, lesion factors and procedure factors and the severity of pneumothorax. Two and multi groups in the categories of factors were analyzed using Mann-Whitney's U test and Spearman's correlation coefficient by rank test, respectively. The predominant risk factors for the severity of pneumothorax were determined by multivariate analyzing by multiple regression analysis of data derived from the univariate analysis. P values < 0.05 were defined as the statistical significant association in univariate and multivariate analysis.

RESULTS

The Severity of Pneumothorax

Pneumothorax occurred in 39/91 procedures (43%), which was revealed on postbiopsy CT in 36 procedures (40%) or subsequently by follow-up chest radiograph in 3 procedures (3%). Postbiopsy CT revealed the severity of pneumothorax as "none" for 55 procedures, "mild" for 26 procedures, "moderate" for 6 procedures and "severe" for 4 procedures. Air aspiration was performed for 3 out of 4 severe pneumothoraces on post biopsy CT. Two severe pneumothoraces were downgraded to moderate and one to no change. In the "none" group on postbiopsy CT, pneumothorax developed to "mild" in 1 procedure, "moderate" in 1 procedure and "severe" in 1 procedure on follow-up chest radiographs (= delayed pneumothorax). In the "mild" group on postbiopsy CT, 1 procedure developed to "moderate" and 2 procedures to "severe" on follow-up chest radiographs. The other pneumothoraces on postbiopsy CT remained stable or showed an improvement by follow-up in the classification of severity. A chest tube was placed one or two days after biopsy for "severe" in 3 (3%) of all procedures, which had developed from 1 procedure of "none" and 2 procedures of "mild", respectively.

Ultimately, the severity of pneumothorax in clinical examination for analysis resulted as "none" for 52 procedures (57%), "mild" for 24 procedures (26%), "moderate" for 8 procedures (9%) and "severe" for 7 procedures (8%).

Univariate analysis of factors for the severity of pneumothorax

Table 1-3 shows a summary of the results.

In patient factors (Table 1), there were no statistically significant associations between all factors and the severity of pneumothorax.

In lesion factors (Table 2), there were statistically significant associations between all factors and the severity of pneumothorax (lesion size, location and pleural contact; p-value < 0.05). Smaller size, lower location and non-pleural contact lesion presented a higher severity of pneumothorax.

In procedure factors (Table 3), there were statistically significant associations between number of pleural punctures, length of needle passes in the aerated lung and number of harvesting samples and the severity of pneumothorax (p-value < 0.05). Position, needle type, needle size, and pleural angle had no statistically significant associations with severity. The an increased number of pleural punctures, longer length of needle passes in the

aerated lung and increased number of harvesting samples presented a higher severity of pneumothorax.

Multivariate analysis of factors for the severity of pneumothorax

Table 4 shows a summary of the results.

Multiple regression analysis among statistical significant factors derived from univariate analysis showed that the factors of location, pleural contact, number of pleural punctures and number of harvesting samples had statistically significant association with the severity of pneumothorax (p-values < 0.05). Lesion size and length of needle passes in the aerated lung had no statistically significant associations with severity.

Other complications

Mild or moderate pulmonary hemorrhage on post biopsy CT or mild hemoptysis was seen in 41 procedures (45%) and mild hemothorax in 1 procedure (1%). All of these patients remained homodynamically stable and they were resolved conservatively. Fatal complications such as air embolism were not seen.

Diagnostic Yield and Accuracy of CT-guided biopsy

Ninety of 91 biopsy procedures (99%) yielded sufficient materials for cytological and/or histological analysis. One procedure contained only skeletal muscle tissues and was inadequate for diagnosis. The final diagnosis of 89 lung lesions, except for 2 lung lesions where sufficient material was not obtained and lost to follow up, was established as malignant in 65 (73 %) and benign in 24 (27%). Diagnostic sensitivity, specificity, and accuracy were 94% (65/69 procedures), 100% (20/20 procedures) and 96% (85/89 procedures), respectively.

DISCUSSION

In our study, the rate of pneumothorax was 43%, and that of requiring chest tube placement was 3%. There were no patients with severe hemorrhage. Diagnostic yield and accuracy were 99% and 96%, respectively. The results were acceptable compared to many reports[2-6, 8-11, 13-15]. Hence, our method of CT-guided lung biopsy is considered to be feasible.

Four factors, of location and pleural contact in lesion factors and number of pleural punctures and number of harvesting samples in procedure factors, were associated with the severity of pneumothorax by multiple regression analysis in our study.

Firstly, lower location as a risk factor is supported by the report of Saji, H. et al[10] that chest tube placement was required significantly. In our study, length of needle passes in the aerated lung in a lower location (mean length: 20.8 mm) was slightly longer than those in upper (mean length: 15.3 mm) and middle locations (mean length: 12.2 mm). Lung parenchyma might be more greatly damaged by needle passes in a lower location. In addition, the lower lung parenchyma moves more up and down to a greater degree. Needle motion during respiration could potentially widen the pleural puncture site and damage the lung parenchyma in the lower location.

Secondly, non-pleural contact lesion was a risk factor. The rates of pneumothorax in pleural contact and non-contact lesions were 30% and 67%, respectively. We consider that some pleural contact lesions seem to adhere to the pleura directly. The length of needle passes in the aerated lung in pleural contact lesions (mean: 9.6 mm) was apparently shorter than those in non-contact lesions (mean: 25.3 mm). Furthermore, 43% (25/58 procedures) of non-pleural contact lesions were biopsied without traversal of aerated lung. These are considered to lead to less damage to adjacent lung parenchyma. Cox, J.E. et al[2] reported that pleural-based lesions in which biopsy was performed without traversal of aerated lung, the pneumothorax rate was 15%. On the other hand, if any amount of aerated lung was traversed, it was 50%.

Table 4. Multivariate Analysis of Factors derived from Univariate Analysis

Factors	p value
Size	0.33
Location	0.019*
Pleural contact	0.035*
Number of pleural puncture	0.017*
Length of needle passes in the aerated lung	0.43
Number of harvesting samples	0.042*

Note – Data analysis is multiple regression analysis.
*There are statistically significant associations with the severity of pneumothorax (p value < 0.05).

Heck, S.L. et al[6] reported that the risk of severe pneumothorax was significantly higher if the lesion was completely surrounded by aerated lung (17% vs. 2%).

Lastly, increased numbers of pleural puncture and harvesting samples were risk factors. Mean numbers of pleural puncture and harvesting samples were 1.48 times and 1.40 times in all procedures. We withdrew the needle from the pleura in order to adjust its position in a very limited number of cases. We consider that the mechanisms as risk factors of these are almost equal. An increased number of pleural puncture sites clearly leads to greater lung parenchymal damage. When the visceral and parietal pleurae are no longer in contact, it is often difficult to pierce the visceral pleura with the biopsy needle[1]. In order to pierce the visceral pleura, a relatively swift needle puncture is needed. We performed additional pleural punctures (one time: 9 procedures, two times: 3 procedures and 3 times: 2 procedures) in 14 procedures under the presence of iatrogenic pneumothorax at the puncture site. The results of the severity of pneumothorax were "mild" in 7 procedures (50%) and "moderate" or "severe" in 7 procedures (50%). The rate of "moderate" and "severe" was higher than those of all pneumothoraces (15/39 procedures: 39%). We speculate that puncture of the visceral pleura induces enlarging of the pleural space with negative pressure and that air is drawn into the space. Saji, H. et al[10] proposed that the number of pleural puncture attempts should never exceed three.

The limitations of our study are its non-uniform method and its non-prospective native. Two different needle types were used for core and aspiration biopsy. There was a free choice of needle size ranging from 21 to 18-gauge, however, 20-gauge was most commonly used. Some reporters positively perform air aspiration for immediate, moderate or severe pneumothorax to avoid worsening pneumothorax[4, 12-15]. In our study, all three "severe" pneumothoraces on post biopsy CT led to immediate air aspiration and chest tube placement was not required. The criteria of Yamagami, T. et al[12, 13] for aspiration was involving more than seven slices with a width of 10 mm on postbiopsy CT. This almost corresponds to the "moderate" and "severe" grades in our definition. We consider that performing air aspiration for those grades of pneumothorax is desirable. In our study, all three cases that required chest tube placement either corresponded to delayed large pneumothoraces (1 procedure) or to enlarging pneumothoraces (2 procedures). Although we performed chest tube placement without late aspiration, aspiration may be useful for such pneumothoraces. Kazerooni, E.A. et al[7] reported that although pulmonary function test findings showed no correlation with the absolute frequency of pneumothorax, severity

of obstructive pulmonary disease indicated by a reduced percentage of predicted forced expiratory volume in 1 second can be useful for identifying the patient population at high risk for requiring chest tube placement. However a pulmonary function test was not included in our protocol. Eventually, prospective trials by a uniform method, including biopsy technique and management for pneumothorax, will be desirable.

In conclusion, lower location, pleural contact, number of pleural punctures and number of harvesting samples were the predominant risk factors for the severity of pneumothorax after CT-guided percutaneous lung biopsy using the single-needle method. We consider that pleural punctures and number of harvesting samples should be kept to a minimum, in particular, for non-pleural contact lesions in a lower location, in order to avoid a higher severity of pneumothorax.

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