Original Article

Proposal for a computed tomography score to predict major complications requiring hospitalization after percutaneous lung biopsy: a single-center retrospective study

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Background: Image-guided percutaneous lung biopsy (PLB) may lead to major complications requiring hospitalization. This study aims to evaluate the rate of major PLB complications and determine a predictive computed tomography (CT) score to define patients requiring hospitalization due to these complications.

Methods: This single-center retrospective study included all PLBs performed from July 2019 to December 2020 in Nimes University Hospital, France. Patients who were undergoing thermo-ablation during the same procedure or for whom PLB procedure data were not available were excluded. All major complications leading to hospitalization were recorded. A Percutaneous Image-guided Lung biopsy In/out Patient score (PILIP) based on variables significantly associated with major complications was calculated by multivariate analysis.

Results: A total of 240 consecutive patients (160 men, 80 women; mean age: 67.3±10.5 years) were included. The major complication rate was 10.4%. Length of lung parenchyma traversed <20 *vs.* 20–40 mm [P=0.017, odds ratio (OR) =5.02; 95% confidence interval (CI): 1.33–18.92] and *vs.* >40 mm (P=0.010, OR =6.15; 95% CI: 1.54–24.53), middle *vs.* superior lobar location (P=0.011, OR =6.34; 95% CI: 1.53–26.31), emphysema along the needle pathway (P<0.0001, OR =10.96; 95% CI: 3.61–33.28), and pleural/scissural attraction (P=0.023, OR =3.50; 95% CI: 1.19–10.32) were independently associated with major complications. Based on these parameters, the PILIP made it possible to differentiate low-risk patients (PILIP <4) from those at high risk (PILIP ≥4) of major complications with 0.40 sensitivity (95% CI: 0.21–0.59), 0.95 specificity (95% CI: 0.93–0.98), a positive predictive value of 0.50 (95% CI: 0.28–0.72) and a negative predictive value of 0.93 (95% CI: 0.90–0.97).

Conclusions: PLB showed a major complication rate of 10.4%. The PILIP is an easy-to-use CT score for differentiating patients at a low or high risk of complications requiring hospitalization.

Keywords: Computed tomography (CT); predictive score; percutaneous lung biopsy (PLB); interventional radiology

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Introduction

Lung cancer is the second most common cancer in men and the third in women (1,2). An increasing number of lung lesions are detected with the development of new imaging technologies, especially spiral computed tomography (CT) (3). Histological diagnosis is often required to determine the most appropriate patient management (3). It is obtained by bronchoscopic biopsy, imaging-guided percutaneous lung biopsy (PLB) or surgical biopsy. Bronchoscopic biopsies are the first line indication for lesions located near the central airways (4). PLBs are recommended for hilar lesions with negative bronchoscopic biopsies, new or enlarging unique pulmonary lesions, mediastinal lesions, multiple nodules without known neoplasia, for cases of focal parenchymal infiltrates without any identified infectious organisms (5) or in the event of persistent consolidation (6). Lastly, surgical biopsies are indicated when the pulmonary lesions are not accessible with a percutaneous approach, but are rarely performed due to their invasiveness and high costs (7).

PLB is often performed and is a widely-accepted procedure as it is highly accurate, minimally-invasive, and has an important impact on patient management (8). It can be performed by core needle biopsy, providing histological material with a high diagnostic performance allowing molecular analyses with a strong impact, both on prognosis and therapeutics (9-12).

PLB is usually performed under CT-, cone beam CT (CBCT)- or ultrasound (US)-guidance, depending on the size and location of the lesions (5,13,14). It has long been performed in association with conventional hospitalization but, as inpatient beds are rare and expensive, daycare PLB has now been developed (15). However, complication rates with percutaneous core needle lung biopsies are relatively high, including common minor complications (pneumothorax without the need for pleural drainage, pulmonary hemorrhage around the target, and transient hemoptysis) and less common major complications requiring hospitalization (pneumothorax requiring pleural drainage, hemoptysis requiring arterial embolization, endobronchial procedures, oxygen therapy or placement of an endotracheal tube) (5,16,17).

Complication rates after PLB vary widely in the literature. This may be explained by the greater sensitivity of CT in detecting complications which may have been overlooked on the chest X-ray (7,18). However, a recent meta-analysis of 23,104 patients reported a 25.9% (range, 4.3–52.4%) incidence of pneumothorax and a 6.9% (range, 0–15%) incidence of chest drain insertion (19).

Major complications have an impact on patient management, as they inevitably lead to interventions requiring hospitalization. Even though the risk of major complications is relatively common, we cannot afford to hospitalize all patients, especially considering that the majority of them will not need it. Indeed, PLB can be performed on an outpatients basis with an acceptable rate of secondary hospitalizations (8,20,21). The risk factors for complications after PLB have already been demonstrated according to the characteristics of the patient, lesions or procedure, such as the presence of emphysema, a smaller and deeper target and the angle of trajectory to the pleura (19,20,22-31). However, the criteria for defining in- or outpatient populations according to the risk of them developing major complications remain unclear.

The purpose of this study was to evaluate the major complication rate of CT- or CBCT-guided PLB, identify risk factors for these complications and determinate a predictive CT score to define in- and outpatient populations. We propose to name this score PILIP (Percutaneous Image-guided Lung biopsy In/out Patient), which can be used to distinguish high-risk patients requiring hospitalization from outpatient cases. We present this article in accordance with the STARD reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-500/rc).

Methods

Study design and patients

This single-center retrospective study included all consecutive patients undergoing a CT-scan or CBCT-guided PLB from July 2019 to December 2020 in Nimes University Hospital, France. Patients who were undergoing thermo-ablation during the same procedure or for whom PLB procedure data were not available were excluded. The

study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Local Institutional Review Board (n°: 23.03.04). Requirement for a written informed consent to participate in the study was waived due to the retrospective nature of the study.

Biopsy procedure and radiographic chest follow-up

Biological parameters, including prothrombin level, activated cephalin time (ACT) and platelet count were assessed before biopsy, which was only performed if the prothrombin level was over 50%, ACT under 1.5 N and platelet count over 50,000/mm^3. It was performed under anesthetic sedation or local anesthesia by one of the Institute's ten interventional radiologists with experience varying from 3 to 20 years.

A planning CT or CBCT imaging was performed. The appropriate needle trajectory was left to the operator's discretion. Helicoidal acquisitions were used for guidance. Trans-thoracic lung biopsy was performed using an 18-gauge core needle with a 17-gauge co-axial (CorVocet ™ biopsy system, MeritMedical) for all patients. The biopsy length was 10 to 20 mm and the number of samplings was left to the operator's discretion. Sterile absorbable gelatin sponge (Curaspon®, Cura Medical) tract embolization was used in some patients and recorded.

A control CBCT or CT-scan was performed at the end of the procedure to check for early complications, then a chest radiograph at one hour, which could be repeated to assess the evolution of undrainable pneumothorax.

Potential risk factors for complications

Potential risk factors evaluated were, on the one hand, patient-related and, on the other, procedure-related and lesion-related as defined on the pre-operative CT. These risk factors included age, sex, body mass index (BMI), medical history of radiotherapy, thoracic surgery, chronic respiratory insufficiency (defined as a PaO_2 <70 mmHg), tobacco exposure (active or passive, smoking pack-year, weaned, no exposure), treatments (anti-platelet drugs and anticoagulants) and emphysema (subjectively quantified according to the Fleischner Society classification) (32), patient's position (prone, supine, left and right lateral decubitus), length of lung parenchyma traversed (from pleural to nodule), presence of emphysema along the needle pathway, number and length of the biopsy samples, needle track embolization and type of imaging-guidance (CT-scan or CBCT). Last, they included the lesion size (mm), composition (solid, ground glass, mixed, excavated), its lobar localization (right upper lobe, RUL; middle lobe, ML; right lower lobe, RLL; left upper lobe including apico-posterior and anterior segments, LUL; lingula, L; left lower lobe, LLL), pleural contact and the presence of spicules with pleural connection (defined as spiculated nodules inducing pleural attraction).

Biopsy-related complications

Only major complications with an impact on patient management and care, i.e., those requiring hospitalization for out-patients or justifying a prolonged hospitalization for in-patient, were recorded in this study (Society of Interventional Radiology, SIR, classification C and D) (33). Pneumothorax was collected if it required a chest tube placement (complete pneumothorax with thickness >2 cm or expansive pneumothorax, dyspnea, oxygen desaturation or chest pain), pulmonary hemorrhage if it required an arterial embolization, endobronchial procedure, oxygen therapy or intubation. Air embolism, hemothorax and death were also recorded. The data regarding major complications were obtained through extraction from the medical records.

Statistical analysis

Qualitative variables are presented as numbers and percentages, and compared using the Chi^2 or Fisher's exact test. Quantitative variables are presented with means and standard deviations and medians and interquartile ranges, and compared using the Student or Wilcoxon-Mann-Whitney test. The variables with a P value <0.20 in univariate analysis were included in the multivariate logistics regression model with a stepwise forward selection. To limit data overfitting, a model with the minimum Akaiké criterion was selected. The area under the curve (AUC) of the model as well as the odds ratios (ORs) and their 95% confidence intervals (95% CI) are presented. Internal validation was performed by the Bootstrap method on the final model and the optimism and area under the corrected curve are presented. The score from the final selected model is presented as well as the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the different thresholds. All test realized were two-sided test.

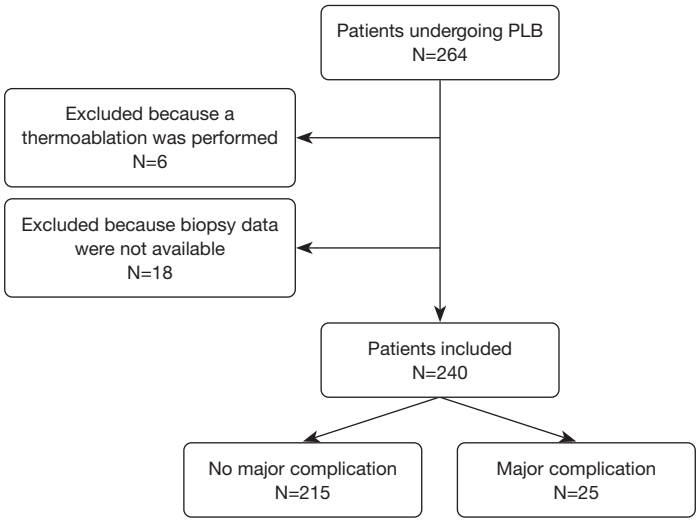

Figure 1 Flow chart of patient inclusion. PLB, percutaneous lung biopsy.

Results

Patient characteristics

From July 2019 to December 2020, 264 patients underwent a PLB. Among them, 24 patients were excluded, 6 because they were undergoing a thermoablation technique during the same procedure and 18 for whom the biopsy data were unavailable (*Figure 1*).

Among these 240 patients there were 160 men (66.7%) and 80 women (33.3%), mean age 67.3±10.5 (SD) years and mean BMI 25.1±5.5 (SD) kg/m^2 (*Table 1*).

Lung biopsy procedure

Among the 240 patients, 100 had biopsies performed under CBCT-guidance (41.7%) and 140 under CT-guidance (58.3%) (*Table 1*). The mean number of biopsy samples collected was 1.8±0.6 (SD) and the mean length of biopsy sample was 13.2±2.4 (SD) mm. The length of lung parenchyma traversed was <20 mm for 116 patients (48.3%), 20 to 40 mm for 74 patients (30.8%) and >40 mm for 50 patients (20.8%). Emphysema along the needle pathway was reported in 31 patients (12.9%). Forty-one patients (17.1%) had needle track embolization.

PLB major complications

There were 25 major complications (10.4%) (*Table 1*). There were no deaths or gas embolism.

Complications reported were 23 pneumothorax requiring chest tube placement (9.6%) and 2 were hemoptysis (0.8%) (1 requiring oxygen therapy, the other intubation).

Predictive factors of major complications after lung biopsy

The univariate analysis showed a correlation between the occurrence of major complications and a lower BMI (P=0.02), a higher COPD (chronic obstructive pulmonary disease) stage (P<0.01), confluent centrilobular emphysema (P=0.01), presence of emphysema along the needle pathway (P<0.01), long distance of lung parenchyma traversed (P<0.01), a position other than prone position (P<0.01), a lesion located in the middle lobe (P=0.02), presence of a spiculated lesion with pleural or scissural attraction (P=0.03) (*Table 2*).

In the multivariate analysis, the following parameters were found to be independent predictive factors of the occurrence of major complications: a length of lung parenchyma traversed of 20–40 *vs.* <20 mm (P=0.017, OR =5.02; 95% CI: 1.33–18.92), a length of lung parenchyma traversed >40 *vs.* <20 mm (P=0.010, OR =6.15; 95% CI: 1.54–24.53), middle *versus* superior lobar location (P=0.011, OR =6.34; 95% CI: 1.53–26.31), presence of emphysema along the needle pathway (P<0.0001, OR =10.96; 95% CI: 3.61–33.28) and a pleural or scissural attraction (P=0.023, OR =3.50; 95% CI: 1.19–10.32) (*Table 3*).

A score to predict major complications

From the multivariable analysis results, we created an

Table 1 Patient characteristics

Characteristics	Total cohort (N=240)
Demographic and patient history	
Age (years)	67.3±10.5 [26.0–87.0]
Sex (female/male)	80 (33.3)/160 (66.7)
BMI (kg/m^2)	25.1±5.5 [14.0–47.0]
Underweight	27 (11.2)
Normal weight	98 (40.8)
Overweight	66 (27.5)
Obesity	49 (20.4)
Tobacco exposure (population)	188
Active smoking	73 (38.8)
Passive smoking	3 (1.6)
Weaned smoker	112 (59.6)
Number of packages year	39.6±30.3 [0.0–135.0]
Proven COPD	78 (32.5)
Stage 1	18 (7.5)
Stage 2	41 (17.1)
Stage 3	17 (7.1)
Stage 4	2 (0.8)
Proven chronic respiratory insufficiency	44 (20.1)
Emphysema	153 (63.7)
Trace CLE (<0.5%)	34 (14.2)
Mild CLE (0.5–5%)	33 (13.7)
Moderate CLE (>5%)	52 (21.7)
Confluent CLE	21 (8.7)
Advanced destructive emphysema	4 (1.7)
Mild paraseptal emphysema (≤1 cm)	97 (40.4)
Substantial paraseptal emphysema (>1 cm)	36 (15.0)
History of radiotherapy	18 (7.5)
History of thoracic surgery	22 (9.2)
Anticoagulant treatment	46 (19.2)
Anti-platelet treatment	87 (36.3)
Lesion characteristics	
Size (mm)	28.9±20.1 [0.0–20.0]
Pleural or scissural contact	133 (55.4)
Pleural or scissural attraction	48 (20.0)
Lesion composition	
Solid	124 (51.6)
Ground glass	45 (18.7)
Mixed (solid + ground glass)	46 (19.2)
Excavated	25 (10.4)
Lesion lobar location	
Superior	142 (59.2)
Middle	23 (9.6)
Lower	75 (31.2)
Lung biopsy procedure	
Length of biopsy sample (mm)	13.2±2.4 [7.0–34.0]
Number of biopsy samples	1.8±0.6 [0.0–4.0]
Length of lung parenchyma traversed (mm)	25.4±22.4 [0.0–106.0]
<20	116 (48.3)
20 to 40	74 (30.8)
>40	50 (20.8)
Type of imaging-guidance	
CBCT	100 (41.7)
CT-scan	140 (58.3)
Patient's position	
Supine	113 (47.1)
Prone	117 (48.7)
RLD	5 (2.1)
LLD	5 (2.1)
Emphysema along the needle pathway	31 (12.9)
Needle track embolization	41 (17.1)
Histological results	
Benign	36 (15.0)
Malignant	183 (76.2)
Inconclusive	21 (8.7)
Complications	
Major complication	25 (10.4)
Pneumothorax	23 (9.6)
Hemoptysis	2 (0.8)
No major complications	215 (89.5)

Data are presented as mean ± SD [range] or n (%). SD, standard deviation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CLE, centrilobular emphysema; CBCT, cone beam computed tomography; CT, computed tomography; RLD, right lateral decubitus; LLD, left lateral decubitus.

Table 2 Univariate analysis of the risk factors for complication

Variables	Complications		P values
	No (N=215)	Yes (N=25)	
Patient-related variables			
Age (years) [range]	67.1 (±10.6) [61–75]	68.7 (±9.4)	0.64
Sex			
Female	71 (33.0)	9 (36.0)	0.77
Male	144 (67.0)	16 (64.0)	
BMI (kg/m^2)	25.31 (±5.5)	22.84 (±5.1)	0.02
Tobacco exposure	169 (78.6)	19 (76.0)	>0.99
Active smoking	63 (37.3)	10 (52.6)	0.11
Passive smoking	2 (1.2)	1 (5.3)	
Weaned smoker	104 (61.5)	8 (42.1)	
Chronic respiratory insufficiency	37 (18.9)	7 (30.4)	0.27
COPD			
Stage I	15 (10.1)	3 (18.8)	<0.01
Stage II	40 (27.0)	1 (6.3)	
Stage III	12 (8.1)	5 (31.3)	
Stage IV	1 (0.7)	1 (6.3)	
Emphysema	133 (63.0)	20 (80.0)	0.09
Trace CLE (<0.5%)	32 (15.2)	2 (8.0)	0.55
Mild CLE (0.5-5%)	31 (14.7)	2 (8.0)	0.54
Moderate CLE (>5%)	44 (20.9)	8 (32.0)	0.20
Confluent CLE	15 (7.1)	6 (24.0)	0.01
Advanced destructive emphysema	3 (1.4)	1 (4.0)	0.36
Mild paraseptal emphysema (≤1 cm)	86 (40.8)	11 (44.0)	0.76
Substantial paraseptal emphysema (>1 cm)	31 (14.7)	5 (20.0)	0.55
History of radiotherapy	16 (7.5)	2 (8.0)	>0.99
History of thoracic surgery	21 (9.8)	1 (4.0)	0.48
Anticoagulant treatment	41 (19.1)	5 (20.0)	>0.99
Anti-platelet treatment	76 (35.4)	11 (44.0)	0.39
Procedure-related variables			
Emphysema along the needle pathway	19 (9.1)	12 (48.0)	<0.01
Length of lung parenchyma traversed (mm)	24.0 (±22.5)	37.4 (±17.7)	<0.01
Patient's position			
Supine	97 (45.3)	16 (64.0)	0.08
Prone	112 (52.3)	5 (20.0)	<0.01
RLD	3 (1.4)	2 (8.0)	0.16
LLD	4 (1.9)	1 (4.0)	0.43

Table 2 *(continued)*

Table 2 *(continued)*

Variables	Complications		P values
	No (N=215)	Yes (N=25)	
Length of the biopsy sample (mm)	13.09 (±2.3)	14.0 (±2.8)	0.19
Number of biopsy samples	1.86 (±0.6)	1.7 (±0.6)	0.27
Needle track embolization	39 (18.1)	2 (8.0)	0.27
Type of imaging-guidance			
CBCT	88 (40.9)	12 (48.0)	0.50
CT-scan	127 (59.1)	13 (52.0)	
Lesion-related variables			
Lesion lobar location			
Upper	129 (60.3)	13 (52.0)	0.42
Middle	17 (7.9)	6 (24.0)	0.02
Lower	69 (32.2)	6 (24.0)	0.40
Pleural or scissural attraction	39 (18.1)	9 (36.0)	0.03
Pleural or scissural contact	120 (56.1)	13 (52.0)	0.70
Size (mm)	29.2 (±20.6)	26.4 (±15.4)	0.69
Lesion composition			
Solid	108 (50.2)	16 (64.0)	0.36
Ground glass	42 (19.5)	3 (12.0)	0.59
Mixed (solid + ground glass)	42 (19.5)	4 (16.0)	0.58
Excavated	23 (10.7)	2 (8.0)	>0.99

Data are presented as mean (± SD) or n (%) unless otherwise stated. BMI, body mass index; COPD, chronic obstructive pulmonary disease; CLE, centrilobular emphysema; RLD, right lateral decubitus; LLD, left lateral decubitus; CBCT, cone beam computed tomography; CT, computed tomography.

Table 3 Multivariate analysis of the risk factors for complication

Variables*	Odds ratio	95% CI	P values
Length of lung parenchyma traversed (20–40 *vs*. <20 mm)	5.02	1.33–18.92	0.017
Length traversed lung parenchyma (40 *vs*. <20 mm)	6.15	1.54–24.53	0.010
Lobar location: lower *vs*. superior	1.87	0.56–6.30	0.312
Lobar location: middle *vs*. superior	6.34	1.53–26.31	0.011
Pleural or scissural attraction	3.50	1.19–10.32	0.023
Emphysema along the needle pathway	10.96	3.61–33.28	<0.0001
BMI°	0.92	0.82–1.02	0.1225
RLD position *vs*. supine position°	7.50	0.46–122.5	0.0922
LLD position *vs*. supine position°	0.48	0.02–13.27	0.4901
Prone position *vs*. supine position°	3.05	0.12–2.01	0.1639
Confluent CLE	1.39	0.31–6.25	0.6681

*, COPD stage could not be integrated because of too much missing data; °, not selected through Akaiké criterion in the final score. CI, confidence interval; BMI, body mass index; RLD, right lateral decubitus; LLD, left lateral decubitus; CLE, centrilobular emphysema; COPD, chronic obstructive pulmonary disease.

Table 4 PILIP risk score to predict major complications

Variables	Score
Length of lung parenchyma traversed (mm)	
<20	0
20–40	1
>40	2
Lobar location	
Lower lobe	0
Superior lobe	0
Middle lobe	2
Pleural or scissural attraction	
None	0
Presence of pleural or scissural attraction	1
Emphysema along the needle pathway	
None	0
Presence of emphysema along the needle pathway	2
Total	0–7

PILIP, Percutaneous Image-guided Lung biopsy In/out Patient.

easy-to-use risk score, the Percutaneous Image-guided Lung biopsy In/out Patient (PILIP) score, ranging from 0 to 7, to predict the occurrence of major complications and distinguish patients at high or low risk of major complications (*Table 4*).

The PILIP score characteristics depending on the chosen cut-off and its ROC curve are presented in *Table 5* and *Figure 2*. The number of patients with and without major complications is shown in *Table 6* for each PILIP score.

With a threshold of 4, the PILIP score showed a sensitivity of 0.40 (0.21–0.59), a specificity of 0.95 (0.93–0.98), a positive predictive value of 0.5 (0.28–0.72) and a negative predictive value of 0.93 (0.90–0.97), with a Youden index of 0.35.

Discussion

The results of the present study reported a 10.4% rate of major complications after CT- or CBCT-guided PLB in 240 patients. Major complications included pneumothorax requiring chest tube placement (9.6%) and hemoptysis requiring oxygen therapy or intubation (0.8%). Predictive factors of the occurrence of major complications were identified, including the length of lung parenchyma traversed, the location of the lesion, pleural or scissural attraction and the presence of emphysema along the needle pathway. From the results of the multivariate analysis, to optimize patient management, we propose the PILIP score, an easy-to-use CT score ranging from 0 to 7, to distinguish those patients at a high risk of major complications from those at a low risk of complications.

A comprehensive systematic review and meta-analysis of pneumothorax rates and risk factors of CT-guided PLB showed an incidence of pneumothorax requiring chest tube of 6.9% (range, 0–15%) (19). The Society of Interventional Radiology (SIR) and the American College of Radiology (ACR) published an estimated rate of hemoptysis requiring hospitalization or specific therapy of 0.5% (34). Although rates may vary in the literature, the results reported here are concordant with the major complication rates published in previous major studies.

In the multivariate analysis, we identified risk factors independently correlated with major complications of PLB including the presence of emphysema along the needle pathway, a longer length of traversed lung parenchyma (20–40, >40 mm), the presence of pleural attraction induced by spiculated nodule, and a lesion located in the middle lobe. These results are concordant with risk factors for pneumothorax after PLB identified in previous studies requiring chest drain insertion: fissure or bulla crossed, emphysema, lesions without pleural contact, deep lesions, patient positioning with puncture site up (*vs.* site down biopsy via aperture in CT Gantry table), history of smoking, and no history of ipsilateral surgery (19,20,22-27).

Additional factors have been shown to be predictive of pneumothorax including the patient's age, prone or supine patient positioning (*vs.* lateral decubitus position with biopsied lung-down), lateral decubitus position with biopsied lung up (*vs.* prone or supine), multiple non-coaxial tissue samples, COPD and interactive breath-holding (19,27,35,36). In this study, a small lesion, a high COPD grade and presence of an underlying emphysema were not found to be significant predictive factors of major complications in the multivariable analysis. Also, a higher risk of major complications was not found in patients with excavated or ground-glass lesions. This may be due to a lack of power. Regarding COPD stages, these were determined according to the results of a pulmonary function test and considered missing data in case of unavailability of the test in 162/240 patients. If the data had been available, most of these patients probably did not have severe COPD, thus introducing a bias in the analysis. The number of patients

Table 5 PILIP score characteristics for various cut-offs

Cut-off	Sensitivity [95% CI]	Specificity [95% CI]	PPV [95% CI]	NPV [95% CI]	Youden index
6	0.04 [0.0–0.12]	1 [1–1]	1 [1–1]	0.90 [0.86–0.94]	0.04
5	0.12 [0.0–0.25]	1 [1–1]	1 [1–1]	0.91 [0.87–0.94]	0.12
4	0.40 [0.21–0.59]	0.95 [0.93–0.98]	0.5 [0.28–0.72]	0.93 [0.90–0.97]	0.35
3	0.68 [0.50–0.86]	0.86 [0.81–0.91]	0.36 [0.22–0.50]	0.96 [0.93–0.99]	0.54
2	0.80 [0.64–0.96]	0.67 [0.61–0.73]	0.22 [0.13–0.30]	0.97 [0.94–1]	0.47
1	0.92 [0.81–1.0]	0.36 [0.30–0.43]	0.14 [0.09–0.20]	0.98 [0.94–1]	0.28

PILIP, Percutaneous Image-guided Lung biopsy In/out Patient; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value.

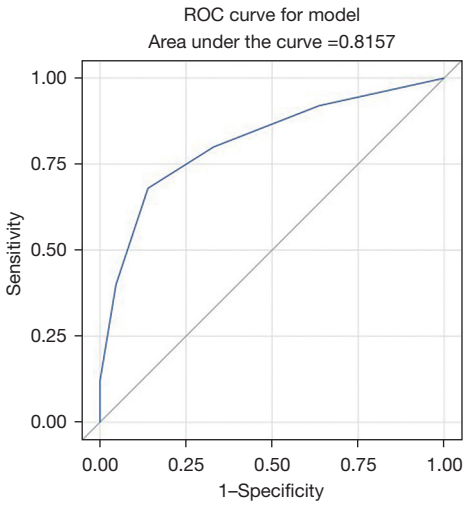

Figure 2 ROC curve of the PILIP score with a threshold of 4. ROC, receiver operating characteristic; PILIP, Percutaneous Image-guided Lung biopsy In/out Patient.

Table 6 Patients' complications for each PILIP score

PILIP score	Patients without major complication, n (%)	Patients with major complication, n (%)	Total, n (%)
0	78 (36.3)	2 (8.0)	80 (33.3)
1	66 (30.7)	3 (12.0)	69 (28.8)
2	41 (19.1)	3 (12.0)	44 (18.3)
3	20 (9.3)	7 (28.0)	27 (11.3)
4	10 (4.7)	7 (28.0)	17 (7.1)
5	0 (0.0)	2 (8.0)	2 (0.8)
6	0 (0.0)	1 (4.0)	1 (0.4)
7	0 (0.0)	0 (0.0)	0 (0.0)
Total	215 (100.0)	25 (100.0)	240 (100.0)

PILIP, Percutaneous Image-guided Lung biopsy In/out Patient.

with no complications and without COPD may have been underestimated, which may explain the absence of a correlation between severe COPD and major complications.

Various techniques such as rapid roll-over with biopsied site down, tract embolization technique using gelatin sponge slurry or haemocoagulase injection, tract plug, and the use of normal saline for sealing the needle track, have been shown to reduce catheter placement drainage due to pneumothorax (37-41). Track embolization of the needle pathway was not a significantly protective factor against major complications, as previously shown (42). It may be due to a lack of power of our study as only 41 patients received needle track embolization.

Longer needle path, lesions without pleural contact, smaller lesions, older age, emphysema, pulmonary hypertension, ground-glass lesions, coaxial technique, sub solid nodules and female sex have been reported as risk factors for high grade pulmonary hemorrhage (5,43-46). We only had two major cases of hemoptysis so we were unable to explore those risk factors.

To the best of our knowledge, in previous studies, the presence of pleural attraction induced by spiculated nodules has never been analyzed as a potential risk factor for major complications. This factor was independently associated with major complications in our study. It may be explained by a mechanical physiopathology: spicules attracting the pleura may promote its detachment in case of pneumothorax, thus increasing the size of the pneumothorax and its necessity to be drained.

The proposed PILIP score is an easy-to-use score based on the preoperative CT scan. The discriminating characteristics of the score are acceptable with a threshold of 4 with a 95% specificity which means that very few serious complications are missed, allowing outpatient management. Applying the PILIP score during the pre-

procedure consultation could help physicians to better select those patients to be hospitalized and thus optimize their workflow. The PILIP score now needs to be evaluated through a multi-center prospective study to confirm these encouraging results.

This study has certain limitations, mainly due to its retrospective and monocentric design, the number of patients included (n=240), the low number of major complications recorded (n=25), and some missing data, thus inducing a lack of power. The low number of complications also resulted in relatively wide estimates. As a result, the weight of some score components could be over- or underestimated. Nevertheless, this does not impact the significant association observed between these factors. The collection of major complications through extraction from medical records may introduce a bias related to missing data, but any significant bias appears highly unlikely, as this type of complication is mandatory to be documented. The large number of interventional radiologists with varying levels of experience who performed the procedure may also have introduced a bias. Indeed, the rate of major complications in this study may have been higher than that previously published due to the lower experience of some operators, even if this theory is still debatable (11,19,44,47,48). Another bias may arise from the fact that we did not consider exsufflation pneumothorax as a major complication as it does not lead to a hospitalization. For this reason, pneumothorax cases treated solely by exsufflation were not included in the count, and their frequency was therefore not determined. Similarly, in-patients who experienced pneumothorax without the need for drainage were not recorded. However, the decision to drain or exsufflate a pneumothorax is not based on strict criteria and is left to the discretion of the operator, which may have caused a bias. Furthermore, our major complications predominantly consist of pneumothorax, which may limit the ability of our score to predict all major complications. However, given that pneumothorax is by far the most common complication, our score remains well-suited for routine clinical practice. Finally, it is worth noting that our scoring system remains potentially improvable.

Conclusions

These results showed a PLB-related major complication rate of 10.4%. Risk factors predictive of major complications were identified including the presence of emphysema along the needle pathway, a longer length of lung parenchyma traversed, the presence of pleural attraction induced by a spiculated nodule, and the lobar location of the lesion. From these factors, we propose the easy-to-use PILIP CT score ranging from 0 to 7 to differentiate those patients at a low risk of developing major complications (score <4) from high-risk patients (score ≥4). Using this score, the low-risk population may be reasonably managed on an outpatient basis, whereas the high-risk population should be scheduled for conventional hospitalization. Further studies are now required to evaluate this score with a multi-center, prospective design. A medico-economic study on the impact of using the PILIP score at institutional and national levels is currently under way.

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Footnote

Reporting Checklist: The authors have completed the STARD reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-500/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-500/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Local Institutional Review Board (n°: 23.03.04). Requirement for a written informed consent to participate in the study was waived due to the retrospective nature of the study.

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