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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Pleural tail sign in computed tomography-guided lung biopsy: an imaging predictor of severe pneumothorax requiring chest tube placement

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PURPOSE

Pneumothorax is the most common complication following computed tomography (CT)-guided percutaneous transthoracic needle biopsy. In severe cases, it may require chest tube placement, which is associated with increased morbidity. The aim of this study was to evaluate the prognostic value of the pleural tail sign (PTS) as an imaging marker for predicting pneumothorax incidence and severity after lung biopsy.

METHODS

A total of 477 patients (mean age 65 ± 11.7 years, 37.2% women) undergoing CT-guided lung biopsies between 2012 and 2021 were retrospectively analyzed in this study. The presence and morphological subtype of PTS-classified as thin PTS or triangular PTS-were assessed on pre-interventional CT imaging. Associations between PTS and pneumothorax outcomes were evaluated using univariate and multivariate binary logistic regression analyses.

RESULTS

No statistically significant association was found between the overall presence of PTS and the incidence of pneumothorax ($P = 0.052$). However, patients with a triangular PTS showed a significantly increased risk of severe pneumothorax requiring chest tube placement (odds ratio: 2.092, 95% confidence interval: 1.097–3.990, $P = 0.025$), whereas a thin PTS did not show a statistically significant effect ($P = 0.456$).

CONCLUSION

Although PTS does not reliably predict overall pneumothorax risk after CT-guided lung biopsy, its triangular subtype may serve as a prognostic imaging marker for identifying patients at increased risk of severe pneumothorax requiring chest tube placement.

CLINICAL SIGNIFICANCE

The identification of a triangular PTS on pre-interventional CT imaging may help to stratify patients at higher risk of severe pneumothorax following CT-guided lung biopsy. This could enable more informed procedural planning, potentially leading to improved patient outcomes.

KEYWORDS

CT, image-guided biopsy, lung biopsy, pleural tail sign, pneumothorax

Computed tomography (CT)-guided percutaneous transthoracic needle biopsy (PTNB) is a well-established and minimally invasive procedure for acquiring tissue samples for the histopathologic evaluation of pulmonary lesions.[1] This procedure is especially suitable for peripheral lung lesions that are challenging to access via bronchoscopy.[2] It offers high diagnostic reliability, with a sensitivity ranging from 85.7% to 97.4% and a specificity from 88.6% to 100%, for correct histology tissue sampling.[3]

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Despite its clinical value, PTNB is associated with various procedure-related complications, of which pneumothorax is the most frequent.[4] A recent meta-analysis reported an average pneumothorax rate of 25.9% following CT-guided lung needle biopsy, with a range between 4.3% and 52.4%.[5] Although many cases of pneumothorax are self-limiting, a subset of patients requires chest tube placement, which can lead to increased morbidity, prolonged hospital stays, and additional healthcare costs. The incidence of post procedural chest tube placements ranges from 2% to 15%.[6]

Various risk factors have been associated with an increased incidence of pneumothorax following CT-guided biopsies, including lesion depth, lesion size, the presence and severity of emphysema, the number of pleural punctures, and patient positioning, as well as lesion heterogeneity described by CT texture analysis.[7-10] Recent investigations have proposed the pleural tail sign (PTS) as a potential predictor of pneumothorax following PTNB.[11,12] The PTS is defined as a linear extension of a pulmonary lesion toward the visceral pleura and is histopathologically associated with interlobular septal thickening caused by tumor infiltration, fibrosis, or desmoplastic reaction.[13,14] It has been hypothesized that lesions with a PTS are more likely to exert traction on the pleural surface or form tethered points between the tumor and pleura.[11,12] During biopsy, this may increase susceptibility to pleural tears or air leakage due to mechanical distortion or reduced pleural compliance.

The aim of this study is to evaluate whether the PTS is associated with the overall risk of pneumothorax and, specifically, with the risk of severe pneumothorax requiring chest tube placement after PTNB. We hypothesized that the PTS represents a high-risk imaging biomarker for clinically significant post-biopsy pneumothorax.

Main points

- The presence of a pleural tail sign (PTS) is not significantly associated with the overall risk of pneumothorax after computed tomography-guided lung biopsy.
- The triangular PTS subtype is significantly associated with an increased risk of severe pneumothorax requiring chest tube placement, whereas the thin subtype is not.
- One in three patients exhibited a PTS (33.3%). Postinterventional pneumothorax occurred in 47.2% of cases, and 11.5% required chest tube placement.

Methods

Patient selection

This retrospective analysis was approved by the Ethics Committee of the University of Leipzig, Germany (register number: 344, approval date: 01.11.2007). A total of 487 patients who underwent CT-guided lung biopsies at our institution between January 2012 and November 2021 were screened for inclusion in the study. Of these, 10 patients were excluded, 8 because the intervention was stopped prior to lung puncture and 2 because of insufficient image quality. A total of 477 patients (37.2% women) with a mean age of 65 ± 11.7 years were included in the final analysis. A flowchart illustrating the patient screening and exclusion for the CT-guided lung biopsies is presented in Figure 1. All CT scans of patients who underwent CT-guided PTNB for pulmonary lesions were systematically reviewed to assess the presence or absence of a PTS. A PTS was defined as an extension from the lung lesion toward the visceral pleura. For cases in which a PTS was identified, further classification was performed based on morphological characteristics. Although various PTS classification systems have been described in the literature,[15-17] we adopted a simplified, clinically applicable two-tier model: a thin PTS, characterized by a linear tail without associated pleural retraction, and a triangular PTS, with pleural retraction at the attachment site. Image evaluation was performed by experienced radiologists with 4 years of general experience, blinded to the clinical outcomes. In addition, lesion size, lesion depth, the number of biopsy samples, and whether the biopsy tract passed through the PTS line were assessed. In a random selection of 30 patients, a senior radiologist with 10 years' experience in radiology and a board-certification in interventional radiology performed a second reading for interreader variability assessment of the PTS classification. Figure 2 provides representative images from the patient cohort.

Computed tomography-guided biopsy procedure

Written informed consent was obtained from all patients at least 1 day prior to CT-guided biopsy. Biopsies were only performed when there was no elevated risk of hemorrhage, as indicated by a platelet count of at least 50,000/mm^3, a partial thromboplastin time of ≤1.5 times the normal value, and a prothrombin time >50%.

Interventions were all performed using the same CT scanner (16-slice CT scanner, Brilliance Big Bore, Philips, Hamburg, Germany). Typical CT parameters were set as follows: 100 kVp; 125 mAs; slice thickness, 1 mm; pitch, 0.9).

Biopsies and chest tube placements, where necessary, were performed by radiologists with at least 2 years' experience in interventional radiology. The procedures, namely positioning and needle pathway, were planned using the latest available CT images. For the biopsies, a needle was inserted in the upper part of the ribs to minimize the risk of hematoma at an angle vertical to the parietal pleura, avoiding lung fissures and large bronchovascular structures, with the needle pathway minimized.

Prior to the biopsies, the skin was disinfected and local anesthesia (10 mL of lidocaine 1%; Xylocitin, Jenapharm, Jena, Germany) was applied. In all cases included in this study, a coaxial 18-gauge biopsy system with a 2-cm-long needle was used (Bard Mission, Bard Medical, Covington, GA, USA,

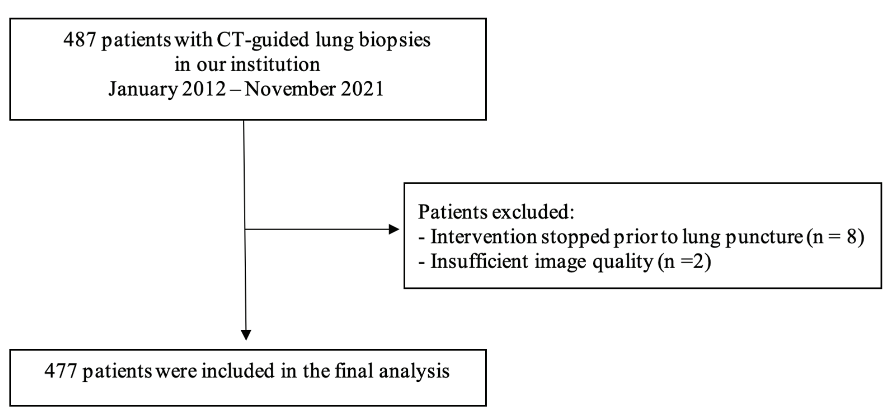


Figure 1. Flowchart illustrating the screening and exclusion criteria for patients undergoing computed tomography (CT)-guided lung biopsies between January 2012 and November 2021.

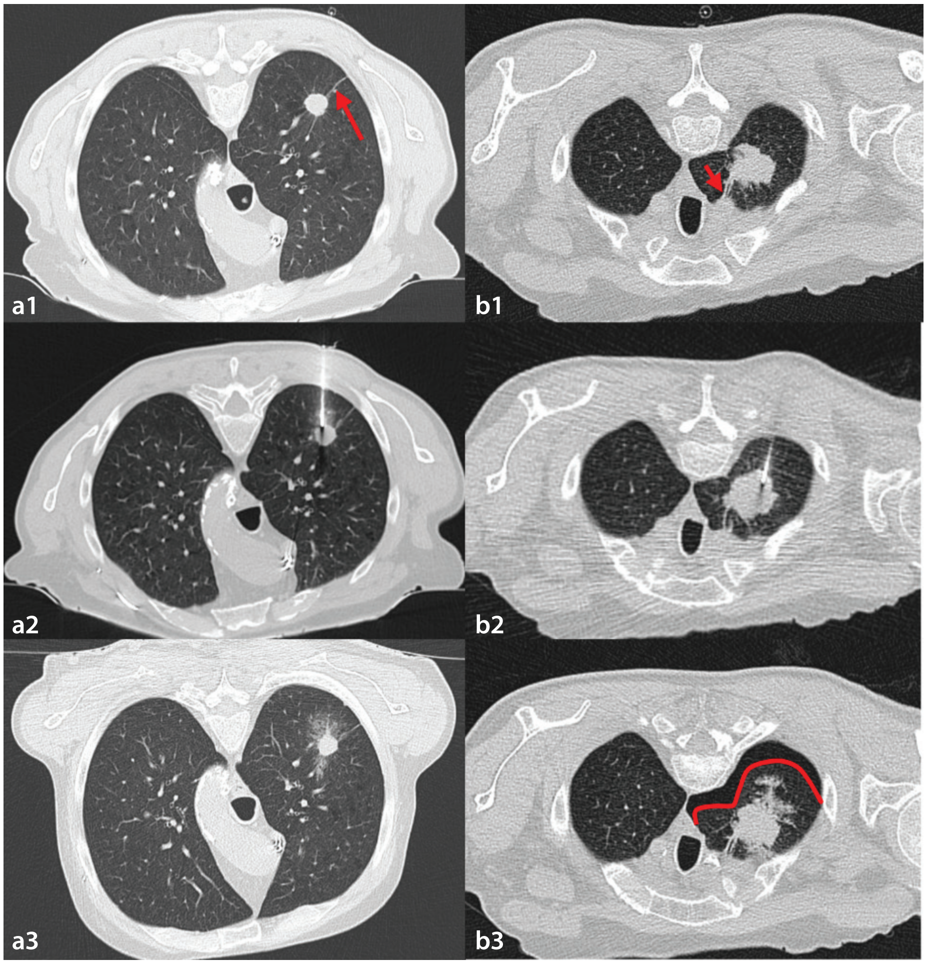


Figure 2. Representative computed tomography (CT) images of patients with pulmonary nodules and an associated thin or triangular pleural tail sign (PTS) undergoing CT-guided lung biopsy. On the left, a patient with primary lung cancer and a thin PTS without postinterventional pneumothorax **(a1-a3).** On the right, a patient with primary lung cancer and a triangular PTS with a severe postinterventional pneumothorax requiring chest tube placement **(b1-b3)**. The red arrows indicate the PTS. The red line demarcates the pneumothorax contour.

or Biopince, Argon Medical Devices, Athens, TX, USA). During the procedures, CT images were retrieved to validate accurate localization of the needle tip. After removal of the biopsy needle, CT images of the whole lung parenchyma were acquired to detect post-interventional complications. To minimize the occurrence of post-biopsy pneumothorax, patients were left to rest without eating or drinking for 2 hours after the procedure. In addition, a plain chest radiograph was obtained 2 hours after the biopsy to detect complications, particularly pneumothorax. Patients with pneumothorax on immediate post-biopsy CT images were labeled as "instant pneumothorax." Cases were classified as "delayed pneumothorax" when a new pneumothorax was identified on the following radiograph. Patients with a pneumothorax >10 mm in width and/or newly occurring symptoms, such as shortness of breath, an increased heart rate, and declining oxygen saturation, received chest tube placement.

Statistical analysis

Statistical analysis was performed using SPSS software (version 29.0; IBM, Armonk, NY, USA). Demographical statistics were provided by mean values with standard deviation. Group differences were analyzed using the Mann–Whitney U test and analysis of variance (ANOVA). Interreader variability was assessed using Cohen's kappa. Univariate and multivariate logistic regression analyses were performed to evaluate the association between the PTS and the occurrence of pneumothorax and pneumothorax requiring chest tube placement. The multivariate analysis included lesion size, lesion depth (distance to pleura), and the number of biopsies as covariates. In a separate univariate analysis limited to patients with a visible PTS, we also tested whether crossing through the PTS with the biopsy needle was associated with pneumothorax severity. The results are reported as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). In all instances, P values <0.05 were interpreted as statistically significant.

Results

Prevalence and distribution of the pleural tail sign

A total of 159 out of all 477 cases (33.3%) were classified as PTS positive. Among these, 64 cases (13.4%) exhibited a thin PTS, and 95 cases (19.9%) had a triangular PTS.

Pleural tail sign and pneumothorax

Of all the cases (n = 477), 47.2% (n = 225) developed a pneumothorax following CT-guided PTNB. Of the 159 cases with a PTS, 53.5% (n = 85) developed a pneumothorax. In the 64 cases classified as having a thin PTS, 51.6% (n = 33) developed a pneumothorax. In the 95 cases with a triangular PTS, 54.7% (n = 52) developed a pneumothorax. In cases without a PTS (n = 318), 44.0% (n = 140) developed a pneumothorax. A Mann–Whitney U test was performed to compare the occurrence of pneumothorax between cases with a PTS and those without. The analysis revealed no statistically significant difference between the two groups (OR: 1.20, 95% CI: 0.99–1.46, P = 0.052). Moreover, ANOVA revealed no statistically significant difference in the PTS grading scale (0–2) between no pneumothorax and pneumothorax (P = 0.067).

Pleural tail sign and instant pneumothorax

For patients with an instant occurrence of pneumothorax (n = 154, of which n = 101 with no PTS, n = 23 with a thin PTS, and n = 30 with a triangular PTS), there was no statistically significant difference between "no PTS" and "any PTS" (OR: 0.93, 95% CI: 0.62–1.40, P = 0.73). Moreover, there was no significant difference in the distribution of the different PTS subcategories among cases with instant pneumothorax occurrence and those without instant pneumothorax (P = 0.82). Analysis of interreader reliability demonstrated good reliability, with Cohen's kappa of 0.617 (P < 0.001).

Pleural tail sign and pneumothorax with necessity of chest tube placement

Of all the cases, 11.5% (n = 55) developed a pneumothorax requiring chest tube placement following CT-guided PTNB. In the PTS group, 15.7% (n = 25) of patients developed a pneumothorax requiring chest tube placement, with 12.5% (n = 8) in the thin PTS subgroup and 17.9% (n = 17) in the triangular subgroup, compared with 9.4% (n = 30) in cases without a PTS. Univariate logistic regression revealed a statistically significant association between the presence of any PTS and the need for chest tube placement (OR: 1.791, 95% CI: 1.014–3.164, $P = 0.043$). Subgroup analysis showed no significant association between chest tube placement and a thin PTS (OR: 1.371, 95% CI: 0.598–3.148, $P = 0.456$), whereas a triangular PTS was significantly associated with an increased risk of requiring a chest tube (OR: 2.092, 95% CI: 1.097–3.990, $P = 0.025$).

In multivariate logistic regression, the presence of a triangular PTS remained an independent predictor of pneumothorax requiring chest tube placement after adjustment for lesion size, depth, and the number of biopsies (OR: 2.02, 95% CI: 1.08–3.79, $P = 0.029$).

In a subgroup analysis of patients with a visible PTS, no significant association was found between the biopsy needle passing through the PTS and the risk of either general pneumothorax (OR: 0.55, $P = 0.159$) or pneumothorax requiring chest tube placement (OR: 0.40, $P = 0.230$). Figure 3 provides an overview of the incidence of pneumothorax with the necessity of chest tube placement stratified by the PTS subgroups, along with the corresponding ORs.

Histopathological entities and pneumothorax and pleural tail sign

Among the histopathological categories, ANOVA revealed significant differences in the rate of PTS positive cases: primary lung cancer (n = 214), metastasis (n = 121), benign lesions (n = 76), and cases with no or an indeterminate histological outcome (n = 66) ($P = 0.005$).

In univariate logistic regression analysis, primary lung cancer was significantly associated with higher odds of exhibiting a PTS than all other histopathological groups combined (metastases, benign lesions, and non-diagnostic cases), with an OR of 1.53 (95% CI: 1.04–2.25, $P = 0.031$).

To assess whether the underlying pathology was associated with the occurrence of pneumothorax, patients were categorized into the same four groups. The ANOVA results revealed no statistically significant differences in the overall pneumothorax rate ($P = 0.646$) or in the rate of severe pneumothorax requiring chest tube placement ($P = 0.192$).

Discussion

Multiple studies have been conducted to identify key risk factors for postinterventional pneumothorax after CT-guided lung biopsy.[18] These studies have consistently identified smaller lesion size, greater distance from the lesion to the pleura, needle paths passing through pulmonary fissures, and emphysema adjacent to the target lesion as factors associated with an increased pneumothorax risk.[10,19] Moreover, our previous investigation identified CT radiomics features of the target lesion and the lung-lobe CT-emphysema score as predictive biomarkers for the occurrence of pneumothorax and the need for chest tube placement after CT-guided PTNB.[10] Technical factors such as patient positioning, entry point relative to gravity, and needle angulation also play a key role and have been shown to significantly influence the risk of pneumothorax.[20-22] Two recent studies identified the PTS as a novel imaging marker associated with an increased risk of pneumothorax following CT-guided lung biopsy.[11,12] One study, based on 311 procedures, reported that the presence of a PTS was an independent risk factor for immediate pneumothorax,[11] whereas another, analyzing 775 cases, found that needle paths passing through the pleural tail significantly increased the pneumothorax rate.[12] However, neither study distinguished between morphological subtypes of the PTS or evaluated complication severity. By contrast, our study applied a two-tier PTS classification (thin vs. triangular) and specifically assessed the severity of pneumothorax, defined by the need for chest tube placement.

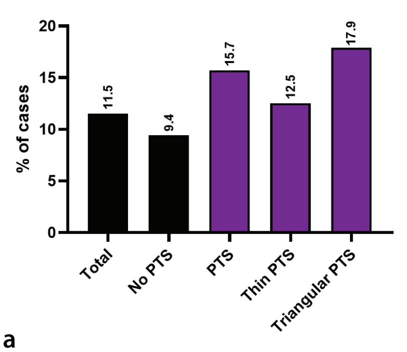
The PTS itself is referred to as a strip connected to a lung lesion, propagating to the pleura.[18] Histological analysis revealed that pleural tails are caused by interlobular thickening caused by lymphatic obstruction, inflammation, desmoplastic reaction, or tumor infiltration.[18,19]

In the current study, no statistically significant difference was found in the distribution of lesions with a PTS and those without a PTS regarding the occurrence of pneumothorax in CT-guided biopsies, although the significance level was close to the threshold of 0.05. In addition, differences in the prominence of PTS (classified as either thin or triangular) and in the timing of pneumothorax occurrence (immediate vs. delayed) did not reach statistical significance. These results differ from those of earlier studies.[11,12]

Nonetheless, we observed statistically significant differences in the occurrence of severe pneumothorax, as defined by the necessity of chest tube placement, both for the mere presence of a PTS and for the triangular subtype. Notably, in our multivariate logistic regression analysis, the presence of a triangular PTS remained an independent predictor for pneumothorax requiring chest tube placement after adjustment for lesion size, depth, and the number of biopsies. To our knowledge, this is the first study demonstrating the clinical significance of the PTS in the context of interventional risk stratification.

In contrast to previous reports, our subgroup analysis among patients with a visible PTS did not demonstrate a significant association between the biopsy needle passing through the PTS and the risk of pneumothorax or the need for chest tube placement.[11] Our study suggests that the pleural vulnerability associated with the PTS may primarily result from intrinsic fibrotic or infiltrative changes rather than from mechanical disruption caused by traversing the PTS.

Notably, the PTS was significantly more common in primary lung cancer than in metastatic or benign nodules. However, neither the overall pneumothorax rate nor



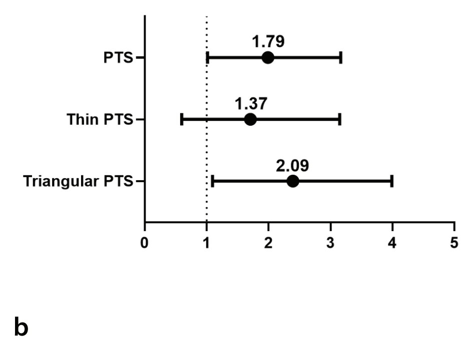


Figure 3. (a) Bar chart showing the percentage of patients who developed a severe pneumothorax requiring chest tube placement, presented for the total cohort as well as stratified by pleural tail sign (PTS) subgroups: no PTS, any PTS, thin PTS, and triangular PTS. **(b)** Forest plot illustrating the corresponding odds ratios for each group. Error bars represent 95% confidence intervals.

the rate of severe, chest tube-requiring pneumothorax differed significantly across histopathological categories, indicating that the histopathological subtype is unlikely to be a major confounder.

The present study has several limitations. First, it is a retrospective study, which poses the risk of a possible known inherent bias. However, the imaging analysis was performed in a blinded fashion to the clinical outcome to reduce possible bias. Second, the identification of a pleural tail and the grading of its features may impose some interreader variability. Third, clinical indications for chest tube placement can vary, as decisions often hinge on the patient's symptoms, the pneumothorax size, and the operator's personal preference.

In conclusion, in this study, we found that the triangular PTS is an independent prognostic imaging marker for identifying patients at higher risk of clinically significant pneumothorax, defined by the need for chest tube placement. Additionally, in our cohort, the PTS was significantly more likely to occur in lesions reflecting primary lung cancer than in other histopathological entities.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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