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Usefulness of CT-Guided Percutaneous Transthoracic Needle Lung Biopsies in Patients with Suspected Pulmonary Infection

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Objective: This study aimed to evaluate the clinical benefits and risks of CT-guided percutaneous transthoracic needle lung biopsies (PTNBs) in patients with a suspected pulmonary infection.

Materials and Methods: This study included 351 CT-guided PTNBs performed in 342 patients (mean age, 58.9 years [range, 17–91 years]) with suspected pulmonary infection from January 2010 to December 2016. The proportion of biopsies that revealed the causative organism for pulmonary infection and that influenced patient's treatment were measured. Multivariate analyses were performed to identify factors associated with PTNB that revealed the causative organism or affected the treatment. Finally, the complication rate was measured.

Results: CT-guided PTNB revealed the causative organism in 32.5% of biopsies (114/351). The presence of necrotic components in the lesion (odds ratio [OR], 1.7; 95% confidence interval [CI], 1.1–2.7; $p = 0.028$), suspected pulmonary tuberculosis (OR, 2.0; 95% CI, 1.2–3.5; $p = 0.010$), and fine needle aspiration (OR, 2.5; 95% CI, 1.1–5.8; $p = 0.037$) were factors associated with biopsies that revealed the causative organism. PTNB influenced patient's treatment in 40.7% (143/351) of biopsies. The absence of leukocytosis (OR, 1.9; 95% CI, 1.0–3.7; $p = 0.049$), presence of a necrotic component in the lesion (OR, 2.4; 95% CI, 1.5–3.8; $p < 0.001$), and suspected tuberculosis (OR, 1.7; 95% CI, 1.0–2.8; $p = 0.040$) were factors associated with biopsies that influenced the treatment. The overall complication rate of PTNB was 19% (65/351).

Conclusion: In patients with suspected pulmonary infection, approximately 30–40% of CT-guided PTNBs revealed the causative organism or affected the treatment. The complication rate of PTNB for suspected pulmonary infection was relatively low.

Keywords: *Image-guided biopsy; Infection; Lung; Multidetector computed tomography*

INTRODUCTION

In patients with a pulmonary infection, identification of the causative organism is often important for providing optimal antimicrobial therapy and individually tailored treatment regimens (1). The delayed diagnosis and treatment of pulmonary infection may result in a prolonged hospital stay, nosocomial outbreaks, respiratory failure, or even mortality (2-4). In addition to sputum specimens, bronchoscopy specimens are obtained frequently to identify

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Korean Journal of Radiology
KJR

pathogens in patients with a suspected pulmonary infection (5-7). However, bronchoscopy techniques often require appropriate patient sedation and the diagnostic yields have been reported to vary, with sensitivities ranging from 36% to 92% (2, 7-10). In addition, contamination of the bronchoscopy specimen during passage through the airways may reduce the accuracy of the results (11, 12).

The diagnosis of focal pulmonary infection has been recognized as an important indication for percutaneous transthoracic needle lung biopsy (PTNB) (7, 13-15). Microbiological exams and histopathology assessments of the lung tissue may reveal causative organisms or families of organisms, and thus enable individually tailored antimicrobial therapy (12, 16). Several studies have shown that PTNB may be an effective tool for identifying the causative organism when bronchoscopy fails to provide a proper diagnosis or when thoracic lesions are not appropriate targets for bronchoscopy (8, 17). However, the benefits of PTNB in patients with a suspected pulmonary infection have been validated in only a few small-scale studies of immunocompromised patients with mainly fungal infections (8, 11, 12, 16-23). We hypothesized that CT-guided PTNB might provide clinically useful information for identifying the causative organism and determining the treatment approach in cases of suspected pulmonary infection beyond immunocompromised patients. Moreover, we hypothesized that there might be clinical factors, imaging findings, or biopsy technique-related factors associated with PTNB that revealed causative organism or affected the treatment of a suspected pulmonary infection. In this study, we aimed to evaluate the clinical benefits and risks of CT-guided PTNB in patients with a suspected pulmonary infection.

MATERIALS AND METHODS

This retrospective study was approved by our Institutional Review Board, and the need for obtaining an informed consent from the patients was waived. The authors did not receive support from any industry and maintained full control of the data at all times.

Patients

From January 2010 to December 2016, 2284 consecutive patients underwent 2409 CT-guided PTNBs at our institution. Among them, we included 376 patients who underwent PTNBs for a suspected pulmonary infection. At our institution, CT-guided PTNB is considered when focal pulmonary lesions indicating a pulmonary infection are suspected (e.g., nodule ≥ 1 cm, mass, or consolidation). Laboratory assessments of sputum, bronchoscopy, and blood culture were performed on a case-by-case basis. We excluded 25 patients who did not fulfill the predefined criteria for the determination of a final diagnosis.

A thoracic radiologist with 2 years of experience in chest imaging retrospectively identified patients with a suspected pulmonary infection, in consultation with a respiratory physician (with 3 years of experience in respiratory medicine) and another thoracic radiologist (with 4 years of experience in chest imaging). The biopsy requisition forms, computerized medical records before PTNB, and pre-procedural chest CT scans were carefully reviewed. The final diagnosis and pathologic reports were blinded. Patients were considered to have a suspected pulmonary infection when pulmonary infection was the only possible diagnosis or was prioritized over other diagnoses. Patients were not considered to have a suspected pulmonary infection when a disease other than pulmonary infection was the most suspected diagnosis or when prioritization between pulmonary infection and other diagnoses was unclear. Finally, 351 PTNBs performed in 342 patients with a suspected pulmonary infection were included (Fig. 1).

Procedures

Patients underwent PTNB under local anesthesia.

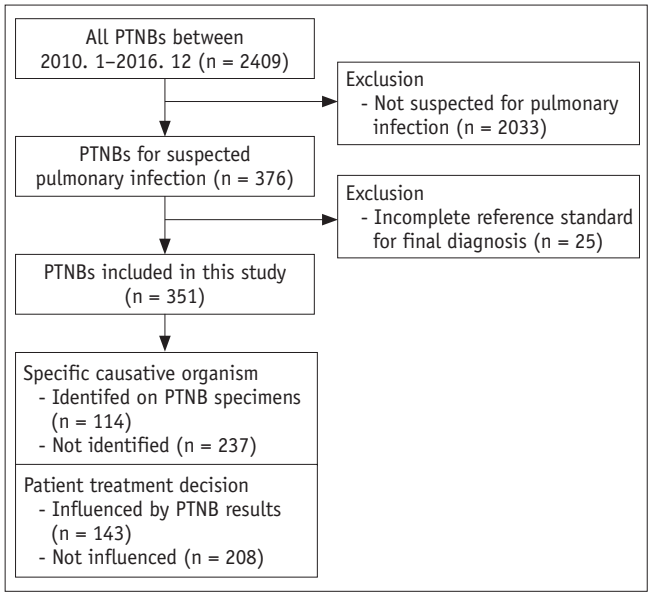

Fig. 1. Flow diagram and outcomes of PTNBs. Numbers in parentheses correspond to numbers of PTNB procedures.
PTNB = percutaneous transthoracic needle lung biopsy

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All procedures were performed by dedicated thoracic radiologists using a conventional CT scanner (Brilliance 64; Philips Medical Systems, Best, the Netherlands). Biopsy procedures were performed by any one of seven chest radiologists who participated in daily practice in our chest radiology section. The PTNB experience levels of the radiologists at the time of biopsy varied from 1 month to > 10 years. Biopsy specimens were obtained via fine needle aspiration (FNA; 22-gauge Westcott biopsy needle; MD TECH, Gainesville, FL, USA) or core needle biopsy (CNB; 19-gauge coaxial system using 20-gauge biopsy; Stericut; TSK Laboratory, Tochigi, Japan). The biopsy needle was selected at the discretion of the performing thoracic radiologists. The lesion size, coagulation parameters, surrounding vessels or bronchial structure, and radiologist's preference were all considered when choosing the type and size of a biopsy needle. Biopsy specimens were placed in 99% ethyl alcohol solution for cytology examination or immersed in 10% formalin solution for histopathology examination. In the majority of cases, fresh tissue specimens were obtained for tissue culture, immersed in normal saline, and delivered to the laboratory medicine department within 1–2 hours. Gram staining, acid-fast staining, and nucleic acid-based amplification tests for *Mycobacterium tuberculosis* detection and bacterial and fungal cultures were obtained at the discretion of the attending physicians, thoracic radiologists, or examining pathologists. Biopsy procedures were performed in the absence of on-site pathologists. Immediate post-procedure CT images were acquired to identify procedure-related complications. After PTNB, the patient maintained the biopsy-down position for 1 hour. Routine post-procedure chest radiographs were taken after 1 hour and 1 day to assess potential complications.

Data Collection

A thoracic radiologist (6 years of experience in chest imaging) and a trained research assistant recorded data related to patients, target lesions, biopsy procedures, and PTNB-related complications. Patient variables included age, sex, immune status (immunocompetent vs. immunocompromised), the presence of fever, and leukocytosis. Target lesion variables included lesion size (long dimension on axial CT), location (upper-middle vs. lower lobe), and presence of necrotic component. If present, the presumptive etiology of pulmonary infection based on original chest CT reports was recorded. Procedural variables included the biopsy needle (FNA, CNB, or both) and the number of tissue sampling. PTNB-related complications (pneumothorax, percutaneous drainage tube insertion due to pneumothorax, hemoptysis, air embolism, and death) were also recorded.

Outcomes

Primary outcomes were the proportions of PTNBs that identified the causative organism and influenced the patient treatment. The effect of PTNB on causative organism identification was defined as present if the histopathology or microbiological results identified a causative organism, and absent otherwise. The influence of PTNB on patient treatment was defined as present if the results influenced patient treatment decisions, including initiating, changing, or discontinuing medications to treat the infection, and absent otherwise (Supplementary Table 1). A thoracic radiologist determined whether the causative organism was identified from biopsy specimens or whether the results influenced patient treatment by reviewing clinical charts and laboratory and PTNB results. Secondary outcomes included factors associated with PTNBs that revealed the causative organism or affected the treatment of suspected pulmonary infection and PTNB-related complications.

Final Diagnosis

To determine the proportion of lesions finally confirmed as malignancy, a thoracic radiologist (20 years of experience in chest imaging) determined the final diagnosis by reviewing all medical records and imaging data. Final diagnosis as either benign or malignant was determined based on one of four approaches (24, 25). First, it was based on a surgical pathologic report if the lesion was surgically resected. Second, it was based on a non-surgical biopsy of the lesion if it showed a specific benign or malignant disease. Third, the lesion was considered benign when it decreased by 20% or more in diameter or was stable in size for at least two years. Fourth, the lesion was considered malignant if the clinical course was consistent with an obvious malignancy.

Statistical Analysis

For this per-biopsy analysis, repeat biopsies within the same patient were considered separate PTNBs. The chi-squared test and Fisher's exact test were used as appropriate to analyze differences between biopsies with and without identified causative organisms with respect to clinical characteristics, target lesion data, biopsy procedure-related variables, and laboratory findings. Variables with *p* values

https://doi.org/10.3348/kjr.2019.0492

Korean Journal of Radiology
KJR

< 0.10 in univariate analyses were used as input variables in the multivariate logistic regression analysis. Univariate and multivariate analyses were performed to determine differences between PTNBs with and without treatment influence. Collinearity was tested using the variance inflation factor (VIF). VIF values were < 5 in all input variables of multivariate analyses. *P* values < 0.05 were considered statistically significant. All statistical analyses were performed using STATA 15.0 (StataCorp LLC, College Station, TX, USA).

RESULTS

Patients

The patients' demographic data are shown in Table 1. The overall mean age was 58.9 years (range, 17–91 years). Male (n = 219) and female (n = 123) patients had mean ages of 58.6 (range, 20–91 years) and 59.5 years (range, 17–86 years), respectively. Regarding the differential diagnosis before PTNB, pulmonary infection was the only possible diagnosis in 168 patients (49.1%), and pulmonary infection was prioritized over other diagnoses in 174 patients (50.9%). Forty-five patients (13.2%) were immunocompromised. Bronchoscopy was performed in 234 patients (68.4%). Tissue culture for PTNB specimens was performed in 72% of biopsies (252/351); there was no significant difference in the culture rates between the FNA and CNB (Supplementary Table 2). Of 351 biopsies, 11 lesions (3%) were finally confirmed as malignant.

Causative Organism Identification

Overall, 32.5% (114/351) of CT-guided PTNBs revealed the causative organism (Fig. 1). In univariate analyses, the causative organism was more frequently identified when the lesion contained a necrotic component (odds ratio [OR], 1.7; 95% confidence interval [CI], 1.1–2.7; $p = 0.027$), the presumptive etiology included tuberculosis (OR, 2.0; 95% CI, 1.2–3.4; $p = 0.010$), or FNA was applied (vs. CNB; OR, 2.6; 95% CI, 1.1–6.2; $p = 0.014$). Causative organism was revealed in 37% (74/198) and 26% (40/153) of lesions with and without necrotic components, respectively. Causative organism was identified in 37% (91/248) and 22% (23/103) of biopsies in which tuberculosis was and was not suspected, respectively. In the multivariable analysis, the presence of a necrotic component (OR, 1.7; 95% CI, 1.1–2.7; $p = 0.028$), consideration of tuberculosis as a presumptive etiology (OR, 2.0; 95% CI, 1.2–3.5; $p = 0.010$), and FNA (vs. CNB; OR, 2.5; 95% CI, 1.1–5.8; $p = 0.037$) were associated with causative organism identification (Table 2, Figs. 2, 3).

Table 1. Study Patients and Target Lesions Characteristics

Characteristic	Total (n = 342)
Age (years), mean ± standard deviation	58.9 ± 14.7
No. of women	123 (36)
Immunocompromised	45 (13)
Fever	37 (11)
Leukocytosis	57 (17)
Antibiotics administration before biopsy	135 (39.5)
Sputum culture performed	269 (78.7)
Bronchoscopy w/ or w/o BAL performed	234 (68.4)
Blood culture performed	119 (34.8)
Lung biopsy culture performed	245 (71.6)
Lesion size (cm), mean ± standard deviation	3.6 ± 1.9
Presumptive diagnosis before diagnosis	
Abscess	36 (11)
Actinomycosis	83 (24)
TB infection	243 (71.1)
NTM infection	44 (13)
Fungal infection	80 (23)
Septic embolism	13 (4)
Others	10 (3)
Final diagnosis	
Benign	
Bacterial infection, pneumonia, lung abscess	102 (29.8)
TB or NTM infection	142 (41.5)
Fungal infection	22 (6)
Co-infection	2 (0.6)
Others*	64 (19)
Malignant	10 (3)

Unless otherwise specified, data represent number of patients (and percentages). For patients who underwent two or more percutaneous transthoracic needle lung biopsies during study period, information at time of initial biopsy is presented in this Table 1. *Consisted of 55 nonspecific inflammation, 3 autoimmune disease, 3 parasitic disease, 2 granulomatous inflammation, 1 hypereosinophilic syndrome, 1 acute fibrinous organizing pneumonia, and 1 pulmonary capillary hemangiomatosis. BAL = bronchoalveolar lavage, NTM = nontuberculous mycobacteria, TB = tuberculosis, w = with, w/o = without

For target lesions with a necrotic component (n = 198), an ad hoc comparison of the causative organism identification rates when the biopsy needle tip targeted the necrotic component vs. the non-necrotic component revealed a higher causative organism identification rate in the former subgroup (44% [54/123] vs. 27% [20/75]; $p = 0.016$) (Fig. 2). The subgroup analysis showed that CT-guided PTNBs identified causative organisms in 34% (38/112), 29% (41/142), and 36% (35/97) of patients

 https://doi.org/10.3348/kjr.2019.0492

Table 2. Results from Univariate and Multivariate Logistic Regression Analyses to Determine Factors Influencing Identification of Causative Organism (Per-Biopsy)

Parameter	Causative Organism Identification				
	Percentage (%) [Numerator/Denominator]	Univariate Analysis, OR (95% CI)	*P*	Multivariate Analysis, AOR (95% CI)	*P*
Age (years)			0.214	-	-
≤ 65	35 [79/227]	1 (reference)			
> 65	28 [35/124]	0.7 (0.5–1.2)			
Sex			0.260	-	-
Male	36 [45/124]	1 (reference)			
Female	30 [69/227]	0.8 (0.5–1.2)			
Immune status			0.366	-	-
Immunocompetent	32 [96/304]	1 (reference)			
Immunocompromised	38 [18/47]	1.3 (0.7–2.5)			
Fever			0.544	-	-
Absent	33 [103/312]	1.3 (0.6–2.6)			
Present	28 [11/39]	1 (reference)			
Leukocytosis			0.391	-	-
Absent	33 [97/290]	1.3 (0.7–2.4)			
Present	28 [17/61]	1 (reference)			
Lesion size (cm)			0.580	-	-
≤ 2.0	30 [23/77]	1 (reference)			
> 2.0	33 [91/274]	1.2 (0.7–2.0)			
Necrotic change*			0.027*		0.028*
Absent	26 [40/153]	1 (reference)		1 (reference)	
Present*	37 [74/198]	1.7 (1.1–2.7)		1.7 (1.1–2.7)	
Differential diagnosis			0.307	-	-
Infection only	35 [61/174]	1 (reference)			
Infection prioritized to other diagnoses	30 [53/177]	0.8 (0.5–1.2)			
Presumptive etiology*					
TB infection*			0.010*		0.010*
Not suspected	22 [23/103]	1 (reference)		1 (reference)	
Suspected	37 [91/248]	2.0 (1.2–3.4)		2.0 (1.2–3.5)	
Abscess†	24 [9/37]	0.6 (0.3–1.4)	0.246	-	-
Actinomycosis†	30 [25/84]	0.8 (0.5–1.4)	0.542	-	-
NTM infection†	31 [14/45]	0.9 (0.5–1.8)	0.834	-	-
Fungal infection†	35 [29/83]	1.2 (0.7–1.9)	0.586	-	-
Septic embolism†	23 [3/13]	0.6 (0.2–2.3)	0.454	-	-
Biopsy needle*			0.014*		0.037*
Fine needle aspiration*	35 [107/309]	2.6 (1.1–6.2)		2.5 (1.1–5.8)	
Core needle biopsy	17 [7/42]	1 (reference)		1 (reference)	
No. of tissue sampling			0.164	-	-
≤ 2	33 [110/330]	1 (reference)			
> 2	19 [4/21]	0.5 (0.2–1.4)			
Culture					
Performed	35 [87/252]	1 (reference)	0.193		
Not performed	27 [27/99]	0.7 (0.4–1.2)			

Ellipsis indicates that variable was not tested in multivariable analysis. *Indicate statistical significance, †OR was calculated as ratio of odds of causative organism identification in presence of corresponding presumptive etiology and odds of causative organism identification in absence of corresponding presumptive etiology. AOR = adjusted odds ratio, CI = confidence interval, OR = odds ratio

https://doi.org/10.3348/kjr.2019.0492

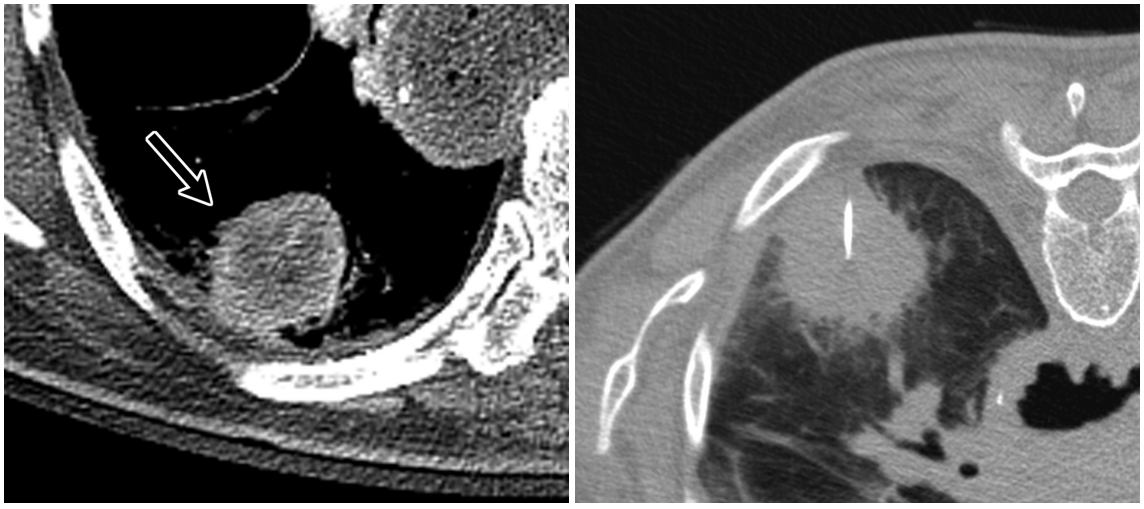
Korean Journal of Radiology
KJR

who did not undergo bronchoscopy and those whose bronchoscopy specimens yielded negative and positive results, respectively.

Patient Management

Overall, the proportion of CT-guided PTNBs that influenced patient treatment was 40.7% (143/351). Thirteen percent (47/351) of PTNBs influenced patient treatment although it failed to reveal the causative organism; the majority of such cases were finally diagnosed either as tuberculosis (20/47, 43%) or abscesses (15/47, 32%).

PTNBs more frequently influenced patient treatment in cases without febrility (OR, 2.1; 95% CI, 1.0–4.6; $p = 0.041$) or leukocytosis (OR, 2.0; 95% CI, 1.1–3.6; $p = 0.023$) and those with a necrotic component (OR, 2.1; 95% CI, 1.4–3.3; $p < 0.001$) or the inclusion of tuberculosis in



A B

Fig. 2. Axial CT images of 78-year-old man who presented with general weakness and fever for seven days. He had undergone Ivor-Lewis operation due to esophageal cancer 10 years ago and was being followed without any evidence of recurrence.
A. Contrast-enhanced chest CT image shows 3-cm consolidation containing necrotic changes in right lower lobe (arrow). Pulmonary septic embolism and fungal infection were considered in differential diagnosis. **B.** CT-guided PTNB was performed by using 22-gauge aspiration needle, and pathological examination confirmed lesion as abscess. *Klebsiella pneumoniae* isolate was cultured from PTNB specimen six days later. Antibiotic regimen was changed from vancomycin and piperacillin-tazobactam to piperacillin-tazobactam only. CT = computed tomography

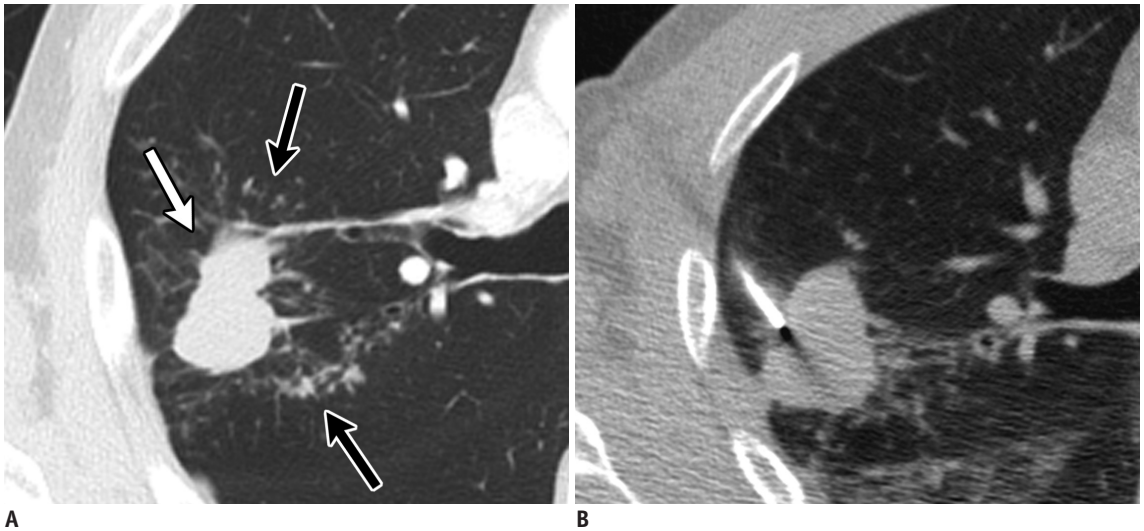


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Fig. 3. Axial CT images of 60-year-old male referred for mild cough and abnormality on chest radiograph.
A. Contrast-enhanced chest CT image shows 3.7-cm mass with lobulated margins (white arrow) and multiple tiny nodular and branching opacities (black arrows) in right upper lobe's posterior segment. CT findings were suggested active pulmonary tuberculosis. **B.** CT-guided PTNB was performed using 20-gauge cutting needle. Pathological examination showed chronic granulomatous inflammation with extensive necrosis, suggesting tuberculosis. Interferon-gamma release assay also presented positive result, and tuberculosis treatment was started. *M. tuberculosis* was confirmed later in culture of PTNB specimen.

https://doi.org/10.3348/kjr.2019.0492

the presumptive etiology (OR, 1.8; 95% CI, 1.1–2.9; p = 0.018). PTNBs influenced treatment in 48% (96/198) and 31% (47/153) of cases with necrotic and non-necrotic lesions, respectively, and in 45% (111/248) and 31% (32/103) of cases with and without suspected tuberculosis, respectively. The multivariable analysis identified the absence of leukocytosis (OR, 1.9; 95% CI, 1.0–3.7; p = 0.049), presence of a necrotic component (OR, 2.4; 95% CI, 1.5–3.8; p < 0.001), and consideration of tuberculosis as a presumptive etiology (OR, 1.7; 95% CI, 1.0–2.8; p = 0.040) as factors associated with PTNBs that influenced patient treatment (Table 3). A subgroup analysis showed that CT-guided PTNB affected the management in 44% (49/112), 41% (58/142), and 37% (36/97) of patients who did not undergo bronchoscopy and those whose bronchoscopy specimens yielded negative and positive results, respectively.

Complications

The overall complication rate of PTNB among lesions suspected of infection was 19% (65/351). Overall, pneumothorax occurred in 63 cases (18%), of which four (1%) required percutaneous drainage tube insertion. Five patients (1%) developed hemoptysis. No cases of air embolism or death occurred due to PTNB. The complication rate did not differ significantly depending on the type of biopsy needle (FNA vs. CNB; 19% vs. 14%, p = 0.452), immune status (immunocompetent vs. immunocompromised; 19% vs. 13%, p = 0.275), or differential diagnosis (pulmonary infection as the only possible diagnosis vs. prioritization over other diagnoses; 17% vs. 20%, p = 0.541).

DISCUSSION

Our results from a relatively large-scale cohort study of patients who underwent CT-guided PTNB for suspected pulmonary infection suggest that CT-guided PTNB is clinically valuable in this population. The benefit of PTNB was not limited to immunocompromised patients with suspected fungal infection. Histological and microbiological examinations of PTNB specimens provided useful information in 30–40% of patients with a suspected pulmonary infection and enabled early and specific antibiotic therapy.

Although the usefulness of CT-guided PTNB was not limited to a particular subgroup of patients with suspected pulmonary infection, several factors were associated with causative organism identification, namely the presence of a necrotic lesion component, tuberculosis as the presumptive etiology, and FNA. The first two factors were also associated with the influence of PTNB on patient management, as was the absence of leukocytosis. Although we cannot conclusively explain this latter association, the absence of leukocytosis was more common in tuberculosis infection, which was itself significantly associated with an influence of PTNB on treatment.

Our observations of higher causative organism identification rates when targeting the biopsy needle tip to the necrotic cavity of the lesion and when using FNA, actually contradicts previous literature describing the methods used to increase the biopsy yield, which recommends avoiding the central necrotic component when diagnosing a malignant pulmonary lesion (26, 27). Moreover, CNB was previously shown to have a higher diagnostic accuracy than FNA, especially for the specific diagnosis of non-malignant lesions (3, 28). This discrepancy can be attributed to the presence of causative organisms in the central necrotic zones of most pulmonary infection lesions (26, 29), and the ease of fluid aspiration from the lesion cavity via FNA (8). We assume that contrast-enhanced CT imaging before PTNB may help to identify the necrotic component and determine the biopsy target accurately in patients with a suspected infection. As fewer cases involved performing PTNBs with CNB (n = 42) than with FNA (n = 309), the superiority of the latter for identifying the causative organisms of pulmonary infection require further validation.

Most previous studies of PTNBs in patients with suspected pulmonary infection assessed small series of predominantly immunocompromised patients with mainly fungal infections and reported causative organism identification rates of 36–80% (8, 11, 12, 18-23, 30). Although immunocompromised patients are predisposed to various infections and may incur more severe complications from delayed treatment than immunocompetent patients may, we often encounter immunocompetent patients with pulmonary infection of unidentified etiology. Thus, we included all consecutive patients with a suspected pulmonary infection in our analysis, regardless of their immune status. Our results suggest that the rate of causative organism identification by CT-guided PTNB was not associated with the immune status: CT-guided PTNB provided useful information in both immunocompetent and immunocompromised patients.

Unexpectedly, the proportion of PTNBs that influenced patient management (40.7%) was slightly higher than that

https://doi.org/10.3348/kjr.2019.0492

Korean Journal of Radiology
KJR

in which the causative organism was identified (32.5%), as well as the proportion that affected patient management in a recent study (29%, 6/21) (17). This discrepancy can be attributed to the fact that most cases in which biopsies influenced the treatment without identifying the causative organism were finally diagnosed with tuberculosis or

Table 3. Results from Univariate and Multivariate Logistic Regression Analyses to Determine Factors Influencing Treatment Effect (Per-Biopsy)

Parameter	Treatment Effect				
	Percentage (%) [Numerator/Denominator]	Univariate Analysis, OR (95% CI)	*P*	Multivariate Analysis, AOR (95% CI)	*P*
Age (years)			0.736	-	-
≤ 65	40 [91/227]	1 (reference)			
> 65	42 [52/124]	1.1 (0.7–1.7)			
Sex			0.055		-
Male	48 [59/124]	1 (reference)		1 (reference)	
Female	37 [84/227]	0.6 (0.4–1.0)		0.7 (0.4–1.1)	
Immune status			0.714	-	-
Immunocompetent	41 [125/304]	1 (reference)			
Immunocompromised	38 [18/47]	0.9 (0.5–1.7)			
Fever			0.041*		0.352
Absent	43 [133/312]	2.1 (1.0–4.6)		1.5 (0.6–3.3)	
Present	26 [10/39]	1 (reference)		1 (reference)	
Leukocytosis*			0.023*		0.049*
Absent*	44 [126/290]	2.0 (1.1–3.6)		1.9 (1.0–3.7)	
Present	28 [17/61]	1 (reference)		1 (reference)	
Lesion size (cm)			0.534	-	-
≤ 2.0	38 [29/77]	1 (reference)			
> 2.0	42 [114/274]	1.2 (0.7–2.0)			
Necrotic change*			< 0.001*		< 0.001*
Absent	31 [47/153]	1 (reference)		1 (reference)	
Present*	48 [96/198]	2.1 (1.4–3.3)		2.4 (1.5–3.8)	
Differential diagnosis			0.809	-	-
Infection only	41 [72/174]	1 (reference)			
Infection prioritized to other diagnoses	40 [71/177]	0.9 (0.6–1.5)			
Presumptive etiology*					
TB infection*			0.018*		0.040*
Not suspected	31 [32/103]	1 (reference)		1 (reference)	
Suspected*	45 [111/248]	1.8 (1.1–2.9)		1.7 (1.0–2.8)	
Abscess†	41 [15/37]	1.0 (0.5–2.0)	0.979	-	-
Actinomycosis†	45 [38/84]	1.3 (0.8–2.1)	0.337	-	-
NTM infection†	40 [18/45]	1.0 (0.5–1.8)	0.941	-	-
Fungal infection†	37 [31/83]	0.8 (0.5–1.4)	0.472	-	-
Septic embolism†	23 [3/13]	0.4 (0.1–1.6)	0.169	-	-
Biopsy needle			0.293	-	-
Fine needle aspiration	42 [129/309]	1.4 (0.7–2.8)			
Core needle biopsy	33 [14/42]	1 (reference)			
No. of tissue sampling			0.799	-	-
≤ 2	41 [135/330]	1 (reference)			
> 2	38 [8/21]	0.9 (0.4–2.2)			

Ellipsis indicates that variable was not tested in multivariate analysis. *Indicate statistical significance, †OR was calculated as ratio of odds of treatment effect in presence of corresponding presumptive etiology and odds of treatment effect in absence of corresponding presumptive etiology.

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abscess. As tuberculosis remains common in South Korea, the treatment was initiated when the pathological findings suggested the possibility of tuberculosis (e.g., chronic granulomatous inflammation with caseous necrosis), even without a clear microbiological confirmation (31). Patients with a diagnosed abscess received prolonged broad-spectrum antibiotic therapies (32, 33).

Our results showed that the role of PTNB in the diagnosis of pulmonary infection might be complementary to that of bronchoscopy, as in the diagnosis of malignant diseases. Even in patients whose bronchoscopy specimens showed negative results, the proportions of CT-guided PTNBs that identified the causative organism and affected management were 29% (41/142) and 41% (58/142), respectively. The indications for bronchoscopy and PTNB should be extensively defined and validated in future studies.

We noted that the complication rate in our study patients (19%, 65/351) was lower than that reported in previous studies (34, 35), as well as in patients without pulmonary infection, during the same study period (31.1%, 633/2033) at our institution. Although we did not perform a formal statistical comparison, we speculate that the discrepancy in this rate might be attributable to a lower prevalence of emphysema (9% [32/351] vs. 23.4% [476/2033]) and less frequent use of CNB (11% [42/351] vs. 21.7% [441/2033]) in patients with suspected pulmonary infection vs. those without a suspected pulmonary infection. Although this complication rate was not high, CT-guided PTNB for suspected pulmonary infections should be performed judiciously after considering its risks and benefits.

Our study had some limitations. First, all biopsies were performed at a single tertiary care hospital. Because the etiology of pulmonary infection varies geographically, our results may not be generalizable. Second, the study participants were selected based on a retrospective review of the medical records and imaging data, and the primary outcomes were retrospectively determined by a thoracic radiologist. Third, as there is no widely accepted objective method for estimating the likelihood of pulmonary infection, we included all patients with a suspected pulmonary infection that was prioritized over other diagnoses. Although we primarily focused on the value of PTNB for diagnosing pulmonary infection, this modality might have also provided crucial information for differentiating between benign and malignant diseases. Fourth, our practices may not be generalizable, as some patients underwent both diagnostic PTNB and bronchoscopy successively during their hospital admission before the laboratory results were reported. This diagnostic work-up process was arranged at the discretion of physicians to minimize diagnostic delays. We included those patients in our study to reduce selection bias. Finally, tissue samples were not available for review by on-site cytopathology technologists due to the low medical cost of PTNBs in South Korea.

In conclusion, approximately 30–40% of CT-guided PTNBs in patients with a suspected pulmonary infection revealed the causative organism or affected the treatment. The complication rate of PTNB for suspected pulmonary infections was relatively low.

Supplementary Materials

The Data Supplement is available with this article at https://doi.org/10.3348/kjr.2019.0492.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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REFERENCES

1. Dellit TH, Owens RC, McGowan JE Jr, Gerding DN, Weinstein RA, Burke JP, et al. Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. *Clin Infect Dis* 2007;44:159-177
2. Cazzadori A, Di Perri G, Todeschini G, Luzzati R, Boschiero L, Perona G, et al. Transbronchial biopsy in the diagnosis of pulmonary infiltrates in immunocompromised patients. *Chest* 1995;107:101-106
3. Yao X, Gomes MM, Tsao MS, Allen CJ, Geddie W, Sekhon H.

Fine-needle aspiration biopsy versus core-needle biopsy in diagnosing lung cancer: a systematic review. *Curr Oncol* 2012;19:e16-e27
4. Zahar JR, Azoulay E, Klement E, De Lassence A, Lucet JC, Regnier B, et al. Delayed treatment contributes to mortality in ICU patients with severe active pulmonary tuberculosis and acute respiratory failure. *Intensive Care Med* 2001;27:513-520
5. Fossieck Jr BE, Parker RH, Cohen MH, Kane RC. Fiberoptic bronchoscopy and culture of bacteria from the lower respiratory tract. *Chest* 1977;72:5-9
6. Bartlett JG, Alexander J, Mayhew J, Sullivan-Sigler N, Gorbach SL. Should fiberoptic bronchoscopy aspirates be cultured? *Am Rev Respir Dis* 1976;114:73-78
7. Segal BH. Aspergillosis. *N Engl J Med* 2009;360:1870-1884
8. Uruga H, Takaya H, Hanada S, Beika Y, Miyamoto A, Morokawa N, et al. Diagnostic efficacy of CT-guided transthoracic needle biopsy and fine needle aspiration in cases of pulmonary infectious disease. *Jpn J Radiol* 2012;30:589-593
9. Baughman RP, Dohn MN, Loudon RG, Frame PT. Bronchoscopy with bronchoalveolar lavage in tuberculosis and fungal infections. *Chest* 1991;99:92-97
10. Chastre J, Fagon JY, Bornet-Lecso M, Calvat S, Dombret MC, al Khani R, et al. Evaluation of bronchoscopic techniques for the diagnosis of nosocomial pneumonia. *Am J Respir Crit Care Med* 1995;152:231-240
11. Gupta S, Sultenfuss M, Romaguera JE, Ensor J, Krishnamurthy S, Wallace MJ, et al. CT-guided percutaneous lung biopsies in patients with haematologic malignancies and undiagnosed pulmonary lesions. *Hematol Oncol* 2010;28:75-81
12. Hwang SS, Kim HH, Park SH, Jung JI, Jang HS. The value of CT-guided percutaneous needle aspiration in immunocompromised patients with suspected pulmonary infection. *AJR Am J Roentgenol* 2000;175:235-238
13. Wu CC, Maher MM, Shepard JA. CT-guided percutaneous needle biopsy of the chest: preprocedural evaluation and technique. *AJR Am J Roentgenol* 2011;196:W511-W514
14. Westcott JL. Percutaneous transthoracic needle biopsy. *Radiology* 1988;169:593-601
15. Manhire A, Charig M, Clelland C, Gleeson F, Miller R, Moss H, et al. Guidelines for radiologically guided lung biopsy. *Thorax* 2003;58:920-936
16. Ishida T, Hashimoto T, Arita M, Osawa M, Tachibana H, Nishioka M, et al. Efficacy of transthoracic needle aspiration in community-acquired pneumonia. *Intern Med* 2001;40:873-877
17. Haas BM, Clayton JD, Elicker BM, Ordovas KG, Naeger DM. CT-guided percutaneous lung biopsies in patients with suspicion for infection may yield clinically useful information. *AJR Am J Roentgenol* 2017;208:459-463
18. Hsu JL, Kuschner WG, Paik J, Bower N, Vazquez Guillamet MC, Kothary N. The diagnostic yield of CT-guided percutaneous lung biopsy in solid organ transplant recipients. *Clin Transplant* 2012;26:615-621
19. Lass-Flörl C, Resch G, Nachbaur D, Mayr A, Gastl G, Auberger J, et al. The value of computed tomography-guided percutaneous lung biopsy for diagnosis of invasive fungal infection in immunocompromised patients. *Clin Infect Dis* 2007;45:e101-e104
20. Carrafiello G, Laganà D, Nosari AM, Guffanti C, Morra E, Recaldini C, et al. Utility of computed tomography (CT) and of fine needle aspiration biopsy (FNAB) in early diagnosis of fungal pulmonary infections. Study of infections from filamentous fungi in haematologically immunodeficient patients. *Radiol Med* 2006;111:33-41
21. Nosari A, Anghilieri M, Carrafiello G, Guffanti C, Marbello L, Montillo M, et al. Utility of percutaneous lung biopsy for diagnosing filamentous fungal infections in hematologic malignancies. *Haematologica* 2003;88:1405-1409
22. Hoffer FA, Gow K, Flynn PM, Davidoff A. Accuracy of percutaneous lung biopsy for invasive pulmonary aspergillosis. *Pediatr Radiol* 2001;31:144-152
23. Caillot D, Casasnovas O, Bernard A, Couaillier JF, Durand C, Cuisenier B, et al. Improved management of invasive pulmonary aspergillosis in neutropenic patients using early thoracic computed tomographic scan and surgery. *J Clin Oncol* 1997;15:139-147
24. Lee SM, Park CM, Lee KH, Bahn YE, Kim JI, Goo JM. C-arm cone-beam CT-guided percutaneous transthoracic needle biopsy of lung nodules: clinical experience in 1108 patients. *Radiology* 2014;271:291-300
25. Hiraki T, Mimura H, Gobara H, Iguchi T, Fujiwara H, Sakurai J, et al. CT fluoroscopy-guided biopsy of 1,000 pulmonary lesions performed with 20-gauge coaxial cutting needles: diagnostic yield and risk factors for diagnostic failure. *Chest* 2009;136:1612-1617
26. Pan JF, Yang PC, Chang DB, Lee YC, Kuo SH, Luh KT. Needle aspiration biopsy of malignant lung masses with necrotic centers. Improved sensitivity with ultrasonic guidance. *Chest* 1993;103:1452-1456
27. Yeow KM, Tsay PK, Cheung YC, Lui KW, Pan KT, Chou AS. Factors affecting diagnostic accuracy of CT-guided coaxial cutting needle lung biopsy: retrospective analysis of 631 procedures. *J Vasc Interv Radiol* 2003;14:581-588
28. Rivera MP, Mehta AC, Wahidi MM. Establishing the diagnosis of lung cancer: diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2013;143(5 Suppl):e142S-e165S
29. Katzenstein ALA. *Infection II. Granulomatous infections*. In: Katzenstein ALA, Askin FB, eds. *Katzenstein and Askin's surgical pathology of non-neoplastic lung disease,* 4th ed. Philadelphia: Saunders, Elsevier, 2006:305-328
30. Haas BM, Elicker BM, Nguyen J, Ordovas KG, Jones KD, Henry TS, et al. Nondiagnostic computed tomography-guided percutaneous lung biopsies are more likely when infection is suspected. *J Thorac Imaging* 2016;31:151-155
31. Park JS, Kang YA, Kwon SY, Yoon HI, Chung JH, Lee CT, et al. Nested PCR in lung tissue for diagnosis of pulmonary

tuberculosis. *Eur Respir J* 2010;35:851-857
32. Torres A, Menéndez R, Wunderink RG. *Bacterial pneumonia and lung abscess*. In: Broaddus VC, Mason RJ, Ernst JD, King Jr TE, Lazarus SC, Murray JF, et al., eds. *Murray & Nadel's textbook of respiratory medicine*, 6th ed. Amsterdam: Elsevier, 2016:580-581
33. Loukeri AA, Kampolis CF, Tomos P, Papapetrou D, Pantazopoulos I, Tzagkaraki A, et al. Diagnosis, treatment and prognosis of lung abscess. *Pneumon* 2015;28:54-60
34. Yoon SH, Park CM, Lee KH, Lim KY, Suh YJ, Im DJ, et al. Analysis of complications of percutaneous transthoracic needle biopsy using CT-guidance modalities in a multicenter cohort of 10568 biopsies. *Korean J Radiol* 2019;20:323-331
35. Heerink WJ, de Bock GH, de Jonge GJ, Groen HJ, Vliegenthart R, Oudkerk M. Complication rates of CT-guided transthoracic lung biopsy: meta-analysis. *Eur Radiol* 2017;27:138-148

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