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Diagnostic Outcomes of CT-guided Percutaneous Transthoracic Needle Biopsy of Pulmonary Consolidation

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ABSTRACT

Pulmonary consolidation is a frequently encountered clinical entity and sometimes needs tissue sampling for definitive diagnosis. We evaluated the diagnostic accuracy and complications of computed tomography (CT)-guided percutaneous transthoracic needle biopsy (PTNB) of pulmonary consolidation. Moreover, we analyzed factors which may predict malignant outcome. All CT-guided PTNB of pulmonary consolidation performed from January 2013 to December 2018 were retrospectively reviewed. Patient demographics, lesion characteristics, procedural techniques, complications, and pathological reports were assessed. The diagnostic accuracy and complications of the procedure were evaluated. Clinical features and imaging characteristics were analyzed as predictors of malignant outcome. Statistical analysis was performed using multivariate analysis**.** Sixty-three patients (male: 39, female: 24, median age: 65 years, range: 20 to 91 years) were enrolled. The final diagnosis was malignancy in 33 (52.4%) patients and benign in 30 (47.6%) patients. CT-guided PTNB provided a diagnostic yield of 88.9%. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of CT-guided PTNB for the diagnosis of malignancy were 96.9%, 100%, 100%, 96.7%, and 98.4%, respectively. The rates of pneumothorax and pulmonary hemorrhage were 33.3% and 38.1%, respectively. All patients had clinical improvement after conservative treatment. No procedure-related mortality was detected. Advanced age ($p = 0.004$) and lower lobe localization ($p = 0.026$) were found to be risk factors for malignant outcome. CT-guided PTNB provides a high diagnostic yield and is a safe technique for characterization of pulmonary consolidation. The risk factors for malignant outcome are advanced age and location in the lower lobe.

Keywords: Accuracy; Complication; Computed tomography; Pulmonary consolidation; Transthoracic biopsy

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1. Introduction

Pulmonary consolidation is defined as an alveolar-filling process by fluid or other material. The causes of pulmonary consolidation can be considered based on the various substances that may fill the airspaces such as pulmonary edema, pulmonary hemorrhage, pneumonia, adenocarcinoma, lymphoma, and alveolar proteinosis. Patient history, imaging data, sputum examination, and serological tests usually guide the initial diagnosis. When the consolidation persists despite adequate initial treatment, or malignancy is suspicious, or unknown etiology of the benign condition, tissue sampling is usually required for definitive diagnosis. Transbronchial lung biopsy (TBLB) has lower rates of morbidity and mortality compared to open lung biopsy, and has lower rates of complications as well, namely, pneumothorax and parenchymal hemorrhage compared to computed tomography (CT)-guided percutaneous transthoracic needle biopsy (PTNB). However, TBLB was found to be inferior to CT-guided PTNB for the evaluation of small (<2 cm) or peripheral lesions [1, 2]. When the result of TBLB is non-diagnostic, or the bronchoscopy fails, PTNB is commonly performed as it is less invasive, has lower morbidity, and involves a shorter hospital stay compared to open lung biopsy [3]. CT-guided PTNB is a safe technique and has high diagnostic accuracy for pulmonary lesions [4-6]. However, there have been a few studies that assessed the diagnostic yield and safety of CT-guided PTNB of patients with pulmonary consolidation [7-11]. The purpose of this study was to determine diagnostic accuracy and safety of CT-guided PTNB of pulmonary consolidation and evaluate the factors associated with a malignant outcome.

2. Materials and Methods

2.1 Study population

This was a single-center, retrospective study that was approved by the Thammasat University Hospital ethics committee that granted an informed consent waiver on 30 January 2020. All CT- guided PTNBs of pulmonary consolidation from January 2013 to December 2018 were reviewed; notes were retrieved using the Radiology Information System. Patients who had no preoperative multidetector computed tomography (MDCT) of the chest, no CT imaging of the biopsy, incomplete procedural data, incomplete medical records, or unknown final diagnosis were excluded from the study.

2.2 Biopsy procedure

Three interventional radiologists (4 years', 8 years', and 18 years' experience in image-guided PTNB) performed all biopsies using a standard protocol. Preoperative preparations included correction of platelet count, performance of coagulogram, discontinuation of antiplatelet drugs and anticoagulants at least 7 days before the procedure, and providing information about indication, procedural process, and probable complications. Informed consent was conducted individually.

The procedures were performed under CT guidance using a 128-slice CT system (Somatom Definition AS, Siemens, Berlin and München, Germany) or a 256-slice CT system (Philips Brilliance ICT, Amsterdam, Netherlands). Patient's position was adjusted depending on the location of the lesion and estimated entry site. A CT scan was performed to detect the target lesion, then the most appropriate pathway was determined. After attaching a marker on the skin, a CT scan was performed again to establish the exact skin entry site. The skin marker was then removed, the skin was prepared using sterile technique, and 10 ml of 1% lidocaine was used for local anesthesia. A 19-guage coaxial introducer needle was advanced to the lesion under repeated CT scan guidance. Then a 20-gauge semiautomated cutting needle (Biofeather, Medax Medical Device, Italy) was inserted into the lesion via the

coaxial needle and the biopsy was performed. The decision to perform core needle biopsy (CNB); both CNB and fine needle aspiration (FNA); or CNB, FNA, and microbiological analysis depended on the clinical suspicion of malignancy, infection, or both. At least 3 biopsies from different areas were obtained.

An immediate post-procedural non-contrast CT of the chest was performed routinely. Each patient was admitted and observed for any clinical symptoms after the procedure for at least 24 hours. A post-procedural chest radiograph was obtained at 2 and 24 hours to evaluate the presence of early or delayed complications and their progression. Management of the complications depended on the clinical picture.

2.3 Medical record and imaging reviews

Patients' demographic data, clinical history, and indication for biopsy were reviewed from their electronic medical records. The chest CT images preceding the biopsy were reviewed by one board-certified interventional radiologist and one board-certified diagnostic radiologist. The pattern of consolidation, associated findings, and biopsied lesion characteristics were documented. Lesion size was defined as the mean diameter of the 2 maximal diameters measured on the axial image.

Complications were recorded based on the immediate post-procedural chest CT images and the follow up chest radiographs. Pulmonary hemorrhage was defined as new air space opacities on the needle path or surrounding the lesion seen on the immediate post-procedural chest CT images. The management of patients with post procedural complications, pathological results, cytological results, microbiological results, and clinical follow-ups were obtained from the Hospital Information System.

2.4 Classification of biopsy result and final diagnosis

The final diagnosis was classified as either malignant or benign. The diagnosis of malignancy was made if the CNB result or surgical pathology result confirmed malignancy. A diagnosis of benignity was made if one of the following was found: 1.) CNB result or surgical pathology result was benign, 2.) microbiological analysis detected a specific microorganism, 3.) the lesion was stable or decreased in size during the 2-year follow-up period without any treatment for malignancy.

The histopathologic results of CNB were divided into five categories as follows: 1.) malignant, 2.) specific benign tumor, 3.) non-specific benign such as fibrosis, granuloma, or inflammation without detected specific microorganisms, 4.) infection and 5.) non-diagnostic such as specimen containing only normal lung tissue, blood, or unsatisfactory specimen.

The cytological results from FNA were classified into three categories as follows: 1.) malignancy or possible malignancy, 2.) benign, and 3.) non-diagnostic.

The histopathologic and cytologic results from the previous bronchoscopy, if performed, were also classified in the same way as the PTNB results.

The sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV) of the CT-guided PTNB for diagnosis of malignancy were measured. Malignancy indicated a positive result whereas specific benign, non-specific benign, or infection indicated a negative result. Non-diagnostic results were excluded from calculation. The diagnostic yield was also calculated and was defined as the number of correct diagnoses obtained at CNB/number of definitive diagnoses.

2.5 Statistical analysis

The sensitivity, specificity, PPV, NPV, and accuracy of the CNB and FNA were calculated. Statistical differences between two groups regarding final diagnosis were analyzed using Chi-square or Fisher exact test for categorical variables, and the Mann-Whitney U test for continuous variables. Multivariate analyses were performed using Cox regression model. The statistical testing was performed using SPSS version 23.0 for Windows (SPSS Inc., Chicago, Illinois, USA) with a *P* value of less than 0.05 indicating a statistically significant difference.

3. Results and Discussion

3.1 Study population

From January 2013 to December 2018, 63 patients were studied. The median age was 65 years (interquartile range [IQR]: 53-75 years, range: 20-91 years). There were 39 (61.9%) male patients and 24 (38.1%) female patients. Twenty-one (33.3%) patients were asymptomatic. Among the presenting symptoms, cough was the most common, which was found in 49.2% of patients. Other symptoms were dyspnea (28.6%), weight loss (27.0%), fever (23.8%), hemoptysis (15.9%), and chest pain (1.6%). Only 1 patient had a history of primary lung malignancy. The median time of consolidation before the procedure was 9 weeks (range 1-207 weeks). The indications for biopsy were to exclude malignancy (50 patients, 79.4%) and to rule out infection (13 patients, 20.6%). Most patients obtained only symptomatic treatment before PTNB (44 patients, 69.8%), the remaining received either antimicrobial drugs (17 patients, 27.0%) or steroids (2 patients, 3.2%).

3.2 Evaluation of consolidation before PTNB

Twenty-one (33.3%) patients underwent sputum examination. All were negative on microbiological analysis. Bronchoscopy was obtained in 14 (22.2%) patients. Two patients received only bronchoalveolar lavage (BAL), 10 patients received BAL with transbronchial biopsy and 2 patients had failed bronchoscopies (failure to pass the scope). Among the patients who had a successful bronchoscopy, 1 was positive for malignancy and 11 had non-specific benign changes. The result of 1 malignant case was obtained from only a BAL, thus PTNB was requested for tissue diagnosis and molecular testing.

3.3 Pattern of consolidation, associated findings, and the biopsied lesion characteristics

Forty-three (68.3%) patients had solitary consolidation and 20 (31.7%) patients had multifocal consolidation. The multifocal consolidation was confined to a single lung in 45.0% of patients and scattered in both lungs in 55.0%. Associated mediastinal or hilar lymphadenopathy was found in 27 (42.9%) patients and pleural effusion was found in 24 (38.1%) patients.

The median size of biopsied lesions was 3.4 cm (IQR: 2.5-5.8 cm, range: 1.0-12.0 cm). Among all biopsied lesions, 5 (7.9%) were cavitary consolidation, 39 (61.9%) had air-bronchograms, and 15 (23.8%) had a ground glass component.

3.4 Biopsy outcome

Among the total of 63 lesions, the final diagnosis was malignancy in 33 (52.4%) lesions and benign in 30 (47.6%) lesions. A final diagnosis of malignancy was made based on surgical pathology (n = 10) and a specific malignant result from CNB (n=23). A final diagnosis of a benign lesion was made based on surgical pathology (n=2), a specific benign result from CNB (n=2), staining or culture for microorganism (n=5), and follow-up clinical and/or imaging (n=21).

CNBs were performed in all lesions, whereas FNAs were only done in 29 of the 63 lesions (46.0%), and microbiological analysis was performed in 47 of the 63

lesions (74.6%). Pathological results from CNB were malignancy (n=31, 49.2%), specific benign result (n=4, 6.3%), nonspecific benign lesion (n=20, 31.7%), infection (n=6, 9.5%), and non-diagnostic result (n=2, 3.2%). Cytological results from FNA were malignancy (n=12/29), benignity (n=14/29), and non-diagnostic result (n = 3/29). The diagnostic yield of CNB for both benign and malignant lesions was 88.9% (56/63 lesions). Of the 33 proven malignant lesions, 31 (93.9%) were accurately diagnosed with CNB. Of the 30 proved benign lesions, 25 (83.3%) were correctly diagnosed with CNB. The correlation between final diagnosis and CNB results are summarized in Table 1.

Table 1. Correlation between final diagnosis and CNB result (n=63).

Lung lesions	Final diagnosis	CNB result
Malignant		
Primary lung malignancy		
Adenocarcinoma	28	26 [a]
Squamous cell carcinoma	2	2
B-cell lymphoma	1	1
Metastasis		
Adenocarcinoma	2	2
Benign		
Nonspecific inflammation	16	20
Infection		
Pulmonary tuberculosis	5	4
Pneumococcal pneumonia	1	0
Cryptococcal pneumonia	1	1
Angioinvasive aspergillosis	1	0
Mucormycosis	1	1
Organizing pneumonia	3	3
Inflammatory myofibroblastic tumor	1	1
Sarcoidosis	1	0
Non-diagnosis	0	2

Note: CNB, core needle biopsy

[a] One result was nonspecific inflammation and the other result was non-diagnosis.

Among the 14 patients who obtained bronchoscopy, PTNB provided a diagnosis of malignancy in 5 cases, 3 of which were non-specific benign lesions by bronchoscopy (Fig. 1), 1 had malignant result from bronchoscopy but inadequate tissue for molecular testing, and 1 was a bronchoscopy failure. For the remaining 9 patients, PTNB results were non-specific benign in 7 patients and infection in 2 patients, which all were true-negative cases.

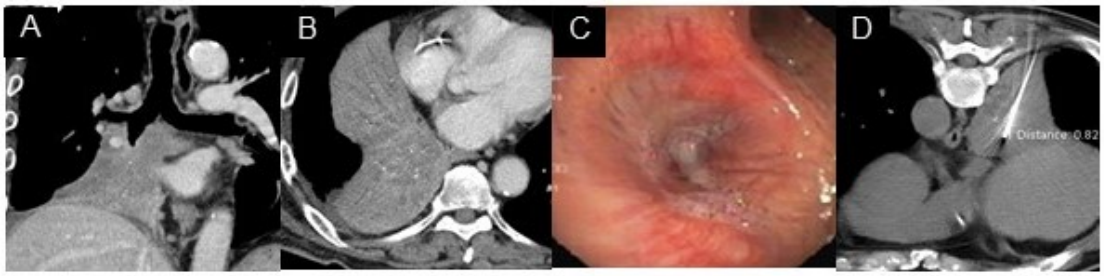

Fig. 1. An 85-year-old male presented with chronic cough for 1 year. Coronal (A) and axial (B) contrast-enhanced CT chest showed abrupt occlusion of right bronchus intermedius with consolidation involving RML and RLL. (C) Bronchoscopy revealed mass at right bronchus intermedius with contact bleeding. The pathological result from bronchial washing showed only reactive pneumocytes with necrotic debris and sparse inflammation. (D) CT chest during the TTNB showing the biopsy needle in the target lesion. The pathological result from CNB was squamous cell carcinoma.

There was 1 false-negative result by CNB, which showed mild chronic inflammation. However, the follow up CT of the chest at the 15th month showed unchanged size, but increased density of the lesion. Percutaneous indocyanine green (ICG) localization followed by surgical lobectomy was performed to confirm the diagnosis of primary adenocarcinoma of the lung (Fig. 2). Sensitivity, specificity, PPV, NPV, and accuracy of the CNB for the diagnosis of malignancy were 96.9%, 100%,

100%, 96.7%, and 98.4%, respectively. Regarding FNA results, there were 4 false-positive cases and 2 false-negative cases. The sensitivity, specificity, PPV, NPV, and accuracy of the FNA for the diagnosis of malignancy were 80.0%, 73.3%, 66.7%, 84.6%, and 76.0%, respectively. The concordance between CNB and FNA results was 58.6%. Sensitivity, specificity, PPV, NPV, and accuracy of CNB alone, FNA alone, and CNB with FNA for the diagnosis of malignancy are summarized in Table 2.

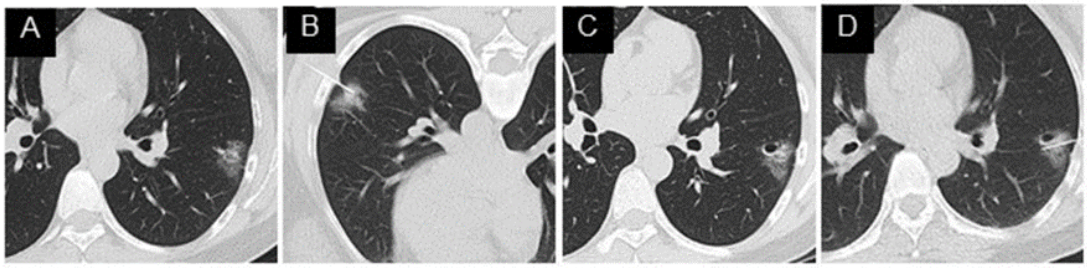

Fig. 2. A 47-year-old female was incidentally found to have a focal patchy opacity on a check-up CXR (not shown). (A) Axial CT chest showed a focal consolidation with peripheral ground glass opacity at the left lower lobe. (B) CT chest during the TTNB procedure in prone position showed the biopsy needle in the target lesion. The pathological result from CNB was mild chronic inflammation and no malignancy. (C) Follow-up CT chest 16 months later showed an unchanged size, but a slightly increased density. (D) CT chest during indocyanine green (ICG) localization showed the needle in the lesion. The pathological result from left lower lobectomy was adenocarcinoma of the lung.

Table 2. Sensitivity, specificity, PPV, NPV, and accuracy for the diagnosis of malignancy.

Diagnostic test	TP	TN	FP	FN	Non-diagnostic [a]	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
CNB (n=63)	31	29	0	1	2	96.9	100.0	100.0	96.7	98.4
FNA (n=29)	8	11	4	2	4	80.0	73.3	66.7	84.6	76.0
CNB + FNA (n=29)	11	17	0	0	1	100.0	100.0	100.0	100.0	100.0

Note: CNB, core needle biopsy; FNA, fine needle aspiration; TP, true positive; TN, true negative; FP, false positive; FN, false negative; PPV, positive predictive value; NPV, negative predictive value

[a] Non-diagnostic result was not used for calculation of sensitivity, specificity, PPV, NPV and accuracy.

3.5 Complications

Pneumothorax occurred in 21 patients (33.3%) but none needed percutaneous drainage. Pulmonary hemorrhage was found in 24 patients (38.1%), and 11 patients (17.5%) had both a pneumothorax and a pulmonary hemorrhage. All improved after conservative treatment. A reactive pleural effusion occurred in 1 patient (1.6%). There was no post procedure-related mortality.

3.6 Potential risk factors for malignant outcome

Correlations between final diagnoses and clinical/imaging features were studied. The result of the univariate analysis to identify independent risk factors for malignancy are shown in Table 3. Multivariate logistic regression analysis is displayed in Table 4. The significant independent risk factors for a malignant result were advanced age (p = 0.004) and lower lobe localization (p = 0.026).

Table 3. Results of univariate analysis to identify risk factors for malignant outcome.

Variables	Malignant (n = 33)	Benign (n = 30)	p-value
Male/Female	17/16	22/8	0.075
Age (years) [M]	71.0 [60.0-76.5]	59.5 [46.5-67.5]	0.003*
Underlying disease			
COPD (+/-) [F]	2/31	1/29	>0.999
Immunocompromise (+/-)	6/27	9/21	0.271
Primary lung malignancy (+/-) [F]	1/32	0/30	>0.999
Other malignancy (+/-)	5/28	8/22	0.259
Pattern of consolidation			
Number (single/multifocal)	24/9	19/11	0.424
Distribution (one lung/both lungs)	29/4	23/7	0.242
Lobar involvement (1 lobe/>1 lobe)	26/7	22/8	0.612
Lymphadenopathy (+/-)	15/18	12/18	0.662
Pleural effusion (+/-)	14/19	10/20	0.458
Biopsied lesion characters			
Lesion size (cm) [M]	3.5 [2.7-6.5]	3.2 [2.2-4.8]	0.154
Area involvement (subsegmental/segmental/lobar)	19/8/6	17/8/5	0.971
Lesion location [F] (RUL/RML/RLL/LUL/LLL)	8/0/13/4/8	6/8/5/6/5	0.008*
(upper & middle lobes/lower lobe)	12/21	20/10	0.016*
GGO (+/-)	8/25	7/23	0.933
Cavity (+/-) [F]	3/30	2/28	>0.999
Air bronchogram (+/-)	21/12	18/12	0.767
Abutting pleura (+/-) [F]	27/6	24/6	0.854

Note: Data are presented as n or median [interquartile range, IQR].
COPD, chronic obstructive pulmonary disease; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; GGO, ground glass opacity.
*Statistically significant at p-value<0.05 determined by Chi-square test, [F] Fisher's exact test and [M] Mann-Whitney U test.

Table 4. Results of multivariate analysis to identify risk factors for malignant outcome.

Factor	Univariate			Multivariate		
	Crude OR	95%CI	p-value	Adjusted OR	95%CI	p-value
Age	1.07	1.02-1.11	0.003*	1.07	1.02-1.11	0.004*
Lesion location						
Upper & middle lobes	Ref.			Ref.		
Lower lobes	3.50	1.24-9.89	0.018*	3.71	1.17-11.77	0.026*

Note: *Statistically significant at p-value<0.05 determined by logistic regression with enter method. OR, Odds ratio; CI, confidence interval; Ref., Reference.

3.7 Discussion

Pulmonary consolidation is a commonly encountered problem caused by various conditions. PTNB plays a role in making a definitive diagnosis. Our study showed that CT-guided PTNB with CNB had an overall diagnostic yield of 88.9% (56/63 lesions), which was 93.9% for malignant lesions and 83.3% for benign lesions. The overall diagnostic yield in this study was slightly better than previous results, which range from 60-87.5% [7-11]. This could have been due to the fact that our study showed a higher accuracy rate on the benign group while having a comparable accuracy rate on the malignant group. Nineteen of 20 (95.0%) nonspecific benign results from CNB in our study were true negatives.

Seven cases of diagnostic failure consisted of 1 failure to detect malignancy (false-negative), 3 failures to detect micro-organisms, 1 failure to diagnose sarcoidosis, and 2 non-diagnostic results. Sensitivity, specificity, PPV, NPV, and accuracy of the CT-guided PTNB for the diagnosis of malignancy were 96.9%, 100%, 100%, 96.7%, and 98.4%, respectively. One false negative result in this study occurred in a patient with focal consolidation and a high degree of surrounding ground glass opacity.

Hur et al. [12] reported that the diagnostic accuracy of needle aspiration biopsy was significantly lower in lesions with high ground glass components. This is probably due to low cellularity of the ground glass lesion making it more difficult to obtain adequate tissue for diagnosis.

Of the 2 non-diagnostic results (3.2%), 1 was a primary adenocarcinoma of the lung and the other was nonspecific inflammation. This suggests that the rate of malignancy in non-diagnostic results is 50%. Even though we only had 2 non-diagnostic patients, this rate is comparable with findings from a meta-analysis [13] which reported that the pooled incidence of non-diagnostic results of PTNB was 6.8% and the pooled malignancy rate of non-diagnostic results was 59.3%. Given the high proportion of missed malignancy in non-diagnostic results, we suggest that patients should be diligently investigated e.g., performing repeat biopsy or surgical exploration in cases of non-diagnostic results where the clinical suspicion of malignancy remains high.

On the other hand, among the 20 (31.7%) nonspecific benign results, 19 (95.0%) were truly benign, mostly due to nonspecific inflammation (16/19, 84.2%). This rate contrasts with the findings of a meta-analysis study [13], which reported that the pooled rate of malignancy in nonspecific benign results was 20.6%. This discrepancy may be due to our small sample size. We suppose that further study of the pooled nonspecific benign result with clinical and imaging subgroup analysis might specifically demonstrate the malignancy rate of nonspecific benign results.

Our study showed that in 14 patients with diagnostic failure from prior bronchoscopy, further CT-guided PTNB provided a definitive diagnosis in 6 (42.9%) patients, provided adequate tissue for molecular testing in 1 (7.1%) patient, and gave a true-negative non-specific benign diagnosis in 7 (50.0%) patients. These results are similar to previous results from Kiranantawat et al. [9] who showed that CT-guided PTNB provided a definitive diagnosis in all cases of consolidation that were not diagnosed by bronchoscopy, be they malignancy or infection. These findings confirm that CT-guided PTNB is a valuable approach to consolidation where bronchoscopy fails to make a diagnosis.

FNA was performed in addition to CNB in 29 (46.0%) of 63 cases. Our study showed that FNA alone had higher rates of false positive, false negative, and non-diagnostic results, resulting in lower sensitivity, specificity, and accuracy for the diagnosis of malignancy as compared with CNB alone. Additionally, the diagnostic yields of FNA alone were only 50.0% (9/18 lesions) for benign diseases and 72.7% (8/11 lesions) for malignancy. With even just a small number of patients with FNA, our results are analogous to previous studies [7, 14-15] which showed that CNB had significantly higher sensitivity for the diagnosis of malignancy and FNA provided fewer specific diagnosis for benignity. This could imply that CNB alone is adequate for diagnosis and additional FNA may not be necessary in daily practice.

In our study, malignancy was found in 33 (52.4%) patients due mostly to primary adenocarcinoma of the lung, consistent with previously reported rates of malignancy in non-resolving pulmonary consolidation, ranging from 39.6% to 69.0% [8-11]. Many CT findings which could potentially aid in differentiating malignant from non-malignant lung disease have been studied [16-19]. Although this study did not analyze the specific imaging characteristics of consolidation, we found that lesions located in the lower lobes were associated significantly with malignancy, as was advanced age.

The second most common etiology of consolidation in our study was nonspecific inflammation (16/63, 25.4%). This finding is similar to that found in a retrospective review by Brioulet et al. [11], who reported a

nonspecific inflammation rate of 32.2% (30/93). This relatively high rate may be due to non-specific inflammation encompassing a broad range of causes such as autoimmune, toxic, allergic, drug, and neoplastic conditions, as well as infection. Even though the pattern of tissue reaction on pathological analysis narrows the differential diagnosis, a complete clinical history, laboratory, and microbiological investigations, as well as imaging and clinical follow-up may be needed for obtaining a definitive diagnosis. In this study, 4 (25.0%) of 16 patients with nonspecific inflammation did not have microbiological analyses performed during PTNB, and 6 (37.5%) of 16 patients received anti-microbial treatment before PTNB. These are likely to obscure the final diagnosis.

In our study, there were no serious complications or deaths. The rate of pneumothorax was 33.3% and none required percutaneous drainage. This rate is consistent to that reported by others for PTNB-related consolidation, varying from 8.3% to 48% [7-11], and all lesion PTNB for percutaneous needle biopsy, 12% to 45% [20]. The rate of pulmonary hemorrhage in this study was 38.1% and all cases improved after conservative management. This is comparable with previous reported rates from two large studies on pulmonary hemorrhage after PTNB, ranging from 26.8% to 41.1% [21, 22]. Tai et al. [22] also found that for lung consolidation, low-grade hemorrhage was significantly more likely to occur than high-grade hemorrhage. Wattanasatesiri et al. [23] reported a significantly lower rate of pulmonary hemorrhage in consolidation compared to other lung lesions. This is probably because consolidation is a compact lesion, which could afford a tamponade effect in the setting of bleeding.

Our study had some limitations. Firstly, this was a small retrospective study, which limited statistical power and could have introduced unknown biases e.g., selection, and incomplete data. Secondly, the biopsy techniques, as well as the choice and number of tissue sampling were based on the operator's discretion, which may have had an impact on diagnostic yield and complications. Thirdly, the final diagnosis was nonspecific inflammation in a large proportion of cases, some 25%, but we believe that with long term follow up, the majority of these lesions would be diagnosed as benign.

4. Conclusion

CT-guided PTNB of pulmonary consolidation provides a high diagnostic yield with a reasonable rate of minor complications. PTNB plays an important diagnostic role for pulmonary consolidation, especially in cases with prior nondiagnostic bronchoscopy. Malignancy was found in 52.4% of patients with pulmonary consolidation due mostly to primary adenocarcinoma of the lung. The risk factors for malignant outcome are advanced age and lower lobe localization.

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