


# The Value of Computed Tomography-Guided Percutaneous Lung Biopsy Combined With Rapid On-Site Evaluation in Diagnosis of Peripheral Pulmonary Nodules

Technology in Cancer Research & Treatment  
Volume 21: 1-7  
© The Author(s) 2022  
Article reuse guidelines:  
sagepub.com/journals-permissions  
DOI: 10.1177/15330338221118718  
journals.sagepub.com/home/tct  


Wei Liu, MD<sup>1</sup>, Chunhua Xu, MD<sup>1,2</sup> , Li Li, MD<sup>1,2</sup>, Qi Yuan, MD<sup>1,2</sup>, Wei Wang, MD<sup>1,2</sup>, and Jue Zou, MD<sup>1</sup>

## Abstract

**Objective:** To investigate the value of computed tomography-guided percutaneous lung biopsy (CT-PLB) combined with rapid on-site evaluation (ROSE) in the diagnosis of peripheral pulmonary lesions (PPLs). **Methods:** A total of 108 patients who diagnosed with PPLs by chest CT examination were prospectively collected and randomly divided into ROSE group (n = 56) and No-ROSE group (n = 52). Both groups received CT-PLB and pathological examination. The smear submitted for ROSE was stained using Diff Quik dye. The accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), number of punctures, puncture time and incidence of complications were compared between the two groups. **Results:** The accuracy, sensitivity, specificity, PPV, and NPV of the ROSE group were 89.29%, 87.50%, 91.67%, 93.33%, and 84.62%, respectively. The number of punctures in the ROSE group was significantly lower than that in the No-ROSE group ( $P < .05$ ). The incidence of pneumothorax and hemoptysis in the ROSE group were lower than those in the No-ROSE group, but there was no statistical difference between the two groups ( $P > .05$ ). ROSE has good concordance with routine pathological examination in the diagnosis of unidentified PPLs (Kappa = 0.786,  $P < .01$ ). **Conclusions:** CT-PLB combined with ROSE is a safe and effective method for the diagnosis of PPLs.

## Keywords

CT-guided, biopsy, rapid on-site evaluation, peripheral pulmonary lesions, diagnosis

Received: November 10, 2021; Revised: July 19, 2022; Accepted: July 21, 2022.

## Introduction

With the development of imaging technology, peripheral pulmonary lesions (PPLs) are becoming more and more common in clinical.<sup>1</sup> Early detection and corresponding intervention can effectively reduce the incidence of lung cancer and improve the prognosis. By systematically analyzing the clinical manifestations and chest imaging characteristics, it is often difficult to judge the benign and malignant of PPLs, which is not conducive to follow-up treatment. At this time, pathological diagnosis is particularly important.

According to the nature of PPLs, they can be divided into benign and malignant lesions. Malignant lesions are usually bronchial lung cancer.<sup>2</sup> Since most patients with lung cancer have developed to the advanced stage at the initial diagnosis, they have lost the opportunity of operation at the time of diagnosis.<sup>3</sup> Computed tomography-guided percutaneous lung

biopsy (CT-PLB) is a common technique to obtain pathological diagnosis of lung lesions. For the successful puncture and removal of diseased tissue, it depends on the empirical judgment of the piercer's naked eye. Finally, it needs to wait for the confirmation of the pathological report. The waiting time

<sup>1</sup> Affiliated Nanjing Brain Hospital, Nanjing Medical University, Nanjing, Jiangsu, China

<sup>2</sup> Nanjing Chest Hospital, Nanjing, Jiangsu, China

Wei Liu and Jue Zou are contributed equally to this work.

## Corresponding Author:

Chunhua Xu, Department of Respiratory Medicine, Affiliated Nanjing Brain Hospital, Nanjing Medical University, Nanjing Chest Hospital, 215 Guangzhou Road, Nanjing 210029, China.  
Email: xuch2188@163.com.



is less than 2–3 days and more than 1 week. If the lesion tissue is not punctured successfully, it needs to be punctured again, which not only wastes the cost, but also wastes the patient's valuable time. Therefore, how to early and quickly judge whether the pathological tissue is successfully punctured and removed is an urgent problem to be solved. At the same time, with the advent of the era of precision treatment, targeted therapy and immunotherapy are playing an increasingly important role in the treatment of lung cancer. It is also an urgent problem to obtain enough samples to evaluate the gene status and immune status of patients. ROSE is a technology for rapid evaluation and preliminary diagnosis of collected tissue samples and guiding the next operation.<sup>4</sup> This technology is mainly used in the process of bronchoscopy. Biopsy specimens are made and stained on site, and then quickly evaluated to judge whether the biopsy is successful.<sup>5,6</sup> It is reported that ROSE was also used in endobronchial ultrasound-guided fine needle aspiration, which can improve the diagnostic yield, reduce the number of puncture, and reduce the incidence and cost of complications.<sup>7,8</sup> ROSE, an auxiliary technique applied in interventional pulmonology, is a real-time cytologic interpretation technology and sampling process.<sup>9–12</sup> Our study is aimed to investigate the value of ROSE in the diagnosis of PPLs during CT-PLB.

## Materials and Methods

### Patients

This study is a prospective randomized clinical study. In total, 204 patients who were hospitalized in Nanjing Chest Hospital from January 2018 to December 2019 and diagnosed as PPLs by chest CT were consecutively recruited, including 108 patients who underwent CT-PLB. The patients were randomly divided into ROSE group (n=56) and No-ROSE group (n=52). Inclusion criteria: chest CT or PET-CT showed PPLs; the lesions were at the level of subsegment and below the segmental bronchus; the age was 18–90 years. Exclusion criteria: patients with severe cardiopulmonary dysfunction; coagulation

dysfunction; those who cannot tolerate puncture. The study has been reported in accordance with the Standards for Reporting Diagnostic accuracy studies (STARD) checklist. Supplemental Figure 1 shows the flow of participants through the study.

### Procedure of CT-PLB

The clinician informed the purpose and precautions of puncture before operation. There was no abnormality in electrocardiogram, coagulation function, other routine examinations before operation. CT examination was performed in all patients. In total, 128 slice spiral CT was used (Aquilion, Toshiba). The supine position was taken, and the slice thickness was 1 mm. Continuous scanning was performed at a 10 mm slice distance from the top of the lung to the bottom of the lung. The puncture was performed by a professional physician, and the patient took the appropriate lying position according to the lesion position shown by CT. CT images were used to measure the size of the lesion and the distance from the pleura, to avoid large blood vessels and bone structure, to select the puncture point, to mark it, to sterilize it regularly, to lay a towel, to infiltrate the anesthetic pleura layer by layer with 2% lidocaine, and to puncture outside the pleura wall. After the CT scan confirms the direction of the puncture needle, puncture the puncture needle into the lung tissue, and scan again to confirm that the direction of the puncture needle is correct. If necessary, adjust the direction and puncture the puncture needle to the focus (Figure 1). All operations were performed by the same physician as the main operator. In ROSE group, the pathologist printed the specimens on site, immediately performed Diff Quik staining, and then read the specimens with a special cytological microscope. The operation was completed within 3 min.<sup>13</sup> If microscopic observation showed pathological cells and the sample was sufficient, the puncture shall be stopped. If no pathological cells were observed or the materials were not sufficient, decide whether to take materials again according to the complications. In the No-ROSE group, the sample satisfaction was judged by the puncture physician with the naked eye, and the puncture times were determined according to the complications.<sup>14</sup> The obtained tissue was fixed with 10% formaldehyde solution and immediately sent to the Department of pathology for examination.

After puncture, routine chest CT scanning was performed to observe whether there were complications such as pneumothorax. Those without pneumothorax and bleeding were advised to stay in bed for 24 h. For patients developed a little pneumothorax post operation, chest x-ray was checked to observe pneumothorax absorption after bed rest and oxygen therapy in 1 week. Patients were ordered to stay in bed and take hemostatics if needle-path hemorrhage or small quantity of hemoptysis was found. The placement of a chest tube and anti-infection was considered in the event a patient became symptomatic and dyspnea, chest distress, massive hemorrhage or a large pneumothorax was found.

### Procedure of ROSE

After each patient's biopsy, pick out the tissue with a disposable 5 ml syringe needle, and smear a circle with a diameter of about



**Figure 1.** Computed tomographic (CT) scan of lesions.

1 to 1.5 cm from the inside to the outside on the special slide for cytology. The thickness is moderate. One smear of each tissue was used for ROSE. The remaining tissue after the smear was placed in the pathology bottle to be sent to the pathology department for routine pathological examination. According to the on-site sampling, at least 2 tissues and 2 smears were biopsied for ROSE. At the operation site, the ROSE cytological smears were quickly stained with Diff Quik dye, and the Diff A solution, Diff B solution, phosphate buffer and clean water were poured into the glass dye tank with cover. Immerse the cytological smears in Diff A solution for 30 to 35 s, then put it into the phosphate buffer dye tank to wash, wash off the Diff A solution, shake it dry, and then soak the substrate in the Diff B solution for 40 s. Finally, wash off the dye in clean water, wipe the glass slide with absorbent paper to complete the dyeing.

### Diagnostic Criteria

Diagnostic criteria of malignant lesions include patients whose biopsy histopathological findings showed malignancy and who received surgical resection were considered as malignant. Patients whose biopsy histopathological findings showed malignancy and with no surgical indication after systemic evaluation or with less willing to accept surgery were considered to be positive when the tumor size was reduced after radiotherapy, chemotherapy, or targeted therapy. Diagnostic criteria for benign lesions: patients whose biopsy histopathological findings showed a benign lesion, a true benign nature was demonstrated if the SPN had shrunk, disappeared, or there was no change after follow-up for more than 1 year.

### Statistical Analysis

SPSS 20.0 software was used to analyze the data. The counting data is expressed in percentage (%), and the comparison is adopted  $\chi^2$  inspection. The measurement data were expressed in  $x \pm s$ , and *t*-test is used for comparison. Correlations between the ROSE group and the final pathological results were assessed using the kappa statistic. The sensitivity, specificity, PPV, NPV and diagnostic accuracy of ROSE during

CT-PLB were derived according to the relevant final pathologic results. A power calculation was performed to estimate the selected sample size for the study.  $P < .05$  was considered statistically significant.

## Results

### Clinical Data

We enrolled 204 patients in our study, including 108 patients who underwent CT-PLB and 96 who did not. There was no significant difference in gender, age, lesion size, distance from lesion to pleura and pulmonary distribution of lesions between the ROSE group and the No-ROSE group ( $P > .05$ ) (Table 1).

### Pathological Results of the ROSE and No-ROSE Group

There were 56 cases in ROSE group, including 30 cases of malignant lesions (53.57%) and 26 cases of benign lesions (46.43%). In ROSE group, the final pathological diagnosis was 32 cases of malignant lesions (57.14%), including 5 cases of squamous cell carcinoma, 24 cases of adenocarcinoma, 2 cases of small cell lung cancer (SCLC), 1 case of non-small-cell lung cancer-not otherwise specified (NSCLC-NOS), and 24 cases of benign diseases (42.86%), including 11 cases of inflammation, 4 cases of tuberculosis, 3 cases of fungal infection, 1 cases of sarcoidosis and 4 cases of atypical hyperplasia. In the No-ROSE group, there were 28 cases (53.85%) of malignant lesions, including 3 cases of squamous cell carcinoma, 19 cases of adenocarcinoma, 2 cases of SCLC and 4 cases of NSCLC-NOS, and 24 cases of benign lesions (46.15%), including 13 cases of inflammation, 4 cases of tuberculosis, 3 cases of fungal infection, 1 cases of sarcoidosis and 3 cases of atypical hyperplasia. The specific pathological types are shown in Table 2.

**Table 2.** Final Pathological Diagnosis Results of CT-PLB With or Without ROSE.

Result		ROSE group (ROSE results)	No-ROSE group
Malignant lesions	Adenocarcinoma	24 (14)	19
	Squamous cell carcinoma	5 (3)	3
	SCLC	2 (3)	2
	NSCLC-NOS	1 (10)	4
	Inflammation	11 (13)	13
Benign lesions	Tuberculosis	4 (5)	4
	Fungal infection	3 (3)	3
	Sarcoidosis	1 (1)	1
	Atypical hyperplasia	4 (4)	3
	Total	56	52

CT-PLB, computed tomography-guided percutaneous lung biopsy; ROSE, rapid on-site evaluation; NSCLC-NOS, non-small cell lung cancer-not otherwise specified; SCLC, small cell lung cancer.

**Table 1.** Characteristics of the 2 Groups of Patients.

Group	Gender(male/ female)	Age (years)	Size of PPLs (mm)	Distance from PPLs to pleura (mm)	Location of PPLs (upper/ lower)
ROSE	30/26	59.83 ± 12.15	2.48 ± 0.42	4.38 ± 0.85	20/36
No-ROSE	28/24	59.36 ± 12.57	3.37 ± 0.54	4.67 ± 1.03	19/33
<i>P</i>	.565	.519	.637	.873	.544

ROSE, rapid on-site evaluation; PPLs, peripheral pulmonary lesions.

**Table 3.** Comparison of CT-PLB Combined With or Without ROSE Diagnosis for PPLs.

ROSE group	Final pathological diagnosis			No-ROSE group	Final pathological diagnosis		
	Malignant lesions	Benign lesions	Total		Malignant lesions	Benign lesions	Total
Malignant lesions	28	2	30		24	4	28
Benign Lesions	4	22	26		5	19	24
Total	32	24	56		29	23	52

CT-PLB, computed tomography-guided percutaneous lung biopsy; ROSE, rapid on-site evaluation; PPLs, peripheral pulmonary lesions.

**Table 4.** Correlation Between the Rapid On-Site Evaluation (ROSE) Results and Pathology in ROSE Group.

ROSE results	Pathological results		
	Malignant lesions	Benign lesions	Total
Malignant lesions	28	2	30
Benign lesions	4	22	26

### Comparison of CT-PLB Combined With or Without ROSE Diagnosis for PPLs

In ROSE group, the diagnosis of PPLs by ROSE combined with CT-PLB, the diagnostic accuracy, sensitivity, specificity, PPV and NPV was 89.29%, 87.50%, 91.67%, 93.33%, and 84.62%, respectively. In No-ROSE group, the diagnostic accuracy, sensitivity, specificity, PPV and NPV was 82.69%, 82.76%, 82.61%, 85.71%, and 79.17%, respectively (Table 3).

### Correlation Between the ROSE Result and Pathology in ROSE Group

The ROSE results and pathological results were shown in Table 4. Among them, the consistent rate of malignant lesions was 87.50% (28 of 32), and that of benign lesions was 84.62% (22 of 26). The ROSE results were in high consistency with the pathological results ( $\kappa = 0.786, P < .01$ ).

### Comparison of Puncture Related Indexes Between ROSE and No-ROSE Group

The number of puncture in ROSE group was ( $2.18 \pm 0.61$ ), the average puncture time was ( $16.08 \pm 3.18$ ) min, and the number of puncture in No-ROSE group was ( $3.38 \pm 0.75$ ), the average puncture time was ( $17.36 \pm 3.36$ ) min. there was no significant difference in puncture time between the two groups ( $P > .05$ ), but there was significant difference in number of puncture ( $P < .05$ ) (Table 5).

In ROSE group, 4 cases of HE staining also showed that the specimens were insufficient, and a second puncture biopsy was performed within 1 month. In No-ROSE group, 11 cases were negative or insufficient, and secondary puncture was performed within 1 month. The second biopsy rate in ROSE group was lower than that in No-ROSE group (7.14% vs 21.15%,  $P < .05$ ) (Table 5).

The incidence of complications in the ROSE group was 28.57%, including pneumothorax in 10.71% of cases and hemoptysis in 17.86% of cases. The incidence of complications in the No-ROSE group was 34.62%, including pneumothorax in 13.46% cases, and hemoptysis in 21.15% of cases. There was no significant difference between the two groups ( $P > .05$ ) (Table 5).

### Cytological Characteristics of Smears by ROSE

Smears of adenocarcinoma were composed of adenoid structure, different sizes, abundant cytoplasm, and cells scattered in multiple nucleoli (Figure 2a). SCLC manifests as obvious irregular cell morphology and naked nucleus drawing like changes (Figure 2b). Pulmonary abscess appears as a large number of neutrophils and necrotic cells (Figure 2c). Tuberculosis presents as granular and amorphous debris with poorly preserved granulomas (Figure 2d).

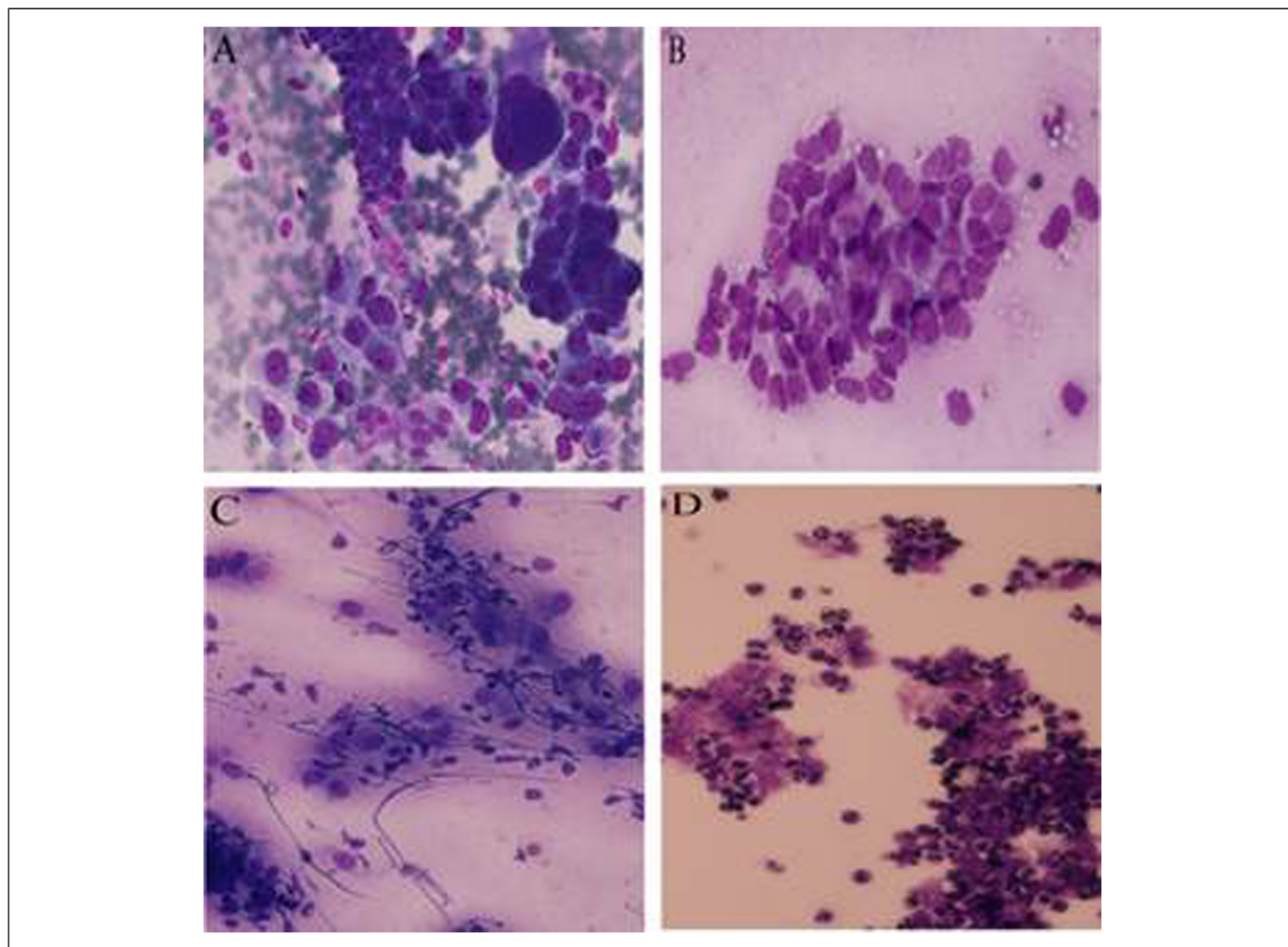
### Discussion

ROSE is a rapid on-site evaluation technology for rapid production, staining and interpretation of the obtained samples when collecting samples by puncture, biopsy, brush film and other methods. Using this technique, the satisfaction of specimens can be quickly evaluated and the flow direction of specimens can be guided. Form a preliminary diagnosis to guide further diagnosis and treatment. It was first applied to the field evaluation of specimens obtained by transbronchial needle aspiration (TBNA). In patients with negative ROSE, the number of TBNA puncture will increase. The positive patients may help to reduce the number of puncture guide the selection of positive sites, take more samples for molecular biology detection, and reduce unnecessary further examination. In the diagnosis and treatment of central lung tumors, ROSE can shorten the operation time and obtain more tissues for postoperative immunohistochemistry and gene detection.<sup>15</sup> However, there are few reports on the application of ROSE during CT-PLB.

This study found that ROSE had high sensitivity and specificity. The PPV was 93.33%, the NPV was 84.62%, and the diagnostic accuracy was 89.29%, which was highly consistent with the histopathological results. ROSE is a rapid staining of cell smears, so it is also insufficient in diagnosis. ROSE lacks histological morphology, can't effectively distinguish the

**Table 5.** Comparison of Index Between Rapid On-Site Evaluation (ROSE) and No-ROSE Group.

Group	Number of puncture (times)	Puncture time (min)	Pneumothorax [% (n)]	Hemoptysis [% (n)]	Secondary biopsy [% (n)]
ROSE	2.18 ± 0.61	16.08 ± 3.18	10.71 (6/56)	17.86 (10/56)	7.14 (4/56)
No-ROSE	3.38 ± 0.75	17.36 ± 3.36	13.46 (7/52)	21.15 (11/52)	21.15 (11/52)
<i>P</i>	.035	.386	.443	.424	.033

**Figure 2.** Cytological characteristics of ROSE for AC, SCLC, tuberculosis and pulmonary abscess. ROSE: rapid on-site evaluation; SCLC: small cell lung cancer.

pathological types of lung cancer, and can only preliminarily judge benign and malignant.

ROSE combined with CT-PLB can ensure the adequacy of sampling, improve the diagnostic yield, reduce the number of puncture and complications, and provide support and help for the early screening of malignant pulmonary lesions.<sup>16-18</sup> This study showed that under the guidance of ROSE technology, the number of punctures is less than that of the No-ROSE group, which may be due to the guidance of ROSE technology for material collection. If satisfactory specimens were obtained, the puncture will be stopped. There was no significant difference in puncture

time between the two groups. Although ROSE may take some time due to dyeing, production and reading, this part of time can be greatly shortened with the increase of operator proficiency, so the difference in puncture time was not statistically significant. With the maturity of this technology, the puncture times will be further controlled and the puncture time will be further shortened.

With the advent of the era of precision treatment, obtaining enough samples to evaluate the patient's pathological type, molecular typing, gene status and immune status is an urgent problem to be solved in medicine. Traditional CT-PLB can't ensure that effective specimens can be taken every operation.

A few patients even need secondary puncture, which increases the cost and risk of patients and even the time for patients to wait for treatment. In this study, the samples were taken under the guidance of ROSE technology. Because they could not be diagnosed, the secondary biopsy rate was lower than that of No-ROSE group. Therefore, ROSE is a significance in specimen prediction and guiding further diagnosis. In clinical, the author is also discussing whether ROSE can retain the tissue for direct gene detection because of its high predictive value, so as to save the time waiting for histopathological examination and avoid the tissue consumption caused by immunohistochemistry for diagnosis. In terms of adverse reactions, pneumothorax and hemoptysis are the most common adverse reactions of CT-PLB. There was no significant difference in the incidence of pneumothorax and hemoptysis between ROSE group and No-ROSE group, indicating that ROSE did not increase the incidence of adverse reactions.

This study was similar to previous studies. The conclusion is that CT-guided fine needle aspiration cytology is a safe and effective method for the diagnosis of pulmonary nodules, with high sensitivity and specificity.<sup>19,20</sup> ROSE can subclass the morphological types of bronchial carcinoma in most cases.<sup>21</sup> The use of ROSE helps to ensure the adequacy of samples and reduce the number of puncture, so as to minimize complications such as pneumothorax.<sup>22</sup>

The technical access requirements for ROSE are relatively low and the required equipment is simple. Only one microscope, Diff reagent and short-term trained medical personnel are required, including clinicians, technicians and even nurses. Studies have shown that after 3 months of training in ROSE diagnostic system, the accuracy rate of general doctors can reach 80%, while that of specialized cytopathologists is 92%. There is no significant difference between the two.<sup>23</sup> Therefore, ROSE has been carried out in about 55% of centers in Asia and almost all (98%) in the United States.<sup>24</sup>

There are two limitations in our studies. First, it is a single-center study. Second, the study sample size is a little small and we hope to continue to study this problem in our future study after more samples were collected.

## Conclusions

In conclusion, the application of ROSE in the diagnosis and treatment of CT-PLB improves the diagnostic efficiency. Without increasing complications, it may predict the flow direction of samples, which is safe and effective, and is worthy of clinical promotion.

## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work

was supported by the the Major Program of Nanjing Medical Science and Technique Development Foundation, (grant number ZKX18047).


## Ethical Statement

The study was approved by the Ethics Committee of Nanjing Chest Hospital, Nanjing, China (April 2014, approval number: 2021067).

## Informed Consent

All patients provided written informed consent before enrollment.

## ORCID iD

Chunhua Xu  <https://orcid.org/0000-0001-8728-2183>

## Supplemental material

Supplemental material for this article is available online.

## References

- Xu C, Wang Y, Wang W, Yuan Q, Hu HD, Li L. Improved diagnostic yield of transbronchial lung biopsy in peripheral pulmonary lesions using a combination of endobronchial ultrasound and rapid on-site evaluation. *J Int Med Res.* 2021;49(3):1-9.
- Harzheim D, Eberhardt R, Hoffmann H, Herth FJ. The solitary pulmonary nodule. *Respiration.* 2015;90(2):160-172.
- Chen W, Zheng R, Baade PD, et al. Cancer statistics in China, 2015. *CA Cancer J Clin.* 2016;66(2):115-312.
- Jain D, Allen TC, Aisner DL, et al. Rapid on-site evaluation of endobronchial ultrasound-guided transbronchial needle aspirations for the diagnosis of lung cancer: a perspective from members of the pulmonary pathology society. *Arch Pathol Lab Med.* 2018;142(2):253-262.
- Yang F, Liu E, Sun S. Rapid on-site evaluation (ROSE) with EUS-FNA: the ROSE looks beautiful. *Endosc Ultrasound.* 2019;8(5):283-287.
- Minami D, Takigawa N, Inoue H, Hotta K, Tanimoto M, Kiura K. Rapid on-site evaluation with BIOEVALUATOR(R) during endobronchial ultrasound-guided transbronchial needle aspiration for diagnosing pulmonary and mediastinal diseases. *Ann Thorac Med.* 2014;9(1):14-17.
- Porfyridis I, Georgiadis G, Michael M, et al. Rapid on-site evaluation with the hemacolor rapid staining method of medical thoracoscopy biopsy specimens for the management of pleural disease. *Respirology.* 2016;21(6):1106-1112.
- Norge V, Roseann W, Stuti S, Cindy M. Cytology and histology: complementary diagnostic modalities during endoscopic ultrasoundguided tissue acquisition. *Tech Gastrointest Endosc.* 2018;20(1):10-14.
- Pearson L, Factor RE, White SK, Walker BS, Layfield LJ, Schmidt RL. Rapid on-site evaluation of fine-needle aspiration by non-cytopathologists: a systematic review and meta-analysis of diagnostic accuracy studies for adequacy assessment. *Acta Cytol.* 2018;62(4):244-252.
- Pearson LN, Layfield LJ, Schmidt RL. Cost-effectiveness of rapid on-site evaluation of the adequacy of FNA cytology

- samples performed by nonpathologists. *Cancer Cytopathol.* 2018;126(10):839-845.
11. Sehgal IS, Dhoria S, Aggarwal AN, Agarwal R. Impact of rapid on-site cytological evaluation (ROSE) on the diagnostic yield of transbronchial needle aspiration during mediastinal lymph node sampling: systematic review and meta-analysis. *Chest.* 2018;153(4):929-938.
  12. Steinfort DP, Leong TL, Laska IF, Beaty A, Tsui A, Irving LB. Diagnostic utility and accuracy of rapid on-site evaluation of bronchoscopic brushings. *Eur Respir J.* 2015;45(6):1653-1660.
  13. Xu C, Liu W, Wang W, Li L, Hu H, Wang J. Diagnostic value of endobronchial ultrasound combined with rapid on-site evaluation of transbronchial lung biopsy for peripheral pulmonary lesions. *Diagn Cytopathol.* 2021;49(6):706-710.
  14. Respiratory branch of Chinese Medical Association, China lung cancer prevention and treatment alliance. Chinese Expert consensus on issues related to small sample sampling of lung cancer. *China J Intern Med.* 2016;55(5):406-413.
  15. Caupena C, Esteban L, Jaen A, et al. Concordance between rapid on-site evaluation and final cytologic diagnosis in patients undergoing endobronchial ultrasound-guided transbronchial needle aspiration for non-small cell lung cancer staging. *Am J Clin Pathol.* 2020;153(2):190-197.
  16. Li YY, Li KS, Wang X, Shan FC, Li CH. Rapid on-site evaluation in CT-guided percutaneous biopsy of peripheral pulmonary nodules. *Chin J Interv Imaging Ther.* 2020;17(1):18-21.
  17. Zhang LT, Wang J, Zhang Y, Li XH, Wang XL. Exploration on the application of ROSE combined with needle biopsy of lung with guided CT by 4D navigation in the diagnosis of pulmonary diseases. *China Medical Equipment.* 2021;18(10):75-78.
  18. Anila KR, Nayak N, Venugopal M, Jayasree K. Role of rapid on-site evaluation in CT-guided fine needle aspiration cytology of lung nodules. *J Cytol.* 2018;35(4):229-232.
  19. Bandyopadhyay A, Laha R, Das TK, Sen S, Mangal S, Mitra PK. CT Guided fine needle aspiration cytology of thoracic mass lesions: a prospective study of immediate cytological evaluation. *Indian J Pathol Microbiol.* 2007;50(1):51-55.
  20. Mukherjee S, Bandyopadhyay G, Bhattacharya A, Ghosh R, Barui G, Karmakar R. Computed tomography-guided fine needle aspiration cytology of solitary pulmonary nodules suspected to be bronchogenic carcinoma: experience of a general hospital. *J Cytol.* 2010;27(1):8-11.
  21. Bruno P, Ricci A, Esposito MC, et al. Efficacy and cost effectiveness of rapid on site examination (ROSE) in management of patients with mediastinal lymphadenopathies. *Eur Rev Med Pharmacol Sci.* 2013;17(11):1517-1522.
  22. Fassina A, Corradin M, Zardo D, Cappellesso R, Corbetti F, Fassan M. Role and accuracy of rapid on-site evaluation of CT-guided fine needle aspiration cytology of lung nodules. *Cytopathology.* 2011;22(5):306-312.
  23. Bonifazi M, Sediari M, Ferretti M, et al. The role of the pulmonologist in rapid on-site cytologic evaluation of transbronchial needle aspiration: a prospective study. *Chest.* 2014;145(1):60-65.
  24. van Riet PA, Cahen DL, Poley JW, Bruno MJ. Mapping international practice patterns in EUS-guided tissue sampling: outcome of a global survey. *Endosc Int Open.* 2016;4(3):E360-E370.