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ORIGINAL RESEARCH

To Evaluate the Diagnostic Performance of Rapid on-Site Evaluation (ROSE) in Combination with Endobronchial Ultrasound (EBUS) for Pulmonary Lesions

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Background: Currently, Endobronchial ultrasound (EBUS) and rapid on-site evaluation (ROSE) are extensively utilized in the clinical practice of respiratory medicine. The combined diagnostic approach has been shown to enhance the clinical diagnostic accuracy; however, certain controversies remain.

Methods: This study included 200 patients who underwent endobronchial ultrasound combined with transbronchial lung biopsy with a guide sheath (EBUS-GS-TBLB) or endobronchial ultrasound combined with transbronchial needle aspiration (EBUS-TBNA) and received histopathological diagnoses at the Bronchoscopy Department, from January 2021 to January 2022. Of these, 168 patients were assigned to the ROSE group and 32 to the non-ROSE group. The diagnosis rates of EBUS-GS-TBLB and EBUS-TBNA, both with and without ROSE, along with the secondary biopsy rate, complication probability, and mean number of biopsies, were compared to analyze the differences between tumors and non-tumors. The safety of EBUS-GS-TBLB and EBUS-TBNA was also evaluated.

Results: The overall diagnostic accuracy was 85.71% in the ROSE group and 65.62% in the non-ROSE group. The diagnostic accuracy of the ROSE group was significantly higher than that of the non-ROSE group ($P < 0.05$). Compared to the non-ROSE group, the rate of secondary biopsy in the ROSE group was significantly reduced ($P < 0.05$), particularly in non-tumor cases. However, there was no significant difference in the incidence of complications and the average number of biopsies between the two groups ($P > 0.05$). Compared to the EBUS-GS-TBLB group, the EBUS-TBNA group showed a significantly lower incidence of complications and fewer biopsies ($P < 0.05$).

Conclusion: The integration of ROSE with EBUS enhanced the diagnostic rate and reduced the need for secondary examinations in the biopsy diagnosis of lung lesions, particularly in the definitive diagnosis of non-neoplastic lesions. The combination of ROSE technology appears to be more advantageous. Compared to EBUS-GS-TBLB, EBUS-TBNA demonstrated a lower incidence of complications and fewer biopsies.

Keywords: rapid on-site evaluation, ultrasound bronchoscopy, diagnostic efficacy, safety comparison, lung biopsy, pulmonary lesions

Introduction

Endobronchial ultrasound (EBUS) is currently widely utilized in the clinical practice of respiratory medicine. This bronchoscopic technique employs ultrasound to visualize the structures of the airway wall, lungs, and mediastinum.[1–3] When combined with transbronchial needle aspiration (TBNA), known as EBUS-TBNA, and transbronchial lung biopsy (TBLB) with a guide sheath, referred to as EBUS-GS-TBLB, these methods enable the performance of several clinical procedures that cannot be achieved through conventional bronchoscopy, such as diagnosing and staging suspected or

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confirmed lung cancer. These techniques allow for sampling from unexplained mediastinal lymphadenopathy, mediastinal masses, peripheral pulmonary nodules, and extrabronchial or peribronchial lesions. During the sampling process, rapid on-site evaluation (ROSE) of cytology specimens serves as a highly valuable auxiliary tool. By swiftly assessing the adequacy of the obtained samples, ROSE plays a crucial role in assessing the success of the biopsy and offers an initial diagnosis that guides subsequent procedures. Despite its utility, histopathological specimens remain the gold standard for clinical diagnosis, and the diagnostic accuracy of combining ROSE with endobronchial ultrasound (EBUS) remains a subject of debate.[4–6] The aim of this study was to retrospectively analyze and evaluate the diagnostic value of endobronchial ultrasound (EBUS) in conjunction with rapid on-site evaluation (ROSE) for pulmonary lesions.

Materials and Methods

Patients

This study is a single-center retrospective cohort study that includes patients who underwent EBUS-GS-TBLB or EBUS-TBNA and received histopathological diagnoses at the Bronchoscopy Department of SIR Run Run Shaw Hospital Qingchun District, affiliated with Zhejiang University School of Medicine, from January 2021 to January 2022. A total of 200 patients were identified for inclusion in the study, with 168 patients randomly assigned to the ROSE group, including 93 males and 75 females, with an average age of 59.07 (±12.93) years and 32 patients to the non-ROSE group including 18 males and 14 females, with an average age of 60.91 (±12.10) years. The baseline characteristics of both groups were comparable, showing no statistically significant differences ($P > 0.05$). The study was approved by the hospital's ethics committee, and all participants provided informed consent.

Intrabronchial Ultrasound Biopsy

All procedures were conducted under general anesthesia. EBUS-TBNA was executed using an ultrasonic bronchoscope (BF-UC260F or BF-UC290F, Olympus, Japan). After positioning with a front-end ultrasonic probe, a puncture aspiration biopsy was performed utilizing a 22-gauge needle (NA-201SX-4022, Olympus, Japan). For EBUS-GS-TBLB, a fiberoptic bronchoscope (BF-P290 or BF-Q290, Olympus, Japan) was used in conjunction with R-EBUS (20 MHz mechanical radial, UM-s20-17s, Olympus, Japan). Additionally, a guide sheath (GS) kit (K-201 or K-203, Olympus, Japan) was employed. Under general anesthesia, the R-EBUS probe and guiding sheath tube were inserted through the working channel of the bronchoscope to the target site, where the location within the lesion was confirmed, and biopsy sampling was conducted. Surgical procedures were performed by respiratory and critical care physicians with extensive experience in ultrasound tracheoscopy biopsies, each having completed at least 100 or more procedures.

Rapid On-Site Evaluation (ROSE)

In the non-ROSE group, tissue samples were obtained from the lesion or suspected lesion areas via biopsy or clip biopsy and immediately fixed in 10% formaldehyde. For the ROSE group, ROSE procedures were conducted according to the ROSE guidelines, utilizing the WHO-recommended Diff-Quik rapid staining method for staining. The samples were evaluated in real-time under a microscope using Diff A solution, Diff B solution, and phosphate-buffered saline (PBS). The staining process involved the following steps: immersing the slide in Diff A solution for 10–30 seconds, rinsing the slide in PBS to remove the Diff A solution and drying it, soaking the slide in Diff B solution for 10–30 seconds, and finally washing the slide in a water staining tank. The slide was then blotted with a paper towel to absorb and dry any residual liquid, completing the staining and drying process before examination under an optical microscope. After evaluating the slides, the adequacy of the sample was determined, and the need for additional sampling was based on whether abnormal cells were detected. If the ROSE result was positive, the same site was resampled. If the result was negative, the sampling site was adjusted, and ROSE analysis was repeated, with a maximum of six attempts allowed.

Final Diagnosis

Tissue samples from both the ROSE group and the non-ROSE group were collected for routine histological examination following the completion of the procedures. The final clinical diagnosis was based on the pathological diagnosis provided

by the pathology department. In cases where the pathological diagnosis of EBUS-GS-TBLB or EBUS-TBNA was negative, but a positive diagnosis was obtained through other invasive procedures such as percutaneous lung biopsy, thoracoscopy, or open surgery, the positive diagnosis was considered the final clinical diagnosis. The adequacy of all specimens was evaluated by the pathology department.

Statistical Methods

Descriptive Analysis

Quantitative data were assessed for normality using skewness and kurtosis, and homogeneity of variance was evaluated using Levene's test. Normally distributed quantitative data were reported as mean ± standard deviation (Mean(±SD)), and group comparisons were conducted using *t*-tests when variances were equal, and *t'*-tests when variances were unequal. Non-normally distributed data were reported as median (interquartile range) [M(Q_1,Q_3)], and group comparisons were performed using the Wilcoxon rank sum test. For multiple group comparisons, normally distributed data were analyzed using ANOVA (*F*-test), and non-normally distributed data were analyzed using the Kruskal–Wallis *H*-test. Categorical data were presented as the number of cases and proportions (n(%)), and group comparisons were conducted using the Pearson chi-square test when the expected frequency was greater than 5, and Fisher's exact test otherwise.

Confidence Level and Statistical Software

The confidence level alpha=0.05 was given. Data cleaning and difference comparison were completed by R version 4.3.3 (2024-02-29 ucrt).

Results

General Clinical Information in the ROSE Group and Non-ROSE Group

Of the 200 lesions, 96 were diagnosed using EBUS-GS-TBLB and 104 using EBUS-TBNA. Histological diagnosis confirmed 98 malignant lesions, including 91 cases of lung cancer, 2 cases each of breast cancer and lymphoma, and 1 case each of colon cancer, hamartoma, and renal cancer. Additionally, 102 lesions were diagnosed as non-tumor lesions, primarily sarcoidosis and pulmonary infections.

In the ROSE group, 168 lesions were diagnosed, with 79 using EBUS-GS-TBLB combined with ROSE and 89 using EBUS-TBNA combined with ROSE. Histological diagnosis confirmed 80 malignant lesions, including 76 cases of lung cancer and 4 cases of other malignant lesions, and 88 non-tumor lesions. In the non-ROSE group, 32 lesions were diagnosed, with 18 confirmed as malignant lesions, including 15 cases of lung cancer, and 14 as non-tumor lesions (Table 1).

Table 1 General Clinical Data of ROSE Group and Non-ROSE Group

Variables	Total (N=200)	ROSE (N=168)	非ROSE (N=32)	Statistics	*P*
Gender, n (%)				χ^2 = 0.000	1.000
Male	111 (55.50)	93 (55.36)	18 (56.25)		
Female	89 (44.50)	75 (44.64)	14 (43.75)		
Age, Mean (±SD)	59.37 (±12.79)	59.07 (±12.93)	60.91 (±12.10)	t = 0.743	0.458
Ultrasonic mode, n (%)				χ^2 = 0.194	0.660
TBLB	96 (48.00)	79 (47.02)	17 (53.12)		
TBNA	104 (52.00)	89 (52.98)	15 (46.88)		
Clinical diagnosis, n (%)				χ^2 = 0.493	0.483
Tumor	98 (49.00)	80 (47.62)	18 (56.25)		
Non-tumor	102 (51.00)	88 (52.38)	14 (43.75)		

Notes: SD: Standard Deviation; M: Median; Q_1: 1st Quartile; Q_3: 3rd Quartile; t: Student's *t* test; *t'*: Satterthwaite *t* test; W: Wilcoxon rank sum test; χ^2: Chi-square test; -: Fisher's exact test.

Table 2 Comparison of Diagnostic Efficiency and Security Between ROSE Group and Non-ROSE Group

Variables	Total (N=200)	ROSE (N=168)	非ROSE (N=32)	Statistics	*P*
Biopsy number, Mean (±SD)	4.71 (±1.28)	4.64 (±1.29)	5.06 (±1.16)	t = 1.705	0.090
Complications, n (%)				–	0.452
Hemorrhage	8 (4.00)	8 (4.76)	0 (0.00)		
Oxygenation index decreased	1 (0.50)	1 (0.60)	0 (0.00)		
Secondary biopsy or not, n (%)				χ^2 = 4.723	0.030
No	162 (81.00)	141 (83.93)	21 (65.62)		
Yes	38 (19.00)	27 (16.07)	11 (34.38)		
Consistency with clinical diagnosis, n (%)				χ^2 = 6.187	0.013
Accord	165 (82.50)	144 (85.71)	21 (65.62)		
Inconformity	35 (17.50)	24 (14.29)	11 (34.38)		

Notes: SD: Standard Deviation; M: Median; Q_1: 1st Quartile; Q_3: 3rd Quartile; t: Student's *t* test; *t'*: Satterthwaite *t* test; W: Wilcoxon rank sum test; χ^2: Chi-square test; -: Fisher's exact test.

Diagnostic Efficacy and Safety Comparison Between the ROSE Group and Non-ROSE Group

The ROSE group comprised 168 cases, of which 144 were consistent with the clinical diagnosis, yielding a total diagnostic accuracy of 85.71% (144/168). Specifically, the diagnostic accuracy for tumor cases was 75% (60/80), and for non-tumor cases, it was 94.45% (84/88). In contrast, the non-ROSE group included 32 cases, with 21 being consistent with the clinical diagnosis, resulting in a total diagnostic accuracy of 65.62% (21/32). For this group, the diagnostic accuracy for tumor cases was 50% (9/18), and for non-tumor cases, it was 85.74% (12/14). The total diagnostic accuracy in the ROSE group was significantly higher than in the non-ROSE group ($P < 0.05$). However, there was no significant difference in the sensitivity of non-tumor diagnosis between the two groups ($P > 0.05$) (Tables 2–4).

In the ROSE group, the secondary biopsy rate was 16.07% (27/168), the complication rate was 5.36% (9/168), and the average number of biopsies was 4.64 (± 1.29). For tumor in the ROSE group, the secondary biopsy rate was 25% (20/80), the complication rate was 7.5% (6/80), and the average number of biopsies was 4.66 (± 1.33). For non-tumor ROSE group, the secondary biopsy rate was 7.95% (7/88), the complication rate was 3.41% (3/88), and the average number of biopsies was 4.63 (± 1.26).

In the non-ROSE group, the secondary biopsy rate was 34.38% (11/32), with a complication rate of 0% (0/32), and the average number of biopsies was 5.06 (± 1.16). For tumors in the non-ROSE group, the secondary biopsy rate was 38.89% (7/18), with a complication rate of 0% (0/18), and the average number of biopsies was 5.22 (± 1.06). In the non-tumor non-ROSE group, the secondary biopsy rate was 28.57% (4/14), with a complication rate of 0% (0/14), and the average number of biopsies was 4.86 (± 1.29). The ROSE group had a significantly lower secondary biopsy rate compared to the non-ROSE

Table 3 Comparison of Diagnostic Efficacy and Safety Between ROSE Group and Non-ROSE Group in Tumors

Variables	Total (N=98)	ROSE (N=80)	非ROSE (N=18)	Statistics	*P*
Biopsy number, Mean (±SD)	4.76 (±1.30)	4.66 (±1.33)	5.22 (±1.06)	t = 1.680	0.096
Complications, n (%)				–	0.658
Hemorrhage	5 (5.10)	5 (6.25)	0 (0.00)		
Oxygenation index decreased	1 (1.02)	1 (1.25)	0 (0.00)		
Secondary biopsy or not, n (%)				–	0.252
No	71 (72.45)	60 (75.00)	11 (61.11)		
Yes	27 (27.55)	20 (25.00)	7 (38.89)		
Consistency with clinical diagnosis, n (%)				χ^2 = 3.290	0.070
Accord	69 (70.41)	60 (75.00)	9 (50.00)		
Inconformity	29 (29.59)	20 (25.00)	9 (50.00)		

Notes: SD: Standard Deviation; M: Median; Q_1: 1st Quartile; Q_3: 3rd Quartile; t: Student's *t* test; *t'*: Satterthwaite *t* test; W: Wilcoxon rank sum test; χ^2: Chi-square test; -: Fisher's exact test.

Table 4 Comparison of Diagnostic Efficacy and Safety Between the ROSE Group and the Non-ROSE Group in Non-Tumor

Variables	Total (N=102)	ROSE (N=88)	⫳ROSE (N=14)	Statistics	*P*
Biopsy number, Mean (±SD)	4.66 (±1.26)	4.63 (±1.26)	4.86 (±1.29)	t = 0.618	0.538
Complications, n (%)				–	1.000
Hemorrhage	3 (2.94)	3 (3.41)	0 (0.00)		
Oxygenation index decreased	0 (0.00)	0 (0.00)	0 (0.00)		
Secondary biopsy or not, n (%)				–	0.042
No	91 (89.22)	81 (92.05)	10 (71.43)		
Yes	11 (10.78)	7 (7.95)	4 (28.57)		
Consistency with clinical diagnosis, n (%)				–	0.190
Accord	96 (94.12)	84 (95.45)	12 (85.71)		
Inconformity	6 (5.88)	4 (4.55)	2 (14.29)		

Notes: SD: Standard Deviation; M: Median; Q_1: 1st Quartile; Q_3: 3rd Quartile; t: Student's *t* test; t': Satterthwaite *t* test; W: Wilcoxon rank sum test; χ^2: Chi-square test; -: Fisher's exact test.

group (P < 0.05), but there was no significant difference in the average number of biopsies and complication rate between the two groups (P > 0.05). The secondary biopsy rate in the tumor ROSE group was lower than that in the tumor non-ROSE group, although this difference was not statistically significant. The non-tumor ROSE group had a significantly lower secondary biopsy rate compared to the non-tumor non-ROSE group (P < 0.05), while there was no significant difference in the number of biopsies or complication rates between the two groups (P > 0.05). (Tables 2–4)

ROSE Staining Result

The typical cytological features of atypical cells under the microscope include irregular arrangement, large and deeply stained nuclei, and variations in cell size; normal columnar epithelial cells are arranged regularly, with relatively uniform cell size, polarity, and visible cilia (Figure 1).

Comparison of Safety Between EBUS-GS-TBLB and EBUS-TBNA

The EBUS-GS-TBLB group had a 9.37% complication rate (9/96), including 8 cases of significant hemorrhage and 1 case of intraoperative oxygen desaturation due to bleeding. The average number of biopsies was 4.97 (± 1.43). The EBUS-TBNA group had a complication rate of 0% (0/104) and an average biopsy count of 4.48 (±1.07). Both the complication rate and the number of biopsies were significantly lower in the EBUS-TBNA group compared to the EBUS-GS-TBLB group (P<0.05) (Table 5).

Discussion

Currently, endobronchial ultrasound (EBUS) is a highly developed endoscopic interventional technology widely applied in respiratory internal medicine. It plays a crucial role in diagnosing and staging lung cancer and mediastinal lymph node

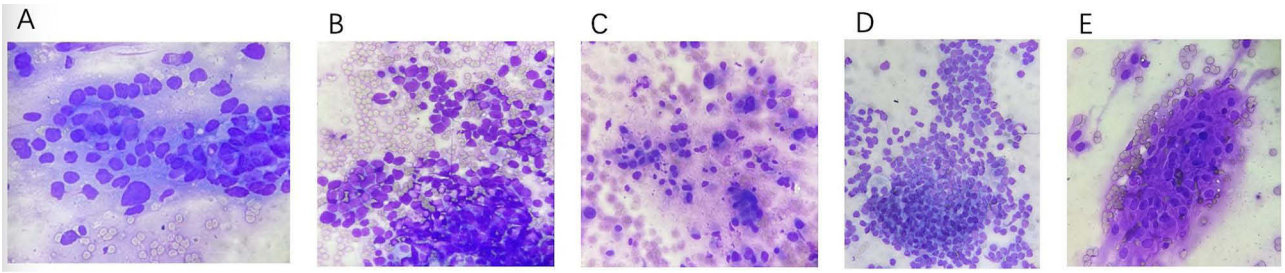

Figure 1 Microscopic Characteristics of the ROSE Image (×400). (**A**) Atypical cells from TBNA (histopathology: squamous cell carcinoma), (**B**) Atypical cells from TBNA (histopathology: small cell lung cancer), (**C**) Atypical cells from TBLB (histopathology: adenocarcinoma), (**D**) Atypical cells from TBLB (histopathology: lymphoma), (**E**) Granulomas from TBLB (histopathology: sarcoidosis).

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Table 5 Safety Comparison Between EBUS-GS-TBLB and EBUS-TBNA

Variables	Total (N=200)	TBLB (N=96)	TBNA (N=104)	Statistics	*P*
Biopsy number, Mean (±SD)	4.71 (±1.28)	4.97 (±1.43)	4.48 (±1.07)	t' = 2.730	0.007
Complications, n (%)				–	0.001
Hemorrhage	8 (4.00)	8 (8.33)	0 (0.00)		
Oxygenation index decreased	1 (0.50)	1 (1.04)	0 (0.00)		
Secondary biopsy or not, n (%)				χ^2 = 2.362	0.124
No	162 (81.00)	73 (76.04)	89 (85.58)		
Yes	38 (19.00)	23 (23.96)	15 (14.42)		

Notes: SD: Standard Deviation; M: Median; Q_1: 1st Quartile; Q_3: 3rd Quartile; t: Student's *t* test; *t'*: Satterthwaite *t* test; W: Wilcoxon rank sum test; χ^2: Chi-square test; -: Fisher's exact test.

lesions, making the quality of histopathological specimens obtained during the procedure particularly critical, as it directly impacts subsequent diagnostic and therapeutic decisions.[7,8]

Rapid On-Site Evaluation (ROSE) of cellular cytology specimens is a valuable auxiliary technique. By promptly assessing the adequacy of on-site specimens, ROSE assists operators in evaluating the quality of biopsy samples, adjusting the biopsy site if necessary, and potentially reducing procedural time and associated risks. This technique is commonly employed in modern interventional pulmonology centers.[9–11]

Although histopathological specimens remain the gold standard for clinical diagnosis, recent studies suggest that ROSE results exhibit a degree of similarity to final pathological outcomes.[12] However, the extent to which ROSE enhances diagnostic efficiency when combined with EBUS remains unclear and is a subject of ongoing debate in clinical practice.[13–15] For instance, a retrospective study by Karan Madan[13] found that ROSE did not improve the diagnostic yield of biopsies. Similarly, Ayşegul Şentürk[16] reported no statistically significant difference in diagnostic outcomes between the ROSE and non-ROSE groups, although they noted that ROSE could reduce the overall procedure time and the number of biopsies required. Conversely, SinemIliaz[17] et al demonstrated that ROSE can enhance diagnostic performance during EBUS, particularly for lung cancer, ensuring adequate histopathological material for molecular testing. Additionally, Chunhua Xu[18] et al found that ROSE can increase the diagnostic rate and reduce procedure time without increasing serious complications. In this study, the overall diagnostic rate for the ROSE group was 85.71%, compared to 65.62% for the non-ROSE group. The diagnostic rate for the ROSE group was significantly higher than that of the non-ROSE group ($P < 0.05$), indicating that ROSE can enhance diagnostic accuracy.

During actual clinical procedures, unsatisfactory sampling or biopsy site selection often leads to false-negative histological and pathological results, necessitating a second clinical biopsy to aid in diagnosis. While EBUS enhances the accuracy of positioning during the procedure, the heterogeneity of certain lesions may result in biopsy samples that do not fully represent the overall characteristics of the lesion. Additionally, due to current technological constraints, simultaneous ultrasound guidance and biopsy for peripheral lung nodules are not feasible, potentially leading to false-negative results in the final biopsy. When integrated with ROSE, EBUS enables more effective evaluation of biopsy site accuracy and specimen adequacy through timely feedback on sampling specimens, thereby reducing the likelihood of requiring a secondary biopsy. In this study, we observed that the rate of secondary examinations in the ROSE group was significantly lower than in the non-ROSE group ($P < 0.05$). Notably, for the diagnosis of non-neoplastic lesions, the combination of EBUS and ROSE demonstrated additional advantages ($P < 0.05$). Additionally, our study observed a lower rate of secondary biopsies in the tumor ROSE group compared to the tumor non-ROSE group, although this difference was not statistically significant (P=0.07). This lack of significance may be due to the limited sample size, and further validation with larger, multi-center datasets is warranted.

Several recent studies have demonstrated that the application of ROSE in EBUS can decrease the number of biopsies and shorten operation time.[11,18–20] However, due to variations in anesthesiologist selection methods, the operation time metric was not included in this study. The ROSE group required 4.64 (±1.29) fewer sampling attempts compared to the non-ROSE group, which required 5.06 (±1.16) attempts, though this difference was not statistically significant (P=0.09). This result may be

influenced by the small sample size or the necessity for multiple samplings for second-generation sequencing or molecular pathology. And it is suggested that ROSE has little effect on the incidence of complications in similar biopsies.

EBUS-guided transbronchial lung biopsy (EBUS-GS-TBLB) and EBUS-guided transbronchial needle aspiration (EBUS-TBNA) are two common interventional techniques used in the diagnosis of lung diseases. Both procedures are generally safe and well-tolerated.[21,22] Common complications of EBUS-GS-TBLB include pneumothorax and bleeding,[22] with a pneumothorax incidence of 2.8% in a study of 467 r-EBUS procedures, where 50% of patients required chest tube insertion. Two patients experienced bleeding volumes exceeding 300 mL, and four had bleeding volumes between 100–300 mL, but all patients had favorable outcomes.[23] The complication rate for EBUS-TBNA is extremely low,[24,25] with a meta-analysis of 1299 patients showing a complication rate of 0.15%. Skilled operators can further minimize complications.[26] A multicenter study by George A Eapen et al confirmed the safety of EBUS-TBNA, reporting a total complication rate of 1.4%, often associated with concurrent transbronchial biopsy. The use of ROSE can further reduce the incidence of complications.[8] In our study, all patients successfully completed the procedure without any operation-related deaths. We observed a higher incidence of complications and a greater number of biopsies in the EBUS-GS-TBLB group compared to the EBUS-TBNA group ($P < 0.05$), which may be attributed to the differences in the procedural techniques. Bleeding is the most common complication in EBUS-GS-TBLB operations.

This study is a single-center retrospective analysis with limited sample sizes for some subgroups, making it challenging to perform detailed subgroup comparisons. Further validation requires larger-scale and multicenter prospective studies.

Conclusion

Our study demonstrates that the integration of ROSE with EBUS enhances the diagnostic accuracy of lung lesion biopsies while reducing the need for repeat examinations and the incidence of complications. This combination appears particularly beneficial for diagnosing non-tumor lesions. The probability of complications and the number of biopsies were lower in the EBUS-TBNA group compared to the EBUS-GS-TBLB group, which may be related to the two surgical operation methods. Bleeding is the most common complication in EBUS-GS-TBLB operation, and general anesthesia sedation may reduce the incidence of pneumothorax. The expertise of endoscopists and the implementation of ROSE (Rapid On-Site Evaluation) intervention ensure the broad advancement of ultrasound-guided procedures. Certainly, future studies should strive to increase the sample size to enhance statistical power and generalizability. Furthermore, we aim to acquire multi-center clinical research data to validate these findings.

Abbreviations

ROSE, Rapid on-site evaluation; EBUS, Endobronchial ultrasound; EBUS-GS-TBLB, Endobronchial ultrasound combined with transbronchial lung biopsy with a guide sheath; EBUS-TBNA, Endobronchial ultrasound combined with transbronchial needle aspiration; PBS, Phosphate-buffered saline.

Ethics Approval and Informed Consent

This study was conducted in accordance with the Declaration of Helsinki and other relevant ethical guidelines and regulations. Ethical approval (Reference Number: 20190725-027) was obtained from the Ethical Review Committee of Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University. The Institutional Review Board (IRB) of Sir Run Run Shaw Hospital determined that informed consent was not required for the use of retrospective data, provided that all personal identifiers were removed from the dataset. This waiver of informed consent was granted due to the study's retrospective nature and the use of de-identified data. All methods and procedures in this study were carried out in compliance with the approved protocol and relevant ethical standards.

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Disclosure

The authors have no conflicts of interest to declare in this work.

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