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The Impact of Rapid On-site Evaluation on Diagnostic Performance of Computed Tomography–Guided Core Needle Biopsy in Lung Cancer

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Purpose: Rapid on-site-evaluation (ROSE) is a technique aimed at improving the diagnostic performance of computed tomography (CT)–guided core needle biopsy (CNB) in lung cancer. The aim of this retrospective study was to investigate the impact of ROSE on the rate of nondiagnostic specimens and on accuracy computed on diagnostic specimens.

Materials and Methods: During a 3-year period, 417 CT-guided CNBs were performed at our center. The biopsies were retrospectively classified into 2 groups: 141 procedures were assisted by ROSE and 276 were not. All of them were reviewed for clinical, procedural, and pathological data. Pathology results were classified as diagnostic (positive or negative for malignancy) or nondiagnostic. The results were compared with the final diagnosis after surgery or clinical follow-up. Nondiagnostic rate, sensitivity/specificity/negative predictive value/positive predictive value for the ROSE and non-ROSE groups were calculated. Finally, procedural complications and the adequacy of the specimens for the molecular analysis were recorded.

Results: The study evaluated 417 CNBs (mean patients' age 71 years, 278 men). Nondiagnostic rates with and without ROSE were 4% (6/142) and 11% (29/276), respectively (P = 0.028). Sensitivity/specificity/negative predictive value/positive predictive value with and without ROSE did not show statistically significant differences, and no difference in major/minor complication rates was observed between the 2 groups. The adequacy of specimen for subsequent molecular analysis was 100% with (42/42) and 82% without ROSE (51/62).

Conclusions: Rapid on-site-evaluation reduced the rate of nondiagnostic specimens by 50% with no change in complication rates or accuracy and increased by 20% the chances of a successful subsequent molecular analysis.

Key Words: lung neoplasms, computed tomography, large-core needle, image-guided biopsy, rapid on-site evaluation

Abbreviations: CNB: core needle biopsy, ICC: intraclass correlation coefficient, IQR: interquartile range. It is the difference between the third and first quartile, that is, the width of the band of values that contains the "central" half of the observed values. The interquartile range is an index of dispersion, that is, a measure of how far the values move away from a central value, ROSE: rapid on-site evaluation

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Transthoracic pulmonary biopsy is a widely used procedure for the pathological diagnosis of lung nodules suspected of malignancy.[1] It is commonly performed by interventional radiologists under imaging guidance, most frequently computed tomography (CT) or CT fluoroscopy.[2] Either a cytological or pathological sample can be obtained, respectively, with fine-needle aspiration biopsy/cytology and core needle biopsy (CNB). Core needle biopsy is the technique to be preferred because it allows for larger specimens necessary for (1) a diagnosis of malignancy or not, (2) a specific histologic diagnosis, and (3) molecular analysis leading to individualized therapy.[3] Core needle biopsy accuracy ranges from 83% to 97%, but it is often unclear whether nondiagnostic specimens, which can make up to 18% of cases, are included when accuracy is computed.[4–6] Indeed, because of the very low rate of CNB false positives (0%–2%), when a specific diagnosis of benign or malignant lesion is made, the patient is treated accordingly.[7] On the contrary, nondiagnostic results lead to uncertainty on how to proceed.[8] Nondiagnostic rates can be lowered up to 10% to 14%[9] by rapid on-site-evaluation (ROSE), a cytological extemporary examination performed by a trained cytologist that allows for an immediate assessment of the specimen adequacy.[9] Rapid on-site-evaluation has been shown to have good correlation with final pathologic diagnosis.[10] After researching PubMed, Embase, and Scopus databases, only 2 studies* have evaluated the diagnostic accuracy of ROSE on CT-guided CNBs[11,12]: Yiminniyaze et al[11] showed an improvement of accuracy from 86% to 96% without an increase in serious complications, while Liu et al[12] demonstrated that ROSE improved the diagnostic accuracy from 83% to 89%, but no statistical evaluation was performed. It should be underlined that in both studies, it was not evident whether nondiagnostic specimens were counted as false-negatives results and thus included or not in the assessment of diagnostic accuracy. Therefore, it remains unclear whether ROSE reduced the rate of nondiagnostic results, improved the accuracy of CT-guided CNB, or both. Moreover, some authors have raised questions about the real usefulness of ROSE in CNB, especially when an adequately sized specimen is obtained, and because ROSE may lead to a loss of valuable tissue for advanced testing and an increase in complication risk.[13]

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*Recently, a meta-analysis focusing on the role of ROSE in lung biopsy has been published,[14] which included 7 studies. Among them, 4 are not available for reading (not only not available, but also written in Chinese language and so beyond our language skill), one focuses on fine-needle aspiration, and the remaining 2 studies are those used for comparison in our research.[11,12]

The aim of our retrospective study was to investigate both the impact of ROSE on the rate of nondiagnostic specimens and the accuracy computed on diagnostic specimens.

MATERIALS AND METHODS

Patients and Study Design

This study was approved by the local ethical review board, and informed consent was obtained for each patient (#18085/OSS). This was a retrospective study of CT-guided CNBs of lung nodules or masses suspected of being cancerous. The inclusion criteria were patients who underwent CT-guided transthoracic biopsy of pulmonary lesions between July 2019 and July 2022 at the Careggi University Hospital - Florence, Italy with available clinical, radiological, and pathological data (Fig. 1). The total number of patients subjected to the CT-guided CNBs was 406, with 11 patients requiring a second subsequent biopsy because of the nondiagnostic result of the first biopsy. For all patients, age and gender were recorded. In addition, CT-guided CNBs were retrospectively classified into 2 groups based on the assistance of ROSE or not: 141 biopsies were assisted by ROSE (ROSE group), whereas 276 were not (non-ROSE group).

Patients' allocation to either group depended on the availability of assistance from the cytologist on the day of the procedure: ROSE assistance was available on 1 day out of three. Scheduling of the procedures was independent of the availability of ROSE assistance and of the clinical condition of the patients.

Computed Tomography Scan and Procedure Techniques

Each patient underwent a chest CT examination before the procedure to locate the target lesion. Computed tomography scans were performed on Siemens Somatom Sensation Open 40 CT scanner (Siemens Healthineers, Erlangen, Germany) with the following parameters: tube voltage 120 kV, pixel size 0.625 mm, both slice thickness and reconstruction 5 mm, current × exposure time 50 mAs, rotation time 0.5 seconds, pitch 1.2 mm, and reconstruction kernel Bf70 very sharp for lung parenchyma and B20f sharp for mediastinum. Scans were performed in full inspiration with the patient positioned prone, supine, or in lateral decubitus, depending on the location of the lesion. The field of view was extended from lung apexes to bases. Intravenous contrast agent was not administered. Potential areas of necrosis in the nodules were identified on the previous diagnostic contrast enhanced CT scan performed no more than 15 days before the procedure. All the pre-CNB chest CT examinations were reviewed to assess lesion size (main diameter in mm) and location (lung lobe). Written informed consent for the unenhanced CT and biopsies was obtained from each patient. Biopsies were performed by 2 interventional radiologists with 20 and 5 years of experience, using 18 gauge Tru-Cut (Merit Medical Systems, South Jordan, UT) or Biomol (H.S. Hospital Service, Rome, Italy) coaxial needles after local anesthesia with 2% lidocaine. The needle gauge and the number of needle passes were recorded. In the ROSE group, a cytologist printed the specimen on site, immediately performed Diff-Quick staining, and then read the specimens under a special cytological microscope. If the microscopic evaluation showed pathological cells, the biopsy was stopped. Otherwise, the radiologists continued the procedure to obtain other samples until ROSE showed pathological cells or major complications occurred. In the non-ROSE group, the adequacy of the material was judged by the radiologist with naked eye, considering the size of the sample, and the radiologist on his own decided if more passages were necessary, again interrupting the procedure in case of major complications. After puncture, a post-CNB chest CT examination was performed to identify any complications, which were recorded and classified according to the Society of Interventional Radiology guidelines into major and minor complications.[15] Major complications included

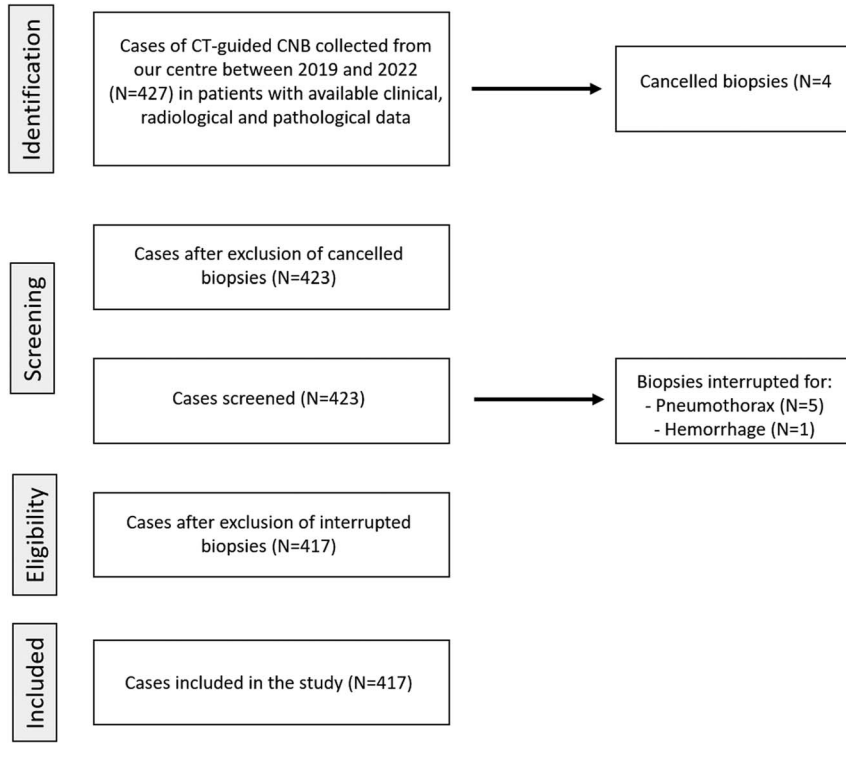

FIGURE 1. Flowchart for cases selection.

pneumothorax requiring intervention (aspiration or drainage positioning), hemothorax, gaseous embolization, needle-tract seeding, and death. Minor complications included pneumothorax that did not require intervention, transient hemoptysis, and ground-glass opacities indicating pulmonary hemorrhage.[15] Patients were then kept under observation for 3 hours, and finally, a posterior-anterior chest x-ray examination both in inspiration and expiration was obtained to rule out the presence of pneumothorax.

Pathological Results

After reviewing the pathological results of the biopsies, they were classified into 2 groups: diagnostic and nondiagnostic biopsies. Diagnostic biopsies included all those with a definite pathological diagnosis—malignant cells, general or specific inflammation; biopsies were considered nondiagnostic when a diagnosis could not be made because of lack of sufficient material or the pathologist reported the presence of necrosis, hemorrhagic material, clots, or a combination of them. Nondiagnostic rate was calculated for both the ROSE and non-ROSE groups. Pathological responses were classified as positive or negative for malignancy and compared with the definitive diagnosis after surgery or clinical follow-up with a minimum duration of 6 months. Pathological results were classified as follows:

- true-positive, when a positive biopsy was confirmed by surgery, or the patient was treated for cancer according to the pathological result;
- true-negative, when clinical and imaging follow-up showed resolution or reduction in size of a lesion with a negative biopsy;
- false-negative, when the patient was later diagnosed with cancer, with a negative biopsy;
- false-positive, when surgery or clinical and radiological follow-up did not confirm a positive biopsy;

Finally, the adequacy of the material for the subsequent molecular analysis was evaluated. Adequacy was determined by dividing the number of adequate samples in each group by the total number of cases in which molecular analysis was requested by oncologists.

Readers and Statistical Analysis

All lesions were separately measured by a radiologist with 10 years of experience in chest imaging and a radiology resident trained to analyze chest CT of patients with lung nodules. The radiologists were blinded to the pathological specimen results. Whenever the readers came to different conclusions, a discussion was held until they reached a consensus. The reliability of the measures (intrareader and interreader agreement) was assessed using the intraclass correlation coefficient (ICC). The ICC values of 0.01 to 0.10, 0.11 to 0.40, 0.41 to 0.60, 0.61 to 0.80, and 0.81 to 1.0 represented no, slight, fair, good, and excellent agreement, respectively. Data were presented as percentages. χ^2 and Mann-Whitney test for independent samples were used to evaluate differences in clinical and demographic data between the 2 groups of patients. χ^2 test was also used to evaluate associations between nondiagnostic sample rates and the group (ROSE and non-ROSE groups). Sensitivity, specificity, negative predictive value (NPV), positive predicted value (PPV), and diagnostic accuracy (ie, (true positives + true negatives) / total number of biopsies) were calculated to test the reliability of CT-guided CNB in the ROSE and non-ROSE groups. For all the diagnostic accuracy parameters, 95% confidence intervals (CIs) were calculated. The values of the diagnostic accuracy parameters of the 2 groups were compared using the Z test. For all the analyses, an α level of 0.05 was considered; therefore, P values lower than such a value determined an observed difference as statistically significant.

For the statistical analysis, the null hypothesis of no differences in accuracy between the ROSE group and the non-ROSE groups was considered. The sample size for both groups ensures a hypothesis testing probability of 5% for type I error and 10% for type II error, when calculating accuracy. In fact, based on the expected data from Yiminniyaze (96.3% for ROSE group, 86.1% for non-ROSE group), an α value of 0.05 (the highest acceptable probability of committing a type I error) and a β value of 0.10 (the highest acceptable probability of committing a type II error), the minimum sample size required was established as 126 for each group. Therefore, a 5% maximum chance of incorrectly rejecting the null hypothesis (and mistakenly concluding that there are differences in accuracy between the 2 groups), and a 10% chance of missing an association between accuracy and the use of ROSE was set. Consequently, the power of 90% ($1 - \beta$) is the probability of observing an effect of the ROSE in the accuracy.

The collected data were analyzed using the IBM SPSS v. 28.0 statistical analysis software (IBM Corp, New York, NY).

RESULTS

In this study, the number of included patients exceeded the minimum sample size calculated to test the null hypothesis of no differences in accuracy between the ROSE and non-ROSE groups. This calculation considered a 5% likelihood of type I error, a 10% likelihood of type II error, and a statistical power of 90%.

The total number of biopsies included was 417, 141 in the ROSE group (34%), and 276 in the non-ROSE group (66%). Biopsy was repeated in 11 patients, 3 in the ROSE group and 8 in the non-ROSE group. In all cases, biopsy was repeated within 1 month. In the ROSE group, the second biopsy provided a correct diagnosis in all cases, while in the non-ROSE group in half of the cases, the new biopsy was again unsuccessful.

True-positive, true-negative and false-negative results were 119 (84%), 14 (10%), and 3 (2%) in the ROSE group and 219 (76%), 16 (6%), and 10 (4%) in the non-ROSE group, without statistically significant differences ($P < 0.05$). No false-positive results were observed in both groups. The average patient age was 71 years (range, 28–92 years), with 248 men (59%) and 169 women (41%). The average nodule size was 35 mm (range, 4–150 mm). Both intraobserver and interobserver agreements were excellent, ICC values ranging from 0.845 to 0.894 and from 0.815 to 0.866 ($P < 0.05$), respectively. Average number of passes was 4 and IQR/range was 0 in ROSE and non-ROSE groups.

No substantial differences in the complications rates between the 2 groups were observed ($P > 0.05$). Minor complications were 38/141 (27%) and 72/276 (26%) in the ROSE and non-ROSE groups, respectively, mainly represented by pneumothorax not requiring intervention (Fig. 2). Major complications occurred in 13/141 (9%) and 24/276 (9%) cases, respectively, represented exclusively by pneumothorax requiring intervention such as aspiration and drainage ($P > 0.05$). Severe hemoptysis, hemothorax, seeding, and death were not observed. Nodule size was slightly higher in the non-ROSE group (36 vs 32 mm, $P = 0.02$). A detailed overview of the complications is presented (Table 1).

Nondiagnostic biopsies in the ROSE and non-ROSE groups were 6/141 (4%) and 29/276 (11%), respectively, with a statistically significant difference ($P = 0.03$) between the 2 groups. Of them, 5/6 (83%) and 25/29 (86%) eventually resulted to be malignant ($P < 0.05$). In particular, in the ROSE group, in 2/5 cases (40%), ROSE was suspicious for malignancy, not confirmed by pathology because of the scarcity of specimen; in the remaining 3/5 cases (60%), all with negative ROSE, samplings could not be repeated because of complications onset twice (severe pneumothorax), and once the sampling was repeated 8 times before

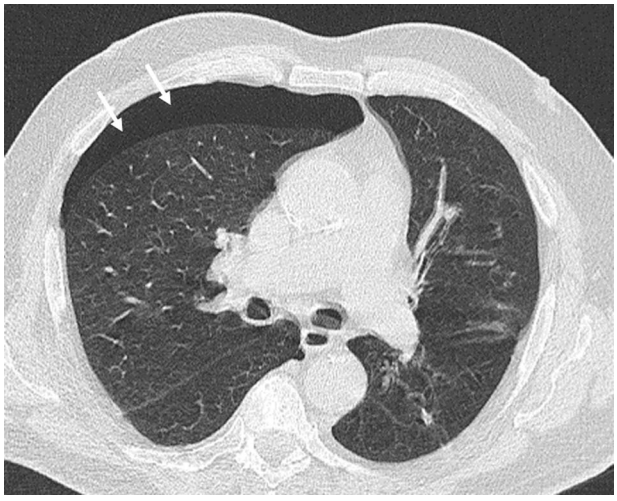

FIGURE 2. Pneumothorax: large anterior apico-basal pneumothorax (white arrow), which required chest tube drainage.

the procedure was suspended because of repeated inconclusive results. In the non-ROSE group, 8/25 (32%) lung primitive tumors (6 adenocarcinoma and 2 small cell lung cancers), 8/25 (32%) metastatic lesions, 2/25 (8%) neoplastic nodules without diagnostic definition (patients were treated with empirical chemotherapy), and 1/25 (4%) lesion increased in diameter at subsequent examinations. Finally, 3/25 (12%) patients died before a definitive diagnosis could be made and 3/25 (12%) were lost to follow-up. Considering the nondiagnostic results only, there was a significant difference in average nodule size, 11 mm in the ROSE group and 32 mm in the non-ROSE group ($P = 0.04$).

After the exclusion of the previously mentioned nondiagnostic specimens, the accuracy for the ROSE and non-ROSE groups was 98% and 96%, respectively. In particular, sensitivity, specificity, NPV, and PPV were 98%, 100%, 81%, and 100% with ROSE and 96%, 100%, 64%, and 100% without ROSE, respectively; no statistically significant differences between the 2 groups (Table 2) were observed.

Molecular analysis was requested in 104/417 cases (25%) (42/141 cases (30%) in ROSE group and 62/276 cases (22%) in non-ROSE group). Its adequacy was 100% and 82% in ROSE and non-ROSE groups, respectively, with a statistically significant difference ($P < 0.01$).

Detailed results of the biopsies, both overall and for the 2 groups individually, are summarized in Table 3. Overall, 338 of the 382 diagnostic specimens (88%) were malignant, of which most were adenocarcinoma (189/338 cases, 56%) followed by squamous cell carcinoma (48/338 cases, 14%) and metastasis (44/338 cases, 13%). Forty-four biopsies (12%) were diagnosed as nonmalignant, 16/338 (11%) and 28/338 (10%) in the ROSE and non-ROSE groups, respectively. Among nonmalignant results, inflammatory infiltrate (Fig. 3) represented the most common diagnosis (38/44 cases, 86%) followed by aspergillosis (2 cases) and hamartoma, hemorrhagic alveolitis, sarcoidosis, and granulomatosis (1 case each). Thirteen of them (30%) proved to be malignant at follow-up and were classified as false-negatives.

DISCUSSION

This study demonstrated that ROSE halved the rate of nondiagnostic specimens, reducing it from 11% to 4% without increasing the rate of complications or affecting sensitivity, specificity, NPV, PPV, and diagnostic accuracy. Moreover, it significantly increased the chances of a successful subsequent molecular analysis.

The results of this study contrasted with those of 2 previous studies,[11,12] which showed an improvement in diagnostic accuracy of 10% and 6%, respectively. Such improvement was likely due to the inclusion of nondiagnostic specimens in the computation of accuracy; therefore, the apparent increment determined by ROSE was probably due to the reduction of nondiagnostic specimens. In fact, the identified difference in the number of nondiagnostic biopsies between the 2 groups (6 in ROSE group vs 29 in non-ROSE group) was statistically significant ($P = 0.03$). In contrast, no accuracy increase between the ROSE and non-ROSE groups was found after the exclusion of nondiagnostic samples.

TABLE 1. Population Characteristics, Lesion Size and Location, and Complications Rates

	ROSE (n: 141)	Non-ROSE (n = 276)	*P*	Total (N = 417)
Age, average (range), y	70 (28–88)	71 (39–92)	>0.05	71 (28–92)
Male (%)	78 (55)	170 (62)	>0.05	248 (59)
Nodule size (range), mm	32 (6–123)	36 (4–150)	0.02	35 (4–150)
Location (%)				
RUL	44 (31)	92 (33)	>0.05	136 (33)
RML	8 (6)	12 (4)	>0.05	20 (5)
RLL	27 (19)	49 (14)	>0.05	76 (18)
LUL	42 (30)	80 (29)	>0.05	122 (29)
LLL	20 (14)	43 (16)	>0.05	63 (15)
Complications (%)				
Minor:	38 (27)	72 (26)	>0.05	110 (26)
Pneumothorax not requiring treatment	31 (22)	65 (24)	>0.05	96 (23)
Hemoptysis not requiring treatment	5 (4)	5 (2)	>0.05	10 (2)
Parenchymal hemorrhage	2 (1)	2 (1)	>0.05	4 (1)
Major:	13 (9)	24 (9)	>0.05	37 (9)
Pneumothorax requiring aspiration	9 (6)	12 (4)	>0.05	21 (5)
Pneumothorax requiring drainage	4 (3)	12 (4)	>0.05	16 (4)

LLL, left lower lobe; LUL, left upper lobe; RLL, right lower lobe; RML, right middle lobe; RUL, right upper lobe.

TABLE 2. Adequacy and Accuracy Parameters of ROSE and Non-ROSE Groups

	ROSE (n = 141)	Non-ROSE (n = 276)	*P**
Diagnostic (%)	135 (96)	247 (89)	<0.05
Nondiagnostic (%)	6 (4)	29 (11)	
Sensitivity (%)	97.5 (92.9–99.5)	95.6 (92.2–97.9)	>0.05
Specificity (%)	100 (75.3–1)	100 (81.5–1)	>0.05
NPV (%)	81.2 (58.6–92.9)	64.3 (49.5–76.7)	>0.05
PPV (%)	100	100	>0.05
Accuracy (95% CI) (%)	97.8 (93.6–99.5)	95.9 (92.7–98.0)	>0.05
Adequacy for molecular analysis (%)	100 (91.5–1)	82.2 (70.5–90.8)	<0.05

*χ^2 test was used to compare nondiagnostic rates; *Z* test was used to compare diagnostic, sensitivity, specificity, NPV, PPV, and diagnostic accuracy. For accuracy parameters, 95% CIs were reported in brackets.

TABLE 3. Final Histologic Diagnosis of Lesions in ROSE and Non-ROSE Groups

	ROSE (n = 141)	Non-ROSE (n = 276)	Total (N = 417)
Malignant (%)	**119 (84)**	**219 (79)**	**338 (81)**
Adenocarcinoma (%)	***68 (57)***	***121 (55)***	***189 (56)***
Squamocellular carcinoma (%)	***17 (14)***	***31 (14)***	***48 (14)***
Other primary lung tumors (%)	***9 (8)***	***40 (18)***	***49 (14)***
NSCLC-NOS	1	13	14
Adenosquamous carcinoma	0	1	1
SCLC	4	6	10
Neuroendocrine tumor	1	4	5
LCNEC	0	6	6
Undifferentiated carcinoma	3	10	13
Metastasis (%)	***19 (16)***	***25 (11)***	***44 (13)***
Other nonlung tumors (%)	***6 (5)***	***1 (0,4)***	***7 (2)***
Germinal tumor	1	0	1
B lymphoma	2	0	2
Neurinoma	1	0	1
Thymoma	1	0	1
Solitary fibrous tumor	1	1	2
PEComa	0	1	1
Nonmalignant:	**13 (9)**	**18 (7)**	**31 (7)**
Inflammation	12	13	25
Hamartoma	1	0	1
Aspergillus	0	2	2
Hemorrhagic alveolitis	0	1	1
Granulomatosis	0	1	1
Sarcoidosis	0	1	1
False-negative (%)	**3 (2)**	**10 (4)**	**13 (3)**
Nondiagnostic (%)	**6 (4)**	**29 (11)**	**35 (8)**

The total number of malignant, nonmalignant, false-negatives and nondiagnostic results is highlighted in boldface. The most frequent malignant lesions are highlighted in boldface-italics.

LCNEC indicates large cell neuroendocrine carcinoma; NSCLC-NOS, nonsmall cell lung cancer–not otherwise specified; PEComa, perivascular epithelioid cell tumor; SCLC, small cell lung cancer.

Interestingly, a significant difference in nodule size of nondiagnostic biopsies was observed between the ROSE and the non-ROSE group, 11 versus 32 mm, respectively. It has already been demonstrated that accuracy for small nodules is lower, while the result for the non-ROSE group is quite surprising, because targeting of larger nodules should be easier.[16] This finding might be explained by the fact that large nodules often include large areas of necrosis and hemorrhage, which lead to nondiagnostic results when sampled, a limitation that ROSE allows to overcome.

To the best of our knowledge, there are not previous studies to investigate the rate of nondiagnostic specimens; therefore, no a priori evaluation of sample size was conducted for that specific objective. Conversely, it should be underlined that the evaluation of sample size of the present study was done for the total amount of patient population in reference with the previous article of Yiminniyaze et al.[11] As a result, the collected data are more than adequate to generalize the results with a high level of confidence. The present analysis showed an overall diagnostic accuracy of 97%, which was in line with that recommended by the Society of Interventional Radiology, namely, a rate of accuracy of at least 90%.[17]

Considering false-negatives samples, the ROSE group comprised three cases, all of them with a suspicious ROSE, but histology revealed normal parenchyma in one case and "fibrosis and chronic inflammation" in the remaining 2 cases (Fig. 4). In the non-ROSE group, there were 10 false-negatives, including 4 cases of normal lung parenchyma, 4 cases of "chronic inflammation," and 2 cases of "granulomatous inflammation." These results were partly consistent with the current literature, showing that when a nonspecific benign diagnosis is made, the probability of a diagnostic mistake by CNBs is high.[7] At the same time, the present results were in contrast with the conclusions of Kim et al,[17] who demonstrated that nonspecific benign findings such as normal structure, fibrous tissue, or generic inflammation have a high chance of being a truly benign lesion.[18] Considering the 4 cases in which histology revealed normal lung parenchyma, these diagnostic failures were probably due to the biopsy not targeting the lesion correctly, despite CT images showing the needle tip inside the lesion. In the current series, also of note was that one third of the specimens judged as "without malignant cells within" revealed themselves as being a true malignancy during the follow-up. These findings reinforced the role of imaging in the characterization of

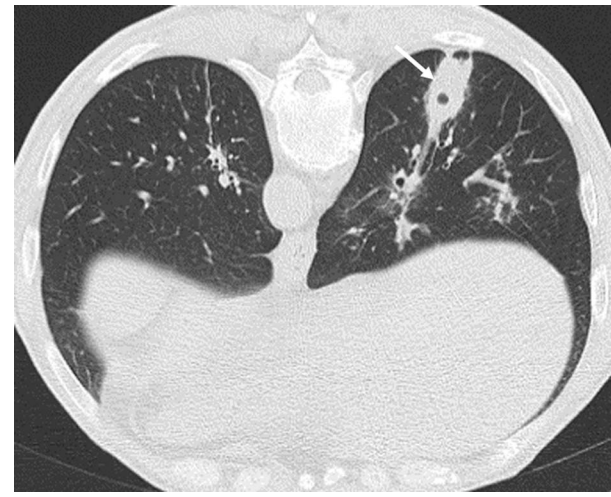

FIGURE 3. Negative result in ROSE group: 35-mm consolidative lesion (white arrow) in the right lower lobe that disappeared at subsequent CT scans. The patient was positioned prone to allow a posterior access to the lesion.

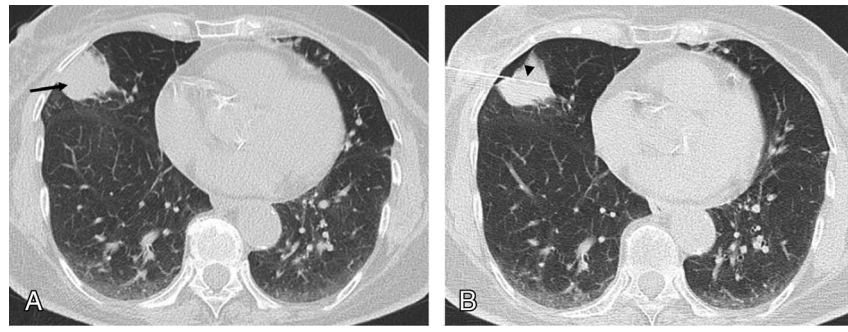

FIGURE 4. False-negative result in ROSE group. A Preprocedural scan showing a 34-mm nodule (black arrow) in the left upper lobe. B, Intraprocedural scan showing the needle tip inside the nodule (black arrow head) with the development of a mild pneumothorax nonrequiring intervention.

lung nodules, even in the case of negative biopsy, which should actually be judged as reliable only if "positive for malignancy." In fact, in a very interesting study, Rigiroli et al[19] demonstrated that when radiologic and pathologic findings are discordant, final diagnosis of malignancy is highly probable—60% of cases—and consequently underline the importance of the radiologist in the patients' management, particularly helping with the identification of false-negative results.

Major and minor complication rates were similar in the ROSE and non-ROSE groups. This result confirmed what was mentioned by Yiminniyaze and Liu,[11,12] in which ROSE did not increase complications, in contrast with the hypothesis proposed by Ferguson et al.[13] Indeed, ROSE did not require further needle passes and thus theoretically could not determine any variation in adverse events. The minor pneumothorax rate was 26%, and chest tube insertion was needed in 4% of cases. Such results were well below the recommended threshold by the Society of Interventional Radiology guidelines, which are of 45% and 20%, respectively.[17]

In contrast with Rekhtman and Ferguson,[13,18] ROSE was found to significantly improve the rate of successful molecular analysis, up to a 100% success rate. Such a value demonstrated that the minimal loss of sampled tissue during the touch preparations was outweighed by the improvement in the quality of the sample itself.[13,20]

The first limitation of this study is its retrospective design. Another limitation is that the overall number of cases in which molecular analysis was performed was low. More studies with larger samples will be required to confirm the improvements in the adequacy of specimens obtained with ROSE for molecular analysis. Lastly, it remains uncertain if the sample preparation by a cytologist in the ROSE group, in place of a radiologist, as occurred in the non-ROSE group, could have influenced its quality. Finally, the difficulty in interpreting nonmalignant histology should be emphasized; therefore, further studies aimed at investigating nonmalignant specimens will be needed.

The assistance of ROSE increases costs and duration of the procedure, but at the same time reduces healthcare costs because of an earlier and more confident diagnosis, which avoids the need of further diagnostic procedures, as demonstrated on a very large sample.[21]

CONCLUSIONS

This study demonstrated that ROSE reduced the rate of nondiagnostic specimens by 50%, with no change in diagnostic accuracy or complications rate. Furthermore, ROSE increased by 20% the chances of a successful molecular analysis.

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