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Original article

Public health impact of a diagnostic improvement intervention supported by Rapid On-Site Evaluation (ROSE) in thoracic CT-guided biopsies: a pre-post study

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Summary

Background. Lung cancer is the leading cause of cancer death worldwide and was the most commonly diagnosed cancer in 2022. The Rapid On-Site Evaluation (ROSE) technique allows immediate evaluation of samples collected during needle aspiration and needle biopsy procedures, improving diagnostic accuracy and reducing the need for repeated procedures.

Study Design. A pre-post study evaluated the health benefits for patients and improved healthcare costs with ROSE diagnostic support from a public health perspective.

Methods. We compared two groups of patients who underwent TC-guided transthoracic needle aspiration/biopsy from March 2017 to March 2022. In the first group (pre-ROSE) the procedures were performed without the support of ROSE, while in the second group (post-ROSE) the pathologist assisted the radiologist in all cases. The diagnostic advantages, the economic-organizational impact of the procedure, and the related benefits for patients were analyzed.

Results. The pre-ROSE group comprised 97 patients, and the post-ROSE group comprised 67. In the group receiving ROSE diagnostic support, the rate of inadequate diagnostic tests requiring repetition decreased from 29.9% to 9.0% ($p = 0.001$). This saved time for the radiologist, pathologist, nurse, radiology technician, laboratory technician, and support staff, freeing up diagnostic slots that could be used to reduce waiting lists and improve the quality of patient service.

Conclusions. ROSE support has improved diagnostic efficacy and sample quality, reducing repeat testing and associated costs. This leads to better management of healthcare resources, reduced waiting times, and more accurate diagnoses, improving the quality of patient care and bringing public health benefits.

Key words: rapid on site evaluation, cytology, trans thoracic needle biopsies, cost assessment

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Introduction

Lung cancer is the leading cause of cancer-related death globally [1] and, in 2022, was the most frequently diagnosed cancer, with nearly 2.5 million new cases [2]. The diagnosis is mainly based on specific diagnostic tests on small cyto-histological samples, and molecular characteriza-

tion is crucial, as it allows the identification of possible therapeutic targets through the analysis of recurrent genetic alterations [3]. The cyto-histological and molecular characterization of tumors is an increasingly relevant field in pathology, and, regarding lung cancer, the search for new methods for early and accurate diagnosis is essential for its effective treatment [4].

Rapid On-Site Evaluation (ROSE) can be used in the cytological diagnosis of pulmonary and mediastinal diseases [5,6], allowing an immediate evaluation of the suitability and adequacy of the sample collected during invasive procedures [7]. The advantage offered by ROSE may be that the affected lesion is directly studied within the procedure setting, allowing for adequate evaluation of the samples and minimizing the need to repeat procedures for additional desired tests (e.g., molecular studies). Some studies have shown that ROSE does not negatively impact the number of aspirations, total procedure time, or post-procedure complication rate. On the contrary, it can provide a preliminary diagnosis that can reduce additional invasive procedures [8]. In addition, the implementation of ROSE in case of endosonography-derived samples decreases the number of sites to be sampled, the times of the procedure and allows thorough molecular profiling in most patients [9]. The pathologist's support with ROSE examination improves patient care significantly. However, the ROSE technique also has disadvantages, such as the need for an experienced and trained pathologist on site, the occurrence of unreimbursed costs, and the fact that it is time-consuming in routine activities.

The study focused on three main areas of interest: i. diagnostic improvement, ii. organizational benefits (economic and time-saving), and iii. improvement of the health service offered to the patient.

The study aims to demonstrate how improving diagnostic procedures can significantly impact public health. Specifically, the outcomes of patients undergoing transthoracic needle aspiration (TTNA) or transthoracic needle biopsy (TTNB) were evaluated with and without ROSE support; the two groups were compared to evaluate the improvement of the diagnostic yield for lung and mediastinal tumors vs. to methods that do not use it. The aim is to avoid re-interventions and to obtain a complete cyto-histological and molecular characterization with a diagnostic procedure. Subsequently, the economic impact of implementing these diagnostic methods in patient management and cost savings is considered from a hospital and healthcare management perspective. This evaluation aims to demonstrate if this can avoid unnecessary repeated tests, improve the quality of care provided to the patient, and lead to a diagnostic advantage in terms of timing, generating a benefit for the entire public health service.

Methods

A pre-post study [10] was conducted from March 2017 to March 2022 at the Maggiore Hospital in Bologna (Italy), a hub of the Local Health Authority of Bologna, to evaluate the success rate of transthoracic needle aspiration/biopsy (TTNA/B), guided by computed tomography (CT) and ultrasound (US) methods using ROSE. For this purpose, two groups of patients undergoing TTNA/B for thoracic lesions were compared with pulmonary and mediastinal origin lesions.

The first group of patients (pre-ROSE group) did not benefit from the ROSE support technique at the time of diagnosis. In contrast, the second group (post-ROSE group) benefited from a systematic use of ROSE during radiological procedures.

ROSE was performed on liquid and biopsy materials. Glass slides for liquid materials were first labelled and then the material smeared and air dried. Tissue biopsies were instead touch imprinted on the glass slide and let the imprint air-dry. The Diff-Quik staining method was utilized for all the ROSE slides. Briefly, slides were sequentially immersed in ethanol 95° for 30", then in eosin G for 30", then in Thiazine for 30", both diluted in phosphate buffer. Slides were then rinsed three times to remove excess dye and read promptly under the microscope without mounting. The entire procedure lasted 5 to 10 minutes according to the operator.

For each of the areas of interest, the following evaluation methods were used:

The diagnostic improvement was calculated as the decrease in repeated exams due to inadequate material after the implementation of the ROSE. Material inadequacy was considered when both cyto-histological and molecular diagnostics were not possible. Cases that were diagnostic at cytology or histology but not sufficient for molecular diagnostic were still considered adequate.

As for organizational benefits, time-saving was calculated considering the operators involved (radiologist, pathologist, nurse, radiologist technician, laboratory technician, and support staff) and the improperly occupied diagnostic slots (CT and US). A further economic evaluation was quantified by estimating the cost of the material used (needles used for TTNA and TTNB). The research was conducted using data extracted from software used within the registries of radiology units and materials purchased from the hospital pharmacy. This led to accurately determining the

costs of needles used in TTNA and TTNB procedures and evaluating the cost of performing diagnostic CT- and US-guided biopsies.
The last area, difficult to quantify economically but significant, is related to avoiding unnecessary radiological risk for patients with increased quality of health services. The patient's benefit is substantial, associated with lower diagnostic delay, lower radiological risk, and the lack of repetition of unnecessary healthcare tests.
Continuous variables were summarized as mean and standard deviation and categorical variables as absolute and relative frequencies. A chi-squared test was conducted to compare the proportions of inadequate diagnoses between the two groups. Statistical significance was set at $p < 0.05$.
The present study has been approved by Comitato Etico Emilia Romagna AVEC - AnaPat ROSE CE 23004; CE AVEC n° 161-2023 -OSS-AUSLBO. All data were collected in compliance with privacy regulations.
Patient risk, cost, and time savings were estimated as reported in Table I.

Table I. List of the patient risks and main costs of the procedures

Risks to the patient, healthcare personnel and material involved	Risk/Cost
Patient	diagnostic delay; radiological risk; repetition of unnecessary healthcare test
Medical Doctor – Radiologist	working-time
Medical Doctor – Pathologist	working-time
Nurse	working-time
Radiology Technician	working-time
Laboratory Technician	working-time
Support Staff	working-time
TTNA Biopsy Needle 25G x 100 mm	unit cost
TTNB Biopsy Needle 18G x 100 mm	unit cost
CT service	diagnostic slot usage
US service	diagnostic slot usage

Notes: TTNA = Transthoracic Needle Aspiration; TTNB = Transthoracic Needle Biopsy; CT = Computed Tomography; US = Ultrasound.

Results

Descriptive Analysis

The study retrospectively analyzed two patient groups: the first did not use ROSE support for diagnosis (pre-ROSE group), and the second used ROSE support (post-ROSE group).
The pre-ROSE group included 97 patients, of whom 57 were males and 40 were females. In contrast, the post-ROSE group included 67 patients, 38 males and 29 females (Tab. II).

Table II. Descriptive analyses of the sample

	pre-ROSE Group	post-ROSE Group
ROSE support	No	Yes
Total (n, %)	97 (100.0%)	67 (100.0%)
Male	57 (58.8%)	38 (56.7%)
Female	40 (41.2%)	29 (43.3%)
Mean Age (years±SD)	67.8±13.0	70.8±12.1
Male	69.5±12.4	73.2±8.7
Female	65.5±13.5	67.6±15.1
Cancer Site (n, %)		
Lung (right and left)	87 (89.7%)	59 (88.1%)
Mediastinum	10 (10.3%)	8 (11.9%)

Notes: ROSE = Rapid On-Site Evaluation; n = number; y.o. = years old; SD = Standard deviation.

The mean age of patients in the pre-ROSE group was 67.8±13.0 years, while 70.8±12.1 years for the post-ROSE group.

Table III. Analysis of diagnostic and molecular aspects

	pre-ROSE Group	post-ROSE Group
ROSE support	No	Yes
Procedure (n, %)		
TTNA	72 (74.2%)	4 (6.0%)
TTNB	25 (25.8%)	63 (94.0%)
Preliminar Diagnosis (n, %)		
Total	-	61 (91.0%)
Single Pass	-	46 (68.7%)
Diagnosis (n, %)		
NSCLC/ADK	34 (35.1%)	27 (40.3%)
NSCLC/SCC	4 (4.1%)	7 (10.4%)
NSCLC/NOS	6 (6.2%)	8 (11.9%)
NSCLC/LCNEC	3 (3.1%)	4 (6.0%)
Others	21 (21.6%)	15 (22.4%)
Molecular Analysis NGS (n, %)		
Total	44 (45.4%)	42 (62.7%)
Of which cytology	27 (61.4%)	28 (66.7%)
Of which histology	17 (38.6%)	14 (33.3%)

Notes: ROSE = Rapid On-Site Evaluation; n = number; TTNA = Transthoracic Needle Aspiration; TTNB = Transthoracic Needle Biopsy; NSCLC/ADK = Non-Small Cell Lung Cancer/Adenocarcinoma; NSCLC/SCC = Non-Small Cell Lung Cancer/Squamous Cell Carcinoma; NSCLC/NOS = Non-Small Cell Lung Cancer/Not Otherwise Specified; NSCLC/LCNEC = Non-Small Cell Lung Cancer/Large Cell Neuroendocrine Carcinoma; NGS = Next-Generation Sequencing.

In the pre-ROSE group, 89.7% of cases involved lung cancer, while 10.3% were related to the mediastinum. In comparison, 88.1% of cases in the post-ROSE group were in the lungs and 11.9% in the mediastinum. In the pre-ROSE group 50 patients (51.5%) underwent CT-guided TTNA or TTNB. In the post-ROSE group, the number of CT-guided TTNA or TTNB raised up to 45 out of 67 total procedures (67.2%).

Only 25.8% of patients in the pre-ROSE group received a transthoracic needle biopsy (TTNB); however, in the post-ROSE group, the rate of TTNB performed increased to 94.0%. Moreover, in 68.7% of cases, a single TTNB pass was sufficient to diagnose the patient and perform cyto-histological and molecular characterization of the sample (Tab. III).

Accordingly, characterization by Next-Generation Sequencing (NGS) [11,12] was possible in 45.4% of cases in the pre-ROSE group, compared to 62.7%in the post-ROSE group.

Diagnostic improvement

The number of inadequate procedures, or those that had to be repeated a second time, statistically significantly (p = 0.001) reduced from 29.9% in the pre-ROSE group to 9.0% in the post-ROSE group (Tab. IV).

Table IV. Chi-square results

	pre-ROSE Group	post-ROSE Group	p-value
Inadequate Diagnosis (n, %)	29 (29.9%)	6 (9.0%)	p = 0.001

Notes: ROSE = Rapid On-Site Evaluation; n = number.

Organizational benefits and improvement of the health service offered to the patient

In the previous paragraph, the main result of our study was shown, that is, how the use of ROSE diagnostic support reduced the repetition rate of inappropriate diagnostic tests by almost two-thirds. Thanks to this result, it is possible to quantify the main costs and performances associated with the diagnostic procedures, as shown in Table V.

In Table VI, we can observe the differences in costs and risks between the two types of intervention. When using the ROSE diagnostic support, the procedure time can increase by up to 10 minutes, and the needle mainly used can cost more. However, this is still a relatively small increase (5.95 euros/needle versus 20.01 euros/needle). Furthermore, it must be considered that the healthcare personnel involved include a Pathologist on site, thus increasing the total staff by one doctor. This results in a slightly lower diagnostic cost without ROSE diagnostic support for the single service.

Net of a slightly higher pathologist's cost, the ROSE technique, reducing the test repetition rate by 20.9%, generates savings in the terms shown in Table VI. It generates savings for the patient (less diagnostic delay, less radiation exposure, and less exposure to unnecessary invasive tests) and savings for the health service (better use of diagnostic slots, the efficiency of use for health personnel, and higher quality of cyto-histological samples collected). It also creates a knowledge advantage thanks to the knowledge shared between professional figures specialized in different fields.

Table V. Quantification of cost and performance savings

Type of Performance or Material	Unit cost
Total duration of the service without ROSE support	35 minutes for diagnosis + 30 minutes post-test waiting time.
Total duration of the service with ROSE support	45 minutes for diagnosis + 30 minutes post-test waiting time
TTNA Biopsy Needle 25G x 100 mm	5.95 euros/needle
TTNB Biopsy Needle 18G x 100 mm	20.01 euros/needle
Saving working-time for Medical Radiologist	35 minutes
Saving working-time for Medical Pathologist	35 minutes
Saving working-time for Nurse/Radiology Technician/Laboratory Technician	35 minutes
Saving working-time for Support Staff	35 minutes
CT service cost	a missed diagnostic slot
Ultrasound service cost	a missed diagnostic slot
Patient risks	delayed diagnosis; radiation exposure; second exposure to invasive testing

Notes: ROSE = Rapid On-Site Evaluation; TTNA = Transthoracic Needle Aspiration; TTNB = Transthoracic Needle Biopsy; CT = Computed Tomography.

Table VI. Comparison of patient risks and costs with and without ROSE diagnostic support.		
	pre-ROSE Group	**post-ROSE Group**
Total Duration of the Service	35 minutes for diagnosis + 30 minutes post-test waiting time.	45 minutes for diagnosis + 30 minutes post-test waiting time
Biopsy Needle	Mainly TTNA Biopsy Needle 25G x 100 mm (5.95 euros/needle)	Mainly TTNB Biopsy Needle 18G x 100 mm (20.01 euros/needle)
Healthcare Personnel Involved	On Site: Radiologist, Nurse, Radiology Technician, Support Staff. In the Laboratory: Pathologist. Laboratory Technician.	On Site: Pathologist, Radiologist, Nurse, Radiology Technician, Support Staff. In the Laboratory: Pathologist. Laboratory Technician.
Advantages and savings of the procedure	For the patient:time-saving of just a few minutes (max 10 minutes). For the healthcare service: lowest unit cost for each test	For the patient: reduced diagnostic delay, lower radiological risk, and fewer unnecessary test repetitions. For the healthcare service: minimize missed diagnostic slots and operators' working time required for test repetitions (-20.9% of test repetitions). Improvement of the collected cyto-histological sample. Collaboration among various professionals to share and implement collective knowledge.

Notes: ROSE = Rapid On-Site Evaluation; TTNA = Transthoracic Needle Aspiration; TTNB = Transthoracic Needle Biopsy

Discussion

The diagnostic efficiency of ROSE was known in the scientific literature [13]. The data of our study show that the ROSE procedure improved the efficiency of TTNA/B examinations and the quality of the samples, allowing more accurate and in-depth characterization of lung and mediastinal tumors, especially as support of endobronchial ultrasound (EBUS) [14]. The consistent execution of ROSE during TTNA/B reduced the number of inadequate samples and increased the diagnostic yield. Furthermore, it allowed the collection of qualitatively valid tissue for further cyto-histological and molecular diagnostic analyses in a single procedure.

Our analysis provides a basis for considering implementing diagnostic strategies that improve the accuracy and completeness of initial tests. As reported in other studies, these strategies could significantly reduce the need for repeat tests, leading to a more efficient use of healthcare resources [15,16].

If diagnostic improvement results align with what was already explored in the scientific literature, this study introduced the most novelties: the organizational and economic advantages and patient benefits. These topics could provide public health decision-makers with even more decision-making tools.

From the analysis of the study results, it emerges that the diagnostic procedure supported by ROSE, despite a very slight increase in unit costs of the service compared to a diagnosis without ROSE support, due to the longer duration of the intervention (up to 10 minutes more) and the use of a more expensive biopsy needle (20.01 euros vs 5.95 euros), generates a number of tests to be repeated because they are not conclusive that is significantly lower from 29.9% to 9.0%. This means that the number of tests to be repeated has dcreased by almost two-thirds thanks to ROSE support. In this way, having to repeat fewer tests, the material used will be less, the working time of the operators to reach the single diagnosis will be less, the diagnostic slots used to get the correct diagnosis will be fewer, and the impact on the patient (diagnostic delay, radiological risk and undergoing unnecessary invasive tests) and caregivers will be less.

The diagnostic improvement was, therefore, 20.9%. The organizational benefits were also manifested with the lower use of diagnostic slots for CT and US (-20.9%) that could be used for new diagnoses and, therefore, helping to reduce waiting lists. Furthermore, by decreasing the rate of repeated tests, the material (e.g., biopsy needles) misused will also be lower. The same percentage of the lower rate of repetition of tests is the same that generates savings in the working time of healthcare personnel who, at this point, can be diverted to new diagnoses rather than repeating inconclusive tests already performed. The difference between personnel involved in the technique with ROSE support is similar to the diagnosis without ROSE. What changes most, as shown in the results, is that with ROSE support, the Pathologist is present on-site at the time of the exam and subsequently sends the sample to the Pathological Anatomy laboratories to be processed by a Laboratory Technician and analyzed by a Pathologist. Without ROSE support, the sample goes directly to the laboratory, where

the personnel involved are the Laboratory Technician and the Pathologist. The substantial advantage of the ROSE technique, having the Pathologist also on site, is that it can immediately direct towards a correct diagnosis and, thanks to the on-site evaluation, reduces by 20.9% the tests that must be repeated twice, saving working time for all the other operators involved. This is also thanks to the collaboration between Radiologists and Pathologists, which focuses on an important area to investigate as such close contact work could bring mutual benefits. Other studies [17] indicate that these specialists could improve their knowledge by working closely and sharing insights.

Furthermore, the Rapid On-Site Evaluation could improve telecytology by facilitating the adoption of new technologies that can positively impact the health service [18].

Another fundamental aspect to consider is that improving the success of an invasive test by 20.9% brings enormous benefits to the patient. In fact, in two-thirds of cases, the patient will not have to undergo a subsequent examination, avoiding an invasive procedure, a further radiological risk, and decreasing the waiting time to have the most accurate diagnosis possible. This substantially impacts the life of the patient and caregivers.

Among the study limitations is the retrospective design used. This study describes an improvement thanks to the introduction of ROSE support. However, the heterogeneity of the groups (different proportions of TTNA and TTNB and different size of the lesions), the different gauge of needles used for TTNA and TTNB, and the different moments in which the intervention was evaluated did not allow us to draw causal solid links as would have been possible with other study designs.

A further limitation is that the study was conducted within the Italian National Health Service, where the costs are standardized and regulated by a national collective agreement. This only allows a partial economic comparison with other international realities. For this reason, the analysis focused mainly on evaluating staff time-savings rather than economic savings, which are more relevant in a different healthcare context.

In conclusion, focusing on diagnostic accuracy from the first examination can lead to a more efficient use of resources and significantly improve healthcare quality. Encouraging further investigations into implementing these strategies in the health sector can provide policy and health decision-makers with a greater awareness of how specific interventions can impact multiple aspects of public health and improve the performance of health services, which can benefit citizens.

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Conflict of interest statement

The authors declare no conflict of interest

Ethical consideration

The present study has been approved by Comitato Etico Emilia Romagna AVEC - AnaPat ROSE CE 23004; CE AVEC n° 161-2023 -OSS-AUSLBO. All data were collected in compliance with privacy regulations.

Authors contribution

FA: histo-cytopathological analyses and manuscritp preparation. MR: Cost analyses and manuscript preparation. NN: histo-cytopathological analyses. JB: Cost analyses. SG: Cost analyses, study design. EM: radiology procedures Michele Imbriani: study design. CL: study supervision. MF: study supervision, manuscript preparation.

References

1 Leiter A, Veluswamy RR, Wisnivesky JP. The global burden of lung cancer: current status and future trends. Nat Rev Clin Oncol. 2023 Sep;20(9):624-639. https://doi.org/10.1038/s41571-023-00798-3. PMID: 37479810.

2 Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024 May-Jun;74(3):229-263. https://doi.org/10.3322/caac.21834. PMID: 38572751.

3 Roy-Chowdhuri S. Molecular Pathology of Lung Cancer. Clin Lab Med. 2024 Jun;44(2):137-147. https://doi.org/10.1016/j.cll.2023.08.002. PMID: 38821637.

4 Wadowska K, Bil-Lula I, Trembecki Ł, et al. Genetic Markers in Lung Cancer Diagnosis: A Review. Int J Mol Sci. 2020 Jun 27;21(13):4569. https://doi.org/10.3390/ijms21134569. PMID: 32604993; PMCID: PMC7369725.

5 Huang Z, Zhuang D, Feng A, et al. Real-time and accuracy of rapid on-site cytological evaluation of lung cancer. Transl Cancer Res. 2021 Jan;10(1):479-486. https://doi.org/10.21037/tcr-20-3294. PMID: 35116277; PMCID: PMC8798460.

6 Wohlschläger J, Darwiche K, Ting S, et al. "Rapid on-site evaluation" (ROSE) in der zytologischen Diagnostik von Lungen- und Mediastinalerkrankungen [Rapid on-site evaluation (ROSE) in cytological diagnostics of pulmonary and mediastinal diseases]. Pathologe. 2012 Jul;33(4):308-15. https://doi.org/10.1007/s00292-012-1578-8. PMID: 22752354.

7 Hassan M. Rapid on-site evaluation: what a microscope will add to the bronchoscopy unit? a concise review. Egypt J Bronchol. 2016;10:206-211. https://doi.org/10.4103/1687-8426.193634.

8 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 Feb;142(2):253-262. https://doi.org/10.5858/arpa.2017-0114-SA. PMID: 28639854.

9 Livi V, Ardizzoni A, Cancellieri A, et al. Adequacy of endosonography-derived samples from peribronchial or periesophageal intrapulmonary lesions for the molecular profiling of lung cancer. Clin Respir J. 2019 Sep;13(9):590-597. https://doi.org/10.1111/crj.13063. PMID: 31343834.

10 Aggarwal R, Ranganathan P. Study designs: Part 4 - Interventional studies. Perspect Clin Res. 2019 Jul-Sep;10(3):137-139. https://doi.org/10.4103/picr.PICR_91_19. PMID: 31404185; PMCID: PMC6647894.

11 Hu T, Chitnis N, Monos D, et al. Next-generation sequencing technologies: An overview. Hum Immunol. 2021 Nov;82(11):801-811. https://doi.org/10.1016/j.humimm.2021.02.012. PMID: 33745759.

12 Slatko BE, Gardner AF, Ausubel FM. Overview of Next-Generation Sequencing Technologies. Curr Protoc Mol Biol. 2018 Apr;122(1):e59. https://doi.org/10.1002/cpmb.59. PMID: 29851291; PMCID: PMC6020069.

13 Yiminniyaze R, Zhang X, Zhang Y, et al. Diagnostic efficiency and safety of rapid on-site evaluation combined with CT-guided transthoracic core needle biopsy in suspected lung cancer patients. Cytopathology. 2022 Jul;33(4):439-444. https://doi.org/10.1111/cyt.13123. PMID: 35362154; PMCID: PMC9324149.

14 Trisolini R, Cancellieri A, Tinelli C, et al. Randomized trial of endobronchial ultrasound-guided transbronchial needle aspiration with and without rapid on-site evaluation for lung cancer genotyping. Chest. 2015 Dec;148(6):1430-1437. https://doi.org/10.1378/chest.15-0583. PMID: 26158441.

15 Nasuti JF, Gupta PK, Baloch ZW. Diagnostic value and cost-effectiveness of on-site evaluation of fine-needle aspiration specimens: review of 5,688 cases. Diagn Cytopathol. 2002 Jul;27(1):1-4. https://doi.org/10.1002/dc.10065. PMID: 12112806.

16 Kılınçarslan MG, Şahin EM, Korkmazer B. Prevalence and associated factors of inappropriate repeat test. Postgrad Med J. 2019 Nov;95(1129):596-600. https://doi.org/10.1136/postgradmedj-2019-136696. PMID: 31341037.

17 Witt BL. Rapid On Site Evaluation (ROSE): A Pathologists' Perspective. Tech Vasc Interv Radiol. 2021 Sep;24(3):100767. https://doi.org/10.1016/j.tvir.2021.100767. PMID: 34861970.

18 Sarode VR. The current practice of telecytology for rapid on-site evaluation (ROSE): Practical considerations and limitations. Semin Diagn Pathol. 2022 Nov;39(6):463-467. https://doi.org/10.1053/j.semdp.2022.06.006. PMID: 35718579.