Diagnostic Accuracy of Surgeon-Led Ultrasound Guided Lung Biopsy In Suspected Thoracic Malignancy

Mahesh Mani Adhikari[1], Binay Thakur[1], Sagar Khatiwada[1], Manoj Tiwari[1], Ashish Kharel[1], Shachee Bhattarai[1], Sandeep Sapkota[1], Saujan Raut[1].

[1]Department of Thoracic Surgery, BP Koirala Memorial Cancer Hospital, Bharatpur, Nepal.

Abstract:

Background: Lung cancer is the leading solid organ malignancy in the world, having the highest share of financial burden in the world population. Increasing lung cancer patients can result in increase in waiting time for early diagnosis and treatment resulting in adverse outcome. Ultrasound guided lung and thoracic core needle biopsies done by non-radiologist clinicians are shown to reduce the waiting time for early diagnosis making the patient care efficient and safe. This study aimed to evaluate the diagnostic accuracy of surgeon led point-of-care ultrasound (POCUS) guided thoracic core needle biopsies for suspected thoracic malignancies in Nepal.

Methodology: This study evaluated 226 patients retrospectively, who underwent POCUS guided thoracic core-needle biopsy at our institution from September 2023 to January 2025. All the biopsy reports available were collected retrospectively and descriptive analysis done.

Results: The diagnostic yield of the surgeon led POCUS thoracic biopsy was 94.7%, 4.4% required repeat biopsy and radiological correlation was advised in 0.9%. Squamous cell carcinoma of the lung (28.3%) was the most common histological diagnosis made in the biopsies. Five cases (2.21%) developed pneumothorax after the core needle biopsy among which two required pigtail chest drain.

Conclusion: Surgeon-led POCUS thoracic biopsies can be done safely increasing the diagnostic efficiency of the institution resulting in reduction in waiting time and reducing the patient load in radiology suit for the same procedure.

Keywords: Lung Cancers, Pulmonary Neoplasm, Mediastinal Neoplasm, Biopsy, Core Needle, Image Guided Biopsy, Ultrasound Imaging, Medical Sonography, Surgeons, Nepal.

Introduction

Lung cancer is the leading solid organ malignancy and it is also the most common cause of cancer related mortality in the world.[1] According to GLOBOCAN 2022 report, there were nearly 2.5 million new cases and more than 1.8 million deaths due to lung cancer.[1] The global economic cost of cancers from 2025 to 2050 was estimated to be $25.2 trillion (considering constant 2017 price of international dollars), in which bronchogenic carcinoma was estimated to take the share of about 15.4%.[2] Shorter time to diagnosis and early initiation of treatment are associated with better long-term outcome, especially in early diseases.[3] A study by Labbé et al (2017) evaluated the waiting time of diagnosis in lung cancer and its effects on outcome, they noted that an average time from referral to diagnosis, to first treatment and to surgery was 21, 56 and 70 days respectively.[4] The waiting time are variable in different international as well as institutional settings, which can be significantly influenced by availability of health resources and service providers. Pandey et al noted the waiting time to be as long as 45.5 days due to disproportionate distribution of specialized health services like intervention radiology in developing nation like Nepal.[5] Therefore, a dedicated team of pulmonary physicians or thoracic surgeons has been found to decrease the waiting time significantly in places with limited radiology services.[6]

The use of ultrasound for managing lung pathology was popularized by French intensivist Daniel

Correspondence: Mahesh Mani Adhikari, Department of Surgical Oncology. BP Koirala Memorial Cancer Hospital, Bharatpur, Nepal

Lichtenstein.[7] Since then, the use of lung ultrasound (US) as Point-of-care ultrasound (POCUS) has gained significant popularity among clinicians and intensivists. The use of lung ultrasound by non-radiologist clinicians for diagnostic purposes in suspected thoracic malignancy is however a relatively recent trend. The role of lung ultrasound for diagnosis of peripheral lung lesions has been recognized by Americal College of Chest Physicians in their clinical practice guidelines.[8] Using POCUS-thoracic biopsy, the waiting time for diagnosis can be shortened significantly and also reduce the patient load added in radiology unit for the same purpose.

US guided transthoracic biopsies for suspected thoracic malignancies have been studied by limited researchers in Nepal. To our knowledge there are three reports regarding US guided thoracic core-needle biopsy of thoracic malignancies by radiologists (sample size ranging from 25 – 132) and only one study by pulmonologists (sample size = 77) and none by thoracic surgeons.[9–12] The thoracic surgery unit in BPKMCH, has been performing POCUS-thoracic biopsy in eligible patients since few years as a part of routine care of suspected lung and thoracic cancer patients. This study was conducted to evaluate the diagnostic accuracy of the surgeon-led POCUS- thoracic biopsy in our center.

Methodology

Study Design and Setting.

A retrospective review of the biopsy reports of all the consecutive patients undergoing POCUS-guided thoracic biopsy from September 2023 to January 2025 by thoracic surgery unit at BP Koirala Memorial Cancer Hospital, Bharatpur-7, Chitwan, Nepal. All biopsies were performed by thoracic surgeons of varying experience in POCUS. Biopsies were performed initially under supervision of surgeon with highest experience. With increasing experience all 7 thoracic surgeons (4 consultants and 3 thoracic surgical oncology residents) were performing ultrasound guided thoracic biopsies with little or no assistance. This initiative was carried out as a part of quality improvement in the services provided by thoracic surgery unit at the BPKMCH.

Inclusion criteria:

Patients were selected and consented for POCUS-guided thoracic during evaluation of suspected lung or thoracic malignancy:

1. ECOG performance score: 0-3
2. CT scan showed lesions >3cm, located in outer 1/3rd of lung field.
3. Mediastinal lesion close to the chest wall.
4. Pleural deposits >2 cm.
5. A clear intercostal window available for percutaneous biopsy.

Exclusion criteria:

1. The lesions were found to be deep into the lung parenchyma or centrally located, patients were referred for CT guided or EUS guided biopsy.
2. Patient had gross pleural effusion or dyspnea on lying down severe enough to decrease the blood oxygen saturation level.
3. Patients having bleeding diathesis.

Lung or mediastinal lesions were initially localized with the help of CT scan images (Fig. 1), then identified using standard sonographic characteristics (Fig. 2): Hypoechoic, well-defined borders and hepatization of lung. Core needle biopsy gun of fixed fire length of 22mm were used.

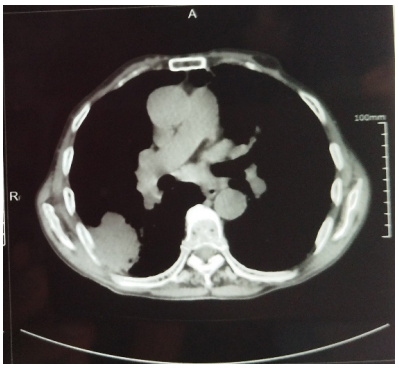


Figure 1 CT scan image of a patient planned for POCUS guided thoracic biopsy with lung lesion seen in the rt lung.

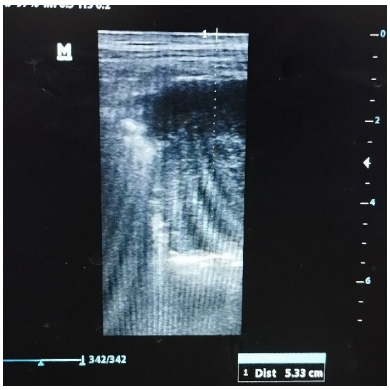


Figure 2. USG image of the lesion shown in Figure 1, the lesion is abutting the chest wall, hypoechoic as compared with to surrounding lung with irregular margins.

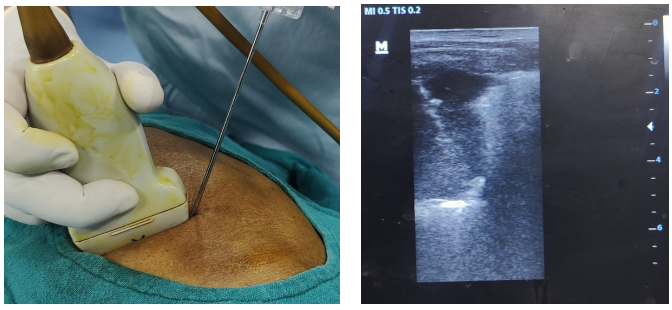
Point-of-care Ultrasound-guided Biopsy technique
Patient positioning: Patient were biopsied in supine, lateral or prone positioning as required.

Localization of lesion: After identifying the location of the lesion in CT images, a curvilinear (2.0-6 MHz) or linear(10-15MHz) US probe with portable USG machine (Mindray DP-20) was used to locate the lesion in the patient.

Sterilization: Standard sterilization technique using 5% povidone iodine solution was used to sterilize the area of biopsy. US probe was disinfected using standard disinfectant.

Anesthesia: 2% lidocaine solution injection was used for local anesthesia under US guidance

A small 2-3 mm nick was given in the skin upto subcutaneous layer using no 11 blade. Under US guidance 16G core needle biopsy was inserted into the lesion and fired obtaining 3-5 samples (Fig. 3). Specimen were initially placed in normal saline then transferred into container with 10% formalin solution (Fig. 4). Surgeons assessed tissues macroscopically and made sure suspicious tissues were obtained before completion of the procedure. Care was taken not to traverse the needle into normal lung parenchyma or vascular structures. In difficulty visualizing the lesions whether due to small size or proximity to vascular structures or presence of gross pleural effusion or normal lungs in between lesion and chest wall, procedure was abandoned and patient referred for CT guided or EUS guided biopsy. After completion of the procedure, patients were evaluated for iatrogenic pneumothorax by POCUS and re-confirmed with standard chest-radiographs.



(A) (B)

Figure 3(A) In-plane position of needle and US probe., (B) US image of the needle tack inside the lesion.

Figure 4 Tissue samples collected in kidney tray with normal saline. These samples are then transferred to bottles with 10% formalin solutions.

Data Collection:
Demographic data of the patients included name, age, sex, date of biopsy and date of reporting were noted. Procedure specific data included site of biopsy (right lung, left lung, mediastinum, supraclavicular nodes, chest wall) and histopathological diagnosis. For nondiagnostic results, repeat biopsy or further procedure were planned and biopsy reports recorded.

Statistical analysis:
Descriptive and univariable statistics were used to describe the results using SPSS statistical package (IBM, version 25) and tables were generated using Microsoft Excel 2016 software.

Results:
A total of 226 patients underwent POCUS thoracic biopsies from September 2023 to January 2025. There were 118 male patients (52.2%) and 108 female (47.8%). Mean age of the patients was 65.94 years, with the range of 25 – 89 years. Ninety-one patients (40.3%) evaluated were in the age group of 61 -70 years, followed by age group of 71-80 (n=59, 26.1%), indicating most of the patients belong to elderly group. Biopsies were taken most commonly from right lung (n=101, 44.7%) while other locations were anterior mediastinum (n=2, 0.9%), chest wall (n=5, 2.2%), left lung (n=85, 37.6%), lung (with side not specified) (n=23, 10.2%) and supraclavicular lymphnodes (n=10, 4.4%). Most common histological diagnosis was Squamous cell carcinoma of lungs (n=64, 28.3%), it was most commonly seen in patients of age group 61-70 years (n=30, 13.3%). 10 cases (4.4%) required repeat biopsies. One case was negative for malignancy; 8 cases were suggestive for malignancy and 1 case was of squamous dysplasia. In 63 cases (27.9%) of

suspected lung cancer diagnosis of Non-Small Cell Lung Carcinoma was made for which further study with Immunohistochemistry was advised. There were 5 cases (2.21%) of pneumothorax, 2 among which required pigtail chest drainage post biopsy.

Table 1. General characteristics of patient and biopsy site and histological reports.

	Characteristics	All patients (n=226)
Age, y	Mean ± SD	65.85 ± 9.92
	Minimum	25
	Maximum	89
Sex		
	Male	108 (47.8%)
	Female	118 (52.2%)
Histopathological reports		
	SCC	64 (28.3%)
	NSCLC	63 (27.9%)
	Adenocarcinoma	50 (22.1%)
	SCLC	19 (8.4%)
	Suggestive for malignancy	8 (3.5%)
	Mets carcinoma	5 (2.2%)
	Poorly differentiated carcinoma	5 (2.2%)
	Inconclusive	3 (1.3%)
	NEC	3 (1.3%)
	Granulomatous lesion	1 (0.4%)
	High grade squamous dysplasia	1 (0.4%)
	Negative for malignancy	1 (0.4%)
	Pleomorphic ca	1 (0.4%)
	Solitary fibrous tumor	1 (0.4%)
	Squamous dysplasia	1 (0.4%)
Biopsy site		
	Right lung	101 (44.7%)
	Left lung	85 (37.6%)
	Lung (side not specified)	23 (10.2%)
	Supraclavicular lymphnode	10 (4.4%)
	Chest wall	5 (2.2%)
	Anterior mediastinum	2 (0.9%)
Remarks		
	Diagnosis reported	121 (53.5%)
	IHC advised	93 (41.2%)
	Repeat biopsy required	10 (4.4%)
	Clinicoradiological correlation	2 (0.9%)

Table 2 Age group wise distribution of patients

Age group (y)	n	%
21-30	1	0.4
31-40	4	1.8
41-50	12	5.3
51-60	46	20.4
61-70	91	40.3
71-80	59	26.1
81-90	13	5.8
Total	226	100.0

Table 3 Five most common histological diagnosis according to age group of patients.

HPE	Age group (n,%)							Total (n,%)
	21-30	31-40	41-50	51-60	61-70	71-80	81-90	
SCC	0(0.0%)	0(0.0%)	2(0.9%)	9(4.0%)	30(13.3%)	19(8.4%)	4(1.8%)	64(28.3%)
NSCLC	1(0.4%)	2(0.9%)	2(0.9%)	13(5.8%)	23(10.2%)	15(6.6%)	7(3.1%)	63(27.9%)
Adenocarcinoma	0(0.0%)	2(0.9%)	5(2.2%)	9(4.0%)	18(8.0%)	15(6.6%)	1(0.4%)	50(22.1%)
SCLC	0(0.0%)	0(0.0%)	1(0.4%)	6(2.7%)	6(2.7%)	6(2.7%)	0(0.0%)	19(8.4%)
Suggestive for malignancy	0(0.0%)	0(0.0%)	0(0.0%)	4(1.8%)	4(1.8%)	0(0.0%)	0(0.0%)	8(3.5%)

Table 4 Five most common histological diagnoses according to biopsy sites.

HPE	Biopsy site (n,%)						Total (n,%)
	Ant. Mediastinum	Chest wall	Left lung	Lung	Right lung	Supraclav. Lns	
SCC	1(0.4%)	2(0.9%)	24(10.6%)	4(1.8%)	32(14.2%)	1(0.4%)	64(28.3%)
NSCLC	0(0.0%)	0(0.0%)	26(11.5%)	8(3.5%)	29(12.8%)	0(0.0%)	63(27.9%)
Adenocarcinoma	0(0.0%)	1(0.4%)	19(8.4%)	5(2.2%)	22(9.7%)	3(1.3%)	50(22.1%)
SCLC	0(0.0%)	0(0.0%)	9(4.0%)	3(1.3%)	6(2.7%)	1(0.4%)	19(8.4%)
Suggestive for malignancy	0(0.0%)	0(0.0%)	2(0.9%)	1(0.4%)	5(2.2%)	0(0.0%)	8(3.5%)

Discussion

US-guided biopsy of thoracic lesions is relatively cost-effective option for histopathological diagnosis. This study evaluated the surgeon-led POCUS thoracic biopsy program in a single center which had the diagnostic yield of 94.7% (n=226). Till the writing of this manuscript, there has been limited reported study of POCUS thoracic biopsies by non-radiologist clinicians in Nepal with good diagnostic yield and lower complication rates. Our study is by far the one with largest sample size in Nepal. A similar study of POCUS thoracic biopsy conducted by Verma et al in 77 patients showed diagnostic yield of 86.7% for core needle biopsy and complication rate of 5.2% for pneumothorax, 2.6% for hemothorax and 1 case of vasovagal shock with hemoptysis.[12] Diagnostic yield of this study is comparable to studies conducted by radiologists in other centers, such as study by Suwal et al had diagnostic yield of 94.7%.[9,10] Presence of squamous cell carcinoma (n=64, 28.3%) was found to be most commonly diagnosed entity in our study. This finding was similar as in the study by Verma et al, but presence of adenocarcinoma as being more common can be found in other studies.[10,12–14] Early experiences of POCUS lung biopsy were reported by Laursen et al in 2016 consisting of 215 consecutive patients. Authors studied the diagnostic yield and prevalence of associated complications, and noted diagnostic yield of 76.9% for malignant diagnoses and 47.6% for benign diagnoses. Most common complications were pneumothorax (2.5%) and pain at the biopsy site (2%).[15] Another study by group of pulmonologists in Malaysia reported a diagnostic yield of 77.8% in 18 patients over 4 years.[16] Corcoran et al in 2022 reported a diagnostic yield of 91.4% in 151 patients over a period of 2 year with 78.8% biopsies done as OPD procedure.[17] The regularity and the relative higher number of biopsies done in our setting must have resulted in a diagnostic yield of 94.7% among 226 patients helping us build confidence to use POCUS thoracic biopsy routinely.

In scenarios with lung lesions found to be located in the hilar region or deep into the lung parenchyma there is probability of significant visceral injury and vascular injuries. Air impedes the travel of ultrasound waves, thus presence of normal lung parenchyma or pneumothorax in between the lesion and the chest wall affects the visualization of the lesion. In these situations, the use of US guided biopsy is not possible. US guided biopsy in the presence of normal lung tissue in between the lesion and the chest wall can result in pneumothorax and may warrant further intervention. So, safer alternative approaches for the biopsy such as CT guided or EUS/EBUS need to be incorporated in the management of the patient.

Utility of POCUS has been shown to improve the care of patients in the hands of non-radiologist clinicians throughout many studies, as this allows rapid use of the ultrasound to make prompt decisions in the care of patients. Use of bedside US help in diagnosis of pleural effusion, hemothorax and pneumothorax without the hassle of shifting the patient to radiology suit for interventions. This particularly plays important role in care of critically ill patients. Bed sided US evaluation is being used for managing pneumothorax or pleural effusion with USG guided chest catheter (Pigtails catheters) placement.[18,19] Bedside lung ultrasound in critically ill patients has also been found to reduce use of bedside chest radiographs, radiation exposure and the cost associated with them.[20] In the armamentarium of various diagnostic test and intervention of non-radiologist clinicians, thoracic POCUS adds as an invaluable tool for rapid diagnosis and intervention of many thoracic urgencies as well as emergencies.

In comparison to other diagnostic modalities such as EBUS, EUS, navigational bronchoscopy and CT guided transthoracic biopsy, EBUS has been shown to have a pooled diagnostic yield of 60% to 82%, higher if the lesion are central or perihilar.[21] CT guided biopsy has higher diagnostic yield ranging from 79.7% to 96.9%.[22] Regarding complications associated with the procedure, EBUS carries relatively low complications of pneumothorax compared to CT guided biopsy (2.87% vs 21.43%) and combined outcome of hospital admission, hemorrhage and pneumothorax of 8.62% vs 31.81%.[23] POCUS thoracic biopsy use are limited by the presence of normal lungs in between the lesions and chest wall resulting of lower rate of pneumothorax, hemothorax and hospital admission of 2.4% to 5.4%.[15,24,25] However, in our study, we noted only 5 cases of pneumothorax as the histopathological reports were collected retrospectively.

Case selection for POCUS thoracic biopsy certainly influenced the procedure to have high diagnostic yield and low adverse events. Patients were selected on the basis of whether their lesions were large enough and close to the chest wall, to have the lesion visualized by the US. This criterion would also decrease the risk with CT guided biopsy as well. As the lesions are situated centrally, the role of POCUS thoracic biopsy fades but EBUS/EBUS become more important modality. This stratifies case selection for different diagnostic modalities as different groups. Those undergoing POCUS thoracic biopsy gained advantage of avoiding hospital readmissions after procedures and were also able to access appropriate systemic or palliative therapy rapidly, reducing the invasive procedure as well as financial burden.

POCUS thoracic biopsy thus opens up a new level of care of the patient in need by reducing the load of patients in radiology, by cutting the waiting time and redirecting valuable time of radiologists in more sophisticated interventions and reporting of more patients efficiently, especially in resource constraint settings like Nepal.

Limitations

Although this study has revealed a significant accuracy of surgeon led POCUS thoracic biopsy, there are number of limitations to be addressed. We have not included data regarding the size of the lesions, even though patients were selected if the lesions were larger than 3 cm. With increase in experience of the surgeons, more difficult location and smaller size were also attempted. We have not studied the complication rates but recorded only those encountered immediately post procedure, which might overlook the risk associated with the procedures. We have not included the data on how much each of the surgeons performed the biopsy and their respective yield, so no correlation between the experience of surgeon and diagnostic yield can be concluded by this study.

Conclusions

In today's era, with increasing number of patients, more diagnoses are made with the availability of health facilities to greater number of populations. There is increase in the burden on the health facilities and service providers, resulting in increase in the waiting period for simple procedures. POCUS thoracic biopsies led by non-radiologist clinicians can significantly reduce this burden on radiologists as well as cut the waiting time for many patients ultimately making the health facility more efficient and safer. The diagnoses are made early, treatments can be started early, this also helps in reducing the chances of letting the disease progress. This simple, efficient and cost-effective procedure can be adopted as a part of comprehensive thoracic malignancy evaluation increasing the efficiency of cancer treatment. We can direct future studies to evaluate the learning curve, complications, reduction in cost and waiting time in the treatment of thoracic malignancy patients.

Conflict of Interest Statement

The authors reported no conflicts of interest.

References

1. Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024;74(3):229–63
2. Chen S, Cao Z, Prettner K, Kuhn M, Yang J, Jiao L, et al. Estimates and Projections of the Global Economic Cost of 29 Cancers in 204 Countries and Territories From 2020 to 2050. JAMA Oncol. 2023;9(4):465–72.
3. Blum TG, Morgan RL, Durieux V, Chorostowska-Wynimko J, Baldwin DR, Boyd J, et al. European Respiratory Society guideline on various aspects of quality in lung cancer care. Eur Respir J. 2023;61(2).
4. Labbé C, Anderson M, Simard S, Tremblay L, Laberge F, Vaillancourt R, et al. Wait times for diagnosis and treatment of lung cancer: a single-centre experience. Curr Oncol. 2017;24(6):367–73.
5. Pandey S, Paudel BD, Acharya B, Acharya SC, Karn A, Poudyal S, et al. Duration of intervals in the care-seeking pathway of lung cancer in Nepal. ecancermedicalscience. 2025;19:1825.
6. Benn BS, Parikh M, Tsau PH, Seeley E, Krishna G. Using a Dedicated Interventional Pulmonology Practice Decreases Wait Time

Before Treatment Initiation for New Lung Cancer Diagnoses. Lung. 2019;197(2):249–55.

7. Lichtenstein DA, Menu Y. A Bedside Ultrasound Sign Ruling Out Pneumothorax in the Critically III: Lung Sliding. Chest. 1995;108(5):1345–8.
8. Rivera MP, Mehta AC, Wahidi MM. Establishing the Diagnosis of Lung Cancer: Diagnosis and Management of Lung Cancer, 3rd ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2013;143(5, Supplement):e142S-e165S.
9. Kayastha P, Adhikari B, Paudel S, Suwal S, Shingh SS, Chapagain P, et al. Ultrasound Guided Biopsy among Patients with Lung Lesions Undergoing Procedures in Interventional Radiology of a Tertiary Care Centre. JNMA J Nepal Med Assoc. 2024;62(269):27–9.
10. Suwal S, Chataut D, Thapa A. Ultrasound guided FNA and biopsy in suspected lung cancer in tertiary cancer center of Nepal. Int J Radiol Res. 2021;3(1):57–9.
11. Yodying J, Sunmahakhun C, Ghimire P, Bista N. Diagnostic Accuracy and Safety Between two Needle Sizes in Percutaneous Trans-Thoracic Biopsy for the Evaluation of Pulmonary Lesions. J Nepal Health Res Counc. 2023;21(01):115–21.
12. Verma A, Bhatta N, Shahi R, Lama U, Aryal P, Pantha S, et al. Ultrasound-Guided Percutaneous Transthoracic Biopsy by Pulmonologists. Nepal Respir J. 2024;3(2):30–4.
13. Kayastha P, Adhikari B, Suwal S, Lohani B, Paudel S. Diagnostic yield of percutaneous computed tomography guided core needle biopsy of lung lesion and its complications in tertiary hospital. Int J Res Med Sci. 2020;8(12):4223.
14. Thandra KC, Barsouk A, Saginala K, Aluru JS, Barsouk A. Epidemiology of lung cancer. Contemp Oncol Onkol. 2021;25(1):45–52.
15. Laursen CB, Naur TMH, Bodtger U, Colella S, Naqibullah M, Minddal V, et al. Ultrasound-guided Lung Biopsy in the Hands of Respiratory Physicians: Diagnostic Yield and Complications in 215 Consecutive Patients in 3 Centers. J Bronchol Interv Pulmonol. 2016;23(3):220.
16. Ismail IN, Alaga A. Pulmonologist-led ultrasound guided lung biopsy safety and efficacy: a 4-year experience from a tertiary centre in Northern Malaysia. Med J Malaysia. 2023;78(6):751–5.
17. Corcoran JP, Taylor LM, Nicholson TW, McDill H, Hassan M, Daneshvar CJ. Outcomes From a Physician-led Ultrasound-guided Transthoracic Biopsy Service: Supporting a Rapid Diagnostic Pathway in Suspected Lung Cancer. J Bronchol Interv Pulmonol. 2022;29(1):86.
18. Chen L, Zhang Z. Bedside ultrasonography for diagnosis of pneumothorax. Quant Imaging Med Surg. 2015;5(4):618–23.
19. Brogi E, Gargani L, Bignami E, Barbariol F, Marra A, Forfori F, et al. Thoracic ultrasound for pleural effusion in the intensive care unit: a narrative review from diagnosis to treatment. Crit Care. 2017;21(1):325.
20. Xirouchaki N, Magkanas E, Vaporidi K, Kondili E, Plataki M, Patrianakos A, et al. Lung ultrasound in critically ill patients: comparison with bedside chest radiography. Intensive Care Med. 2011;37(9):1488–93.
21. Baaklini WA, Reinoso MA, Gorin AB, Sharafkaneh A, Manian P. Diagnostic Yield of Fiberoptic Bronchoscopy in Evaluating Solitary Pulmonary Nodules. Chest. 2000;117(4):1049–54.
22. Yao X, Gomes MM, Tsao MS, Allen CJ, Geddie W, Sekhon H. Fine-needle aspiration biopsy versus core-needle biopsy in diagnosing lung cancer: a systematic review. Curr Oncol. 2012;19(1):e16–27.
23. Ho ATN, Gorthi R, Lee R, Chawla M, Patolia S. Solitary Lung Nodule: CT-Guided Transthoracic Biopsy vs Transbronchial Biopsy With Endobronchial Ultrasound and Flexible Bronchoscope, a Meta-Analysis of Randomized Controlled Trials. Lung. 2023;201(1):85–93.
24. Portela-Oliveira E, Souza CA, Gupta A, Bayanati H, Inacio J, Rakhra K. Ultrasound-guided percutaneous biopsy of thoracic lesions: high diagnostic yield and low complication rate. Clin Radiol. 2021;76(4):281–6.
25. Safety and Yield of Ultrasound-Assisted Transthoracic Biopsy Performed by Pulmonologists | Respiration | Karger Publishers [Internet]. [cited 2026 Mar 11].