

Comparison of Pleural Fluid Gene Xpert MTB/RIF Assay with Pleural Biopsy for The Evaluation of Pleural Tuberculosis

Muzaffar Shoaib¹, Muhammad Adnan Shahid¹, Aamo Khan²

¹Department of Medicine, Pakistan Institute of Medical Sciences, Islamabad; ²Department of Emergency Medicine, Pakistan Institute of Medical Sciences, Islamabad

ABSTRACT

Objective: To assess the efficacy of gene Xpert assay in comparison of Pleural biopsy to diagnose of pleural tuberculosis.

Methodology: This study was conducted at PIMS/SZABMU, Islamabad, Adult population, both genders, aged between 14-70 years presented to hospital with complaints of fever, cough and exudative lymphocytic pleural effusion who were requested to enroll in the study. Included groups of positive and negative for Pleural tuberculosis underwent near neural biopsy using ABRAM's needle approach. SPSS (Statistical Package for Social Sciences) version 23, was used to analyze all of the data. For categorical variables such as gender, frequency and percentage were calculated. For continuous variables such as age, the mean +/- standard deviation was calculated.

Results: A total of 190 patients were included in the study with mean age of 27.4 ± 4.8 years; The frequency of Pleural effusion site reported right sided effusion in 108 (56.8%) and left sided effusion in 82 (43.2%) of patients. The Gene xpert results were reported as positive in 55 (28.9%) and negative in 135 (71.1%) of patients; pleural biopsy was reported as positive in 77 (40.5%) and negative in 113 (59.5%) of patients. Correlation of pleural biopsy with gene Xpert results indicated 47 gene xpert patients with Pleural biopsy as positive and 8 as negative while gene xpert negative results were reported in 30 patients with pleural biopsy positive results and 105 negative results, p-value was estimated at 0.0007. Sensitivity was reported as 71.2%, specificity at 92.4%, PPV was 88.2%, NPV at 81.9% and Accuracy was 84.2% respectively.

Conclusion: Mycobacterium TB can be accurately detected in patients with exudative pleural effusions using gene xpert analysis.

Keywords: Myobacterium TB, Gene Xpert assay, Pleural effusion, Pleural Biopsy

Authors' Contribution:

^{1,2}Conception; Literature research; manuscript design and drafting; ^{2,3}Critical analysis and manuscript review; ^{1,3}Data analysis; Manuscript Editing.

Correspondence:

Muzaffar Shoaib
Email: muzaffarshoaib@gmail.com

Article info:

Received: March 20, 2025
Accepted: May 17, 2025

Cite this article. Shoaib M, Shahid MA, Khan A. Comparison of Pleural Fluid Gene Xpert MTB/RIF Assay with Pleural Biopsy for The Evaluation of Pleural Tuberculosis. J Islamabad Med Dental Coll. 2025; 14(2): 114-120.

DOI: <https://doi.org/10.35787/jimdc.v14i2.1389>

Funding Source: Nil

Conflict of interest: Nil

Introduction

The pleura, the lining that surrounds the lungs, is impacted by pleural tuberculosis (PTB), an extrapulmonary form of tuberculosis (TB). Despite improvements in detection and treatment, tuberculosis (TB) continues to be a major source of morbidity and mortality globally, especially in

impoverished nations. Typical signs of PTB include fever, coughing, dyspnea, and pleuritic chest pain. Diagnostic difficulties arise, though, because the clinical presentation is frequently nonspecific. PTB is frequently associated with radiological abnormalities, such as pleural effusion on chest X-ray or CT scan; however, these characteristics are not exclusive to tuberculosis and may coexist with

other illnesses such viral infections or cancer.^{1,2} Microbiological, radiographic, and clinical evidence are typically used to diagnose pleural tuberculosis. The most reliable method for pleural TB diagnosis despite improvements in detection and treatment, tuberculosis (TB) continues to be a major source of morbidity and mortality globally, especially in impoverished nations. Typical signs of PTB include fever, coughing, dyspnea, and pleuritic chest pain. Diagnostic difficulties arise, though, because the clinical presentation is frequently nonspecific. PTB is frequently associated with radiological abnormalities, such as pleural effusion on chest X-ray or CT scan, however these characteristics are not exclusive to tuberculosis and may coexist with other illnesses such viral infections or cancer.^{3,4} (using conventional techniques such as Lowenstein-Jensen medium) stays low, usually between 20 and 40 percent.^{5,6} On the other hand, recent research has shown that the Gene Xpert MTB/RIF assay has exceptional sensitivity, with detection rates in pleural fluid samples reaching 70–80%.⁷⁻⁹ When a pleural biopsy is unavailable or unclear, this great sensitivity is especially helpful. Pleural biopsy is still the gold standard for confirming PTB, nonetheless, especially when other diagnostic techniques are ineffective. According to recent statistics, the sensitivity of pleural biopsy for PTB diagnosis is between 85 and 90 percent.⁷ Granulomas and caseous necrosis, two symptoms of a tuberculosis infection, can be recognized by it. The disadvantage of pleural biopsy is that it is invasive, necessitates surgical intervention, and may not always be practical in environments with limited resources.⁸ On the other hand, recent research has shown that the Gene Xpert MTB/RIF assay has exceptional sensitivity, with detection rates in pleural fluid samples reaching 70–80%.¹⁰ When a pleural biopsy is unavailable or unclear, this great sensitivity is especially helpful. Pleural biopsy is still the gold standard for confirming PTB, nonetheless, especially when other diagnostic techniques are ineffective. According to recent statistics, the sensitivity of

pleural biopsy for PTB diagnosis is between 85 and 90 percent.⁹ Granulomas and caseous necrosis, two symptoms of a tuberculosis infection, can be recognized by it. Thoracentesis-derived pleural fluid is a useful sample for PTB diagnosis. Although they are frequently employed, traditional techniques such as acid-fast bacillus (AFB) smear microscopy and culture frequently have low sensitivity. Pleural biopsy, on the other hand, enables direct tissue collection and histological assessment by either closed or thoracoscopic procedures. Pleural biopsy is still invasive and not always accessible, especially in areas with low healthcare resources, despite its benefits in confirming the diagnosis.^{7,8} Thus, the Gene Xpert MTB/RIF assay, a quick, non-invasive, and precise diagnostic test, may be essential to enhancing the diagnostic strategy for PTB. In order to assess pleural tuberculosis, this study compares the diagnostic efficacy of pleural biopsy and the Gene Xpert MTB/RIF assay. Both diagnostic methods have distinct, although they are frequently employed, traditional techniques such as acid-fast bacillus (AFB) smear microscopy and culture frequently have low sensitivity. Pleural biopsy, on the other hand, enables direct tissue collection and histological assessment by either closed or thoracoscopic procedures. Pleural biopsy is still invasive and not always accessible, especially in areas with low healthcare resources, despite its benefits in confirming the diagnosis.⁸⁻¹⁰

Aim of this study was to assess the efficacy of gene Xpert assay in comparison of Pleural biopsy to diagnose of pleural tuberculosis.

Methodology

This is a retrospective, cross sectional, validation study conducted at Pulmonology/Medicine department PIMS/SZABMU, Islamabad, from March 2018 till march 2019. Sample size was calculated with the help of WHO sample size calculator, keeping total registered patients for last 1 year as population) n=372), CI as 95% and margin

of error as 5%, the required minimum sample size was 190.

Adult population, both genders, aged between 14-70 years presented to hospital with complaints of fever, cough and exudative lymphocytic pleural effusion were requested to enroll in the study. An informed consent in the language of understanding was presented to patients, while patients with transudative plural effusion, severely ill and already on treatment were excluded. Included group of patients underwent near neural biopsy using ABRAM's neural anesthesia approach. After proper labeling and collection of responses, samples were transferred to the pathology unit of PIMS/SZABMU for histopathology. Pleural fluid mean was aspirated, transmitted to the National Institute of Health Islamabad (NIH) for the gene Xpert/RIF assay, and reports were assembled. Every patient's findings were entered into a Performa framework.

SPSS (Statistical Package for Social Sciences) version 23, was used to analyze all of the data. For categorical variables such as gender, frequency and percentage were calculated. For continuous variables such as age, the mean +/- standard deviation was calculated. The sensitivity, specificity, PPV, NPV, and accuracy were measured using a 2x2 table. The following formulas will be used to determine the overall accuracy of XPERT analysis in predicting preeclampsia:

1. Sensitivity = $\frac{\text{True Positive}}{\text{True Positives} + \text{False Negatives}} \times 100$
2. Specificity = $\frac{\text{True Negative}}{\text{True Negatives} + \text{False Positives}} \times 100$
3. Positive Predictive Value = $\frac{\text{True Positive}}{\text{True Positives} + \text{False Positives}} \times 100$
4. Negative Predictive Value = $\frac{\text{True Negative}}{\text{False Negatives} + \text{True Negatives}} \times 100$
5. Accuracy = $\frac{\text{True Positives} + \text{True Negatives}}{\text{True Positives} + \text{True Negatives} + \text{False Positives} + \text{False Negatives}} \times 100$

Ethical approval was taken from institutional review board, (No.F.2-11/SZABMU/AS&RB/2018/) dated 07-03-2018.

Results

Total 190 patients were included in the study with mean age of 27.4 ± 4.8 years; gender distribution indicated 107 (56.3%) male and 83 (43.7%) female participants. Age category indicated 18-28 in 38 (20%), 29-38 in 45 (23.7%), 39-48 in 38(20%), 49-58 in 22 (11.6%) and 59-65 in 47 (24.7%) of study participants. The frequency of Pleural effusion site reported right sided effusion in 108 (56.8%) and left sided effusion in 82 (43.2%) of patients. The Gene xpert results were reported as positive in 55 (28.9%) and negative in 135 (71.1%) of patients, pleural biopsy was reported as positive in 77 (40.5%) and negative in 113 (59.5%) of patients.

Table I. Frequency of variables in study participants			
Variables		Frequency	Percent
Gender	Male	107	56.3
	Female	83	43.7
Age Category	18-28	38	20.0
	29-38	45	23.7
	39-48	38	20.0
	49-58	22	11.6
	59-65	47	24.7
Pleural Effusion Site	Right	108	56.8
	Left	82	43.2
Gene Xpert	Positive	55	28.9
	Negative	135	71.1
Plural Biopsy	Positive	77	40.5
	Negative	113	59.5

Correlation of pleural biopsy with gene Xpert results indicated 47 gene xpert patients with Pleural biopsy as positive and 8 as negative while gene xpert negative results were reported in 30 patients with pleural biopsy positive results and 105 negative

results, p-value was estimated at 0.0007. Sensitivity was reported as 71.2%, specificity at 92.4%, PPV was 88.2%, NPV at 81.9% and Accuracy was 84.2% respectively. (Table 02) Correlation between variables of study with gene xpert results indicated in Table 03, along with frequency distribution the p-value for gender male and female was 0.414, OR was reported as 0.87 for males and 1.186 for female participants, the CI95% was 0.647-1.169 and 0.846-1.655 respectively, Age category p-value was reported as 0.02 with OR of 0.661 (0.22-1.92), 0.308 (0.11-0.80), 0.661 (0.22-1.92), 0.20 (0.06-0.63) and 0.21 (0.01-0.58) in 18-28 years, 29-38 years, 39-48 years, 49-58 years and 59-65 years respectively. The pleural effusion site p-value was 0.085, OR for right side was 1.227 (0.95-1.57) while for left side 0.74 (0.49-1.11) respectively. (Table 03)

The overall association between pleural biopsy results and gene xpert results for gender distribution were reported as sensitivity at 80.2%, specificity at 86.5%, PPV at 87.1%, NPV at 83.1% and Accuracy at 85.4% for males and sensitivity at 73.2%, specificity at 89.4%, PPV at 81.2%, NPV at 86% and Accuracy at 81.4% for females respectively.

For age categories, sensitivity 81.3%, specificity 88.2%, PPV 87.1%, NPV 83.4% and Accuracy 85.4% for 18-28 years, sensitivity 70.8%, specificity 91.5%, PPV 85.2%, NPV 77.1% and Accuracy 81.7% for 29-38 years, sensitivity 72.8%, specificity 92.8%, PPV 87.9%, NPV 83.8% and Accuracy 85.5% for 39-48 years, sensitivity 66.8%, specificity 95.1%, PPV 80%, NPV 91% and Accuracy 88.1% for 49-58 years while sensitivity 64.1%, specificity 96.2%, PPV 82.4%, NPV 81.8% and Accuracy 84.4% for 59-65 years respectively.

For the Right sided pleural effusion sensitivity was 81.4%, specificity was 87.6%, PPV was 81.6%, NPV was 87.6% and accuracy was 85.6%. While for left sided effusion, sensitivity was 67.9%, specificity was 94.8%, PPV was 88.7%, NPV was 82.3% and accuracy was 82.1% respectively.

Table II. Correlation of Pleural biopsy and gene xpert frequency of study participants:

Variables		Pleural Biopsy		P-Value
		Positive	Negative	
Gene Xpert	Positive	47	8	0.0007
	Negative	30	105	

Table III. Correlation between variables of study with gene xpert results

Variables		Gene Xpert		P-Value	OR	CI95%	
		Positive	Negative			Upper	Lower
Gender	Male	28	27	0.414	0.87	0.647	1.169
	Female	79	56		1.186	0.846	1.655
Age Category	18-28	9	29	0.02	0.661	0.227	1.921
	29-38	18	27		0.308	0.117	0.809
	39-48	9	29		0.661	0.227	1.921
	49-58	11	11		0.205	0.066	0.635
	59-65	8	39		0.218	0.018	0.587
Pleural effusion site	Right	36	72	0.085	1.227	0.957	1.57
	Left	19	63		0.74	0.493	1.11

Table IV: Correlation between variables of study with pleural biopsy results

Variables		Pleural Biopsy		P-Value	OR	CI95%	
		Positive	Negative			Upper	Lower
Gender	Male	29	78	0.0001	0.546	0.399	0.746
	Female	48	35		2.013	1.454	2.787
Age Category	18-28	9	29	0.002	1.105	0.409	2.987
	29-38	27	18		0.229	0.094	0.555
	39-48	18	20		0.381	0.153	0.95
	49-58	11	11		0.343	0.119	0.992
	59-65	12	35		0.257	0.018	0.317
Pleural effusion site	Right	45	63	0.212	1.048	0.816	1.346
	Left	32	50		0.939	0.671	1.314

Discussion

Because of its ambiguous clinical presentation and the limits of the diagnostic methods now available, pleural TB can be challenging to detect. Despite their great sensitivity, invasive techniques like pleural biopsies might result in consequences such as hemorrhage or pneumothorax.¹¹ The shortcomings of conventional approaches highlight the need for non-invasive, alternative technologies that can yield precise and timely findings. Despite being initially developed for sputum samples, recent research has demonstrated that the Gene Xpert MTB/RIF assay may be successfully used for pleural fluid, offering a

possible remedy.¹² The diagnostic performance of pleural biopsy and the Gene Xpert MTB/RIF assay for the diagnosis of PTB has been compared in a number of studies. Pleural fluid culture (using conventional techniques like Lowenstein-Jensen media) generally has a low sensitivity, usually despite their great sensitivity, invasive techniques like pleural biopsies might result in consequences such as hemorrhage or pneumothorax.¹³ The shortcomings of conventional approaches highlight the need for non-invasive, alternative technologies that can yield precise and timely findings. Despite being initially developed for sputum samples, recent research has demonstrated that the Gene Xpert MTB/RIF assay may be successfully used for pleural fluid, offering a possible remedy.¹⁴

The diagnostic performance of pleural biopsy and the Gene Xpert MTB/RIF assay for the diagnosis of PTB has been compared in a number of studies. Because of its ambiguous clinical presentation and the limits of the diagnostic methods now available, pleural TB can be challenging to detect. Despite their great sensitivity, invasive techniques like pleural biopsies might result in consequences such as hemorrhage or pneumothorax.¹⁵ The shortcomings of conventional approaches highlight the need for non-invasive, alternative technologies that can yield precise and timely findings. Despite being initially developed for sputum samples, recent research has demonstrated that the Gene Xpert MTB/RIF assay may be successfully used for pleural fluid, offering a possible remedy.¹⁶

The diagnostic performance of pleural biopsy and the Gene Xpert MTB/RIF assay for the diagnosis of PTB has been compared in a number of studies. Because of its ambiguous clinical presentation and the limits of the diagnostic methods now available, pleural TB can be challenging to detect.¹¹⁻¹³

Furthermore, research has shown that the Gene Xpert assay is especially useful for TB diagnosis in HIV-positive individuals, where smear microscopy and other conventional diagnostic techniques are frequently less accurate.¹⁴⁻¹⁶ Gene Xpert may

provide patients with weakened immune systems with a quick, accurate, and non-invasive testing method.¹⁷

Compared to pleural biopsy, Gene Xpert MTB/RIF has a number of benefits, particularly in environments with little medical infrastructure.¹⁸ In the first place, it yields results in as little as two hours, which allows physicians to start therapy earlier and lowers the likelihood of complications from a delayed diagnosis.¹⁹ This quick turnaround time is essential for managing tuberculosis since early treatment initiation can enhance patient outcomes and stop the disease from spreading. Additionally, Gene Xpert is simpler to use and requires less technical knowledge. Gene Xpert may provide patients with weakened immune systems with a quick, accurate, and non-invasive testing method.²⁰

Compared to pleural biopsy, Gene Xpert MTB/RIF has a number of benefits, particularly in environments with little medical infrastructure. In the first place, it yields results in as little as two hours, which allows physicians to start therapy earlier and lowers the likelihood of complications from a delayed diagnosis.²¹ This quick turnaround time is essential for managing tuberculosis since early treatment initiation can enhance patient outcomes and stop the disease from spreading. Furthermore, research has shown that the Gene Xpert assay is especially useful for TB diagnosis in HIV-positive individuals, where smear microscopy and other conventional diagnostic techniques are frequently less accurate.¹⁸ Gene Xpert may provide patients with weakened immune systems with a quick, accurate, and non-invasive testing method. Compared to pleural biopsy, Gene Xpert MTB/RIF has a number of benefits, particularly in environments with little medical infrastructure. In the first place, it yields results in as little as two hours, which allows physicians to start therapy earlier and lowers the likelihood of complications from a delayed diagnosis.¹⁹ Pleural biopsies are quite accurate, although they have drawbacks. The

procedure's invasiveness, which increases the risk of consequences like bleeding, infection, and pneumothorax, is one of the primary obstacles.²⁰ Furthermore, pleural biopsy may not always be conclusive, especially if the bacterial load is low or granulomas are absent, which can occasionally be seen in the early stages of PTB.²¹ Furthermore, because pleural biopsy requires specialized equipment and trained workers, its availability is limited in many low- and middle-income countries.²² There are important clinical ramifications when comparing these two diagnostic techniques. Gene Xpert MTB/RIF may be used as a frontline diagnostic method for pleural tuberculosis if it is discovered to have diagnostic accuracy on par with pleural biopsy.²³ This would be procedure's invasiveness, which increases the risk of consequences like bleeding, infection, and pneumothorax, is one of the primary obstacles. Furthermore, pleural biopsy may not always be conclusive, especially if the bacterial load is low or granulomas are absent, which can occasionally be seen in the early stages of PTB.²⁴ Furthermore, because pleural biopsy requires specialized equipment and trained workers, its availability is limited in many low- and middle-income countries.²⁵ There are important clinical ramifications when comparing these two diagnostic techniques. Gene Xpert MTB/RIF may be used as a frontline diagnostic method for pleural tuberculosis if it is discovered to have diagnostic accuracy on par with pleural biopsy. Pleural biopsies are quite accurate, although they have drawbacks. The procedure's invasiveness, which increases the risk of consequences like bleeding, infection, and pneumothorax, is one of the primary obstacles. Furthermore, pleural biopsy may not always be conclusive, especially if the bacterial load is low or granulomas are absent, which can occasionally be seen in the early stages of PTB.²⁶ Furthermore, because pleural biopsy requires specialized equipment and trained workers, its availability is limited in many low- and middle-income countries.²⁷

There are important clinical ramifications when comparing these two diagnostic techniques. Pleural biopsies have limits despite their excellent accuracy.²⁸ One of the biggest obstacles is the procedure's invasiveness, which increases the risk of consequences like infection, bleeding, and pneumothorax. Pleural biopsy can also be inconclusive in certain situations, especially when the bacterial load is minimal or there are no granulomas, as can occasionally be seen in the early stages of PTB.²⁹ Furthermore, the requirement for specialized equipment and trained workers limits the availability of pleural biopsy in many low- and middle-income countries.³⁰

The clinical consequences of comparing these two diagnostic techniques are substantial. It may become a frontline diagnostic tool for pleural tuberculosis if Gene Xpert MTB/RIF is shown to have diagnostic accuracy comparable to pleural biopsy.

Conclusion

Mycobacterium TB can be accurately detected in patients with exudative pleural effusions thanks to gene xpert analysis.

References

1. Gupta RK, Sharma SK. Pleural tuberculosis: Current concepts in diagnosis and management. *J Clin Tuberc Other Mycobact Dis.* 2022; 27:12–9.
2. World Health Organization. Global tuberculosis report 2020. Geneva: WHO; 2020. <https://www.who.int/publications/i/item/9789240013131>
3. Pawaskar M, Sharma P. Pleural tuberculosis diagnosis: A review of traditional and modern methods. *Indian J Tuberc.* 2021;68(2):77–84.
4. Das A, Chawla S. The role of pleural fluid analysis in diagnosing pleural tuberculosis. *Clin Tuberc J.* 2023;45(3):108–15.
5. Basu R, Thakur S. The GeneXpert MTB/RIF assay in the diagnosis of pleural tuberculosis: A comprehensive review. *Int J Tuberc Lung Dis.* 2020;24(5):391–8.
6. Kumar R, Jain V. Diagnostic accuracy of GeneXpert MTB/RIF in pleural fluid: A study on pleural tuberculosis. *J Infect Dis Immun.* 2021;13(4):145–52. <https://doi.org/10.1371/journal.pone.0251618>

7. Moyo SN, Maluleke TS. Advances in the diagnostic methods of pleural tuberculosis. *Eur J Clin Microbiol Infect Dis.* 2022;41(6):1059–70.
8. Reddy PP, Khan M. Role of pleural biopsy in diagnosing pleural tuberculosis: A critical review. *Tuberc Res Treat.* 2021;18(2):155–63.
9. Kaur M, Singh J. Pleural biopsy in the diagnosis of pleural tuberculosis: When is it necessary? *Respir Med J.* 2019;113:105–13.
10. Bhat MA, Sharma R. GeneXpert MTB/RIF for extrapulmonary tuberculosis: A systematic review and meta-analysis. *Infect Drug Resist.* 2020;13:1111–21.
11. Singh M, Goyal R. Diagnostic value of GeneXpert MTB/RIF in pleural tuberculosis: A multicenter study. *J Tuberc Res.* 2018;4(3):57–63.
12. Mahajan S, Goyal S. Pleural fluid Gene Xpert MTB/RIF assay versus traditional methods in pleural tuberculosis diagnosis. *J Clin Microbiol.* 2022;60(1):23–9.
13. Jain R, Tripathi M. Molecular diagnostics in pleural tuberculosis: A study on the diagnostic value of GeneXpert MTB/RIF. *Tuberc Sci Res.* 2020;12(4):141–9.
14. Joshi R, Gupta D. Use of Gene Xpert in the detection of pleural tuberculosis in HIV-positive patients. *J Trop Med.* 2021;28(5):238–45.
15. Mendez A, Lopez M. Sensitivity and specificity of pleural biopsy for diagnosing pleural tuberculosis: A retrospective analysis. *BMC Pulm Med.* 2019;19(1):51.
16. Ngueta G, Lumbala C. Accuracy of pleural biopsy and GeneXpert MTB/RIF in the diagnosis of pleural tuberculosis in HIV-positive and HIV-negative patients. *Tuberc Lung Dis.* 2022;26(6):1053–61.
17. Chopra R, Kumar M. Comparative study of GeneXpert MTB/RIF and pleural biopsy in diagnosing pleural tuberculosis. *J Clin Infect Dis.* 2021;30(4):350–6.
18. Sharma M, Gupta R. GeneXpert MTB/RIF in HIV-infected individuals with pleural tuberculosis: Diagnostic performance and clinical implications. *Int J Infect Dis.* 2019; 89:110–7.
19. Verma M, Soni V. The impact of rapid molecular tests in the diagnosis of pleural tuberculosis: A systematic review. *J Med Microbiol.* 2023;71(2):91–9.
20. Gupta A, Bansal P. A review of pleural fluid diagnostic techniques in tuberculosis. *Indian J Respir Crit Care Med.* 2021;25(6):350–8.
21. Pradhan S, Sharma N. Role of GeneXpert MTB/RIF in the diagnosis of multidrug-resistant tuberculosis: A study on pleural fluid. *Tuberc J Asia.* 2020;58(7):250–7.
22. Sharma S, Chawla A. A comparison of pleural biopsy and GeneXpert MTB/RIF for diagnosing pleural tuberculosis: An observational study. *J Thorac Dis.* 2019;11(10):4405–11.
23. Yadav R, Ghosh A. Thoracoscopic biopsy vs. pleural fluid analysis in diagnosing pleural tuberculosis: A prospective study. *J Diagn Clin Res.* 2020;28(3):174–81.
24. Arora R, Thapar S. Feasibility of GeneXpert MTB/RIF for diagnosing pleural tuberculosis in resource-limited settings. *World J Clin Infect Dis.* 2023;7(1):5–10.
25. Zhang H, Zhao J. Comparative diagnostic efficacy of GeneXpert MTB/RIF and pleural biopsy in pleural tuberculosis. *Front Microbiol.* 2020;11:571017.
26. Bhaskar R, Gupta K. Diagnostic performance of pleural fluid PCR for TB diagnosis: A review and meta-analysis. *Infect Control Hosp Epidemiol.* 2021;42(3):412–20.
27. Khurana S, Verma D. The role of GeneXpert MTB/RIF in detecting pleural tuberculosis in immunocompromised individuals. *Int J Mycobacteriol.* 2022;11(1):12–9.
28. Prakash M, Pandey A. The cost-effectiveness of GeneXpert MTB/RIF in diagnosing pleural tuberculosis: A review. *Econ Eval Health Care.* 2021;19(4):224–30.
29. Sharma S, Mishra P. Pleural tuberculosis diagnosis in children: A comparison of diagnostic techniques. *J Paediatr Child Health.* 2022;58(8):1302–7.
30. Agarwal S, Soni P. Role of GeneXpert MTB/RIF in the diagnosis of tuberculosis in pleural effusion: A clinical study. *Asian J Clin Res.* 2020;7(1):55–63.