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Original Research Article

Ziehl-Neelsen Smear Microscopy versus GeneXpert MTB/RIF for Diagnosing Pulmonary Tuberculosis: A Retrospective Diagnostic Accuracy Study from Nepal

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ABSTRACT:

Introduction: Ziehl-Neelsen (ZN) sputum smear microscopy remains widely used for tuberculosis diagnosis in resource-limited settings, but its sensitivity is limited in paucibacillary disease. GeneXpert MTB/RIF offers higher sensitivity, yet real-world comparative data from Nepal remain scarce. **Methods**: This retrospective, record-based cross-sectional study was conducted at Lumbini Medical College and Teaching Hospital, Palpa, Nepal. Records of 643 patients with presumptive pulmonary tuberculosis who underwent paired ZN smear microscopy and GeneXpert MTB/RIF testing were reviewed. Using GeneXpert as the reference standard, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of ZN smear microscopy were calculated with 95% confidence intervals (Wilson method). Agreement was assessed by Cohen's kappa, and McNemar's test compared paired proportions. Receiver operating characteristic (ROC) curve analysis evaluated ZN smear grade discrimination. **Results**: ZN smear microscopy was positive in 42 of 643 participants (6.53%) and GeneXpert in 61 (9.49%). ZN sensitivity was 68.85% (95% CI 56.41–79.06), specificity 100.00% (99.34–100.00), PPV 100.00% (91.62–100.00), NPV 96.84% (95.12–97.97), and overall accuracy 97.05% (95.43–98.10). Agreement was substantial ($\kappa = 0.80$; $p < 0.001$). The area under the ROC curve was 0.844. Rifampicin resistance was detected in 1 of 61 GeneXpert-positive samples (1.64%). **Conclusions**: ZN smear microscopy showed high specificity but moderate sensitivity, missing one-third of GeneXpert-positive cases. GeneXpert MTB/RIF should remain the preferred initial diagnostic test where capacity allows.

Keywords: Diagnostic accuracy; GeneXpert MTB/RIF; Pulmonary tuberculosis; Rifampicin resistance; Ziehl-Neelsen smear microscopy.

INTRODUCTION:

Tuberculosis (TB) remains a leading infectious cause of death worldwide, with an estimated 10.8 million cases in 2023, predominantly in low- and middle-income countries where diagnostic infrastructure is limited.[1] Pulmonary tuberculosis (PTB) is the most common and transmissible form, making rapid, accurate diagnosis essential for control programs.[2]

Ziehl-Neelsen (ZN) sputum smear microscopy has been the mainstay of TB diagnosis in resource-limited settings for over a century due to its low cost, speed, and simplicity. However, it requires several thousand organisms per milliliter for reliable detection, limiting sensitivity in paucibacillary disease.[3,4] The GeneXpert MTB/RIF assay detects Mycobacterium tuberculosis complex

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DNA and rifampicin resistance mutations within approximately two hours.[5] Since WHO endorsement, it has been adopted as an initial diagnostic test, with higher sensitivity than ZN, particularly in smear-negative disease.[6–8]

Despite this, real-world ZN performance relative to GeneXpert varies (sensitivity 60% to over 90%),[9–11] making setting-specific data valuable where GeneXpert capacity is constrained. Local Nepali data in general presumptive-PTB populations remain limited.[7]

This retrospective study therefore aimed to determine the diagnostic accuracy of ZN smear microscopy against GeneXpert MTB/RIF among presumptive pulmonary tuberculosis patients at Lumbini Medical College and Teaching Hospital, Palpa, Nepal, hypothesizing high specificity but lower sensitivity for ZN.[6,9]

METHODS:

This retrospective, record-based cross-sectional study was conducted in the Department of Microbiology in collaboration with the DOTS/TB unit at Lumbini Medical College and Teaching Hospital (LMCTH), Palpa, Nepal. Ethical approval was obtained from the IRC-LMCTH (Approval 32420260918). Confidentiality and anonymity were maintained.

Laboratory records generated between 12/02/2026 and 12/08/2026 were reviewed and extracted between 01/09/2026 and 15/09/2026. The study population comprised patients with clinically presumptive pulmonary tuberculosis (cough >2 weeks, with or without fever, weight loss, night sweats, or hemoptysis) who submitted sputum for both ZN smear microscopy and GeneXpert MTB/RIF at LMCTH during the study period. Records with complete paired results were included. Those with missing or invalid results for either test, extrapulmonary samples, and non-sputum respiratory specimens were excluded.

The minimum sample size was calculated using Buderer's method,[12] which incorporates anticipated disease prevalence into diagnostic accuracy formulas: $n = Z^2 \times Sn(1-Sn)/(L^2 \times P)$ for sensitivity and $n = Z^2 \times Sp(1-Sp)/(L^2 \times (1-P))$ for specificity, where Z=1.96, Sn=75%, Sp=95%, L=12 percentage points (desired half-width of the 95% CI), and P=9.49% (GeneXpert positivity observed in this dataset). The minimum required sample was 528; the final analytic sample (n=643, including 61 GeneXpert-positive cases) exceeded this target, with the achieved 95% CI half-width for sensitivity (~11.3 percentage points) within the targeted precision.

Two sputum specimens were collected per participant, consistent with current WHO/national guidance; earlier protocols required three specimens, but this was revised after evidence that a third adds only 2–5% incremental yield.[13,14] Specimen quality independently affects smear sensitivity: adequate volume (≥5 mL) and early morning timing substantially improve detection.[15,16] At LMCTH, specimens were collected as a spot specimen at presentation and an early morning specimen the following day, or as two supervised spot specimens ≥1 hour apart.

Direct smears were prepared on clean, grease-free slides, air-dried, heat-fixed, and stained using the modified ZN technique per RNTCP guidelines. Results were graded as negative, scanty, 1+, 2+, or 3+ per standard RNTCP/IUATLD grading. Sputum was processed for GeneXpert MTB/RIF (Cepheid Inc., Sunnyvale, CA, USA) per manufacturer instructions, with results categorized as MTB not detected or MTB detected with semi-quantitative bacillary load (trace, very low, low, medium, high) and rifampicin resistance status (detected, not detected, indeterminate). GeneXpert was the reference standard.

Data on demography, district, collection site, case type, symptoms, ZN grade, GeneXpert result, and rifampicin resistance were extracted from laboratory and DOTS/TB registers into a structured sheet; identifiers were anonymized.

Data were analyzed using PSPP software. Categorical variables were summarized as frequencies and percentages; age as mean ± SD. ZN and GeneXpert results were cross-tabulated in a 2×2 table to calculate sensitivity, specificity, PPV, NPV, and overall accuracy with 95% CIs (Wilson method). Cohen's kappa quantified agreement, interpreted per Landis and Koch.[17] Chi-square tested sex–GeneXpert association; McNemar's test compared paired positive proportions. A p-value <0.05 was significant; exact p-values are reported.

RESULTS:

A total of 643 patients with presumptive pulmonary tuberculosis and paired ZN smear microscopy and GeneXpert MTB/RIF results were included (**Fig 1**). The mean age was 55.74 ± 21.29 years (median 61, range 2–98), with half the participants older than 60 years; males and females were approximately equally represented. Janajati was the most common ethnic group, and almost all participants were new cases. All participants had cough >2 weeks, while other symptoms were less frequent (**Table 1**).

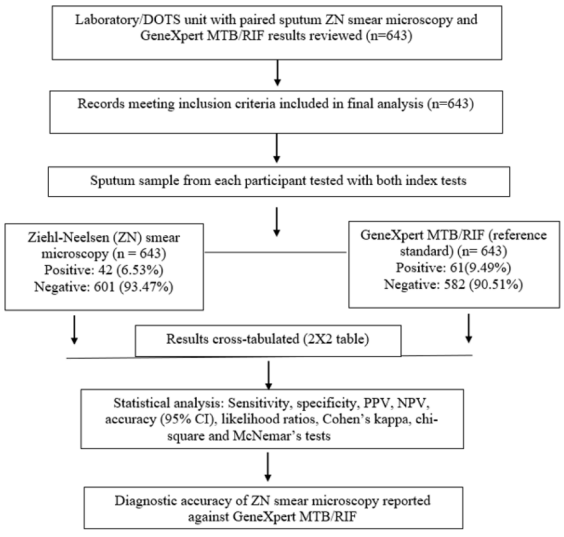


Fig 1. *STARD-style flow diagram of the study, showing the number of records reviewed, the data-quality check performed and the pathway from sputum collection through statistical analysis.*

ZN smear microscopy was positive in 42 of 643 participants (6.53%), while GeneXpert MTB/RIF was positive in 61 (9.49%). All ZN-positive samples were also GeneXpert-positive; no false positives occurred. Nineteen samples were ZN-negative but GeneXpert-positive (**Table 2**).

Using GeneXpert as the reference standard, ZN smear microscopy showed a sensitivity of 68.85% (95% CI 56.41–79.06) and a specificity of 100.00% (95% CI 99.34–100.00), with a PPV of 100.00%, an NPV of 96.84%, and an overall accuracy of 97.05% (**Table 3**). The negative likelihood ratio was 0.31; the positive likelihood ratio was not estimable because no false positives occurred. Agreement between the two tests was substantial ($\kappa = 0.80$), and McNemar's test confirmed a significant difference in paired proportions (19 discordant pairs, all ZN-negative/GeneXpert-positive; $p < 0.001$).

Higher ZN smear grades corresponded closely with higher GeneXpert bacillary load categories, while all ZN-negative samples were either GeneXpert-negative or in the trace/very low categories; no ZN-negative sample fell into a low, medium, or high GeneXpert category (**Table 4**).

Table 1. *Socio-demographic and clinical characteristics of study participants (n = 643)*

Characteristic	Variables	n (%)
Age group (years)	≤ 15	44 (6.84)
	16–30	52 (8.09)
	31–45	78 (12.13)
	46–60	145 (22.55)
	> 60	324 (50.39)
Sex	Male	340 (52.88)
	Female	303 (47.12)
Ethnicity	Janajati	321 (49.92)
	Brahmin	126 (19.60)
	Dalit	121 (18.82)
	Chhetri	69 (10.73)
	Madhesi	5 (0.78)
	Muslim	1 (0.16)
Type of case	New case	640 (99.53)
	Previous treatment	2 (0.31)
	Retreatment	1 (0.16)
Presenting symptom*	Cough > 2 weeks	643 (100)
	Fever	262 (40.75)
	Weight loss	147 (22.86)
	Night sweats	33 (5.13)
	Hemoptysis	10 (1.56)

**participants could report more than one symptom*

Table 2. *Cross-tabulation of Ziehl-Neelsen (ZN) smear microscopy against GeneXpert MTB/RIF*

ZN smear microscopy result	GeneXpert MTB/RIF positive	GeneXpert MTB/RIF negative	Total
Positive	42 (a)	0 (b)	42
Negative	19 (c)	582 (d)	601
Total	**61**	**582**	**643**

a=true positives; b=false positives;c=false negatives; d=true negatives

Table 3. *Diagnostic performance of Ziehl-Neelsen smear microscopy, using GeneXpert MTB/RIF as the reference standard*

Diagnostic parameter	Value (%)	95% CI*
Sensitivity	68.85	56.41-79.06
Specificity	100.00	99.34-100.00
Positive Predictive Value	100.00	91.62-100.00
Negative Predictive Value	96.84	95.12-97.97
Overall diagnostic accuracy	97.05	95.43-98.10

**CI=confidence interval*

Table 4. *Relationship between Ziehl-Neelsen smear grade and GeneXpert MTB/RIF semi-quantitative bacillary load category (n = 643)*

ZN smear grade	Not detected	Trace detected	Very low	Low	Medium	High
Negative	582	9	10	0	0	0
1+	0	0	1	12	1	0
2+	0	0	0	0	10	1
3+	0	0	0	0	0	17

Note: Cell values are counts (n) of participants.

The discriminative ability of ZN smear grade (negative, 1+, 2+, 3+, as an ordinal score) for GeneXpert MTB/RIF positivity was assessed by ROC curve analysis (**Fig 2**). The AUC was 0.844, indicating good overall discrimination that was limited primarily by sensitivity rather than specificity at every grade threshold.

Male sex was significantly associated with GeneXpert MTB/RIF positivity (13.24% of males vs. 5.28% of females; $\chi^2 = 10.90$, df = 1, $p < 0.001$). Among the 61 GeneXpert-positive samples, rifampicin resistance was detected in only 1 (1.64%), was indeterminate in 9 (14.75%), and was not detected in the remaining 51 (83.61%). Secondary analyses of geographic/collection-point distributions are presented in **Supplementary Tables S1 and S2** available online.

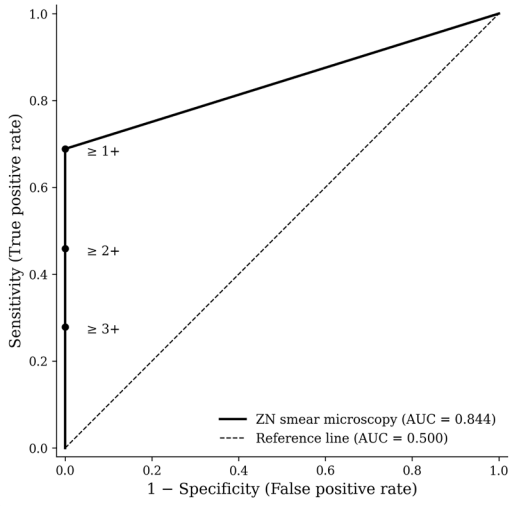


***Fig 2**. Receiver operating characteristic (ROC) curve for Ziehl-Neelsen (ZN) smear microscopy grade (negative, 1+, 2+, 3+, as an ordinal score), taking GeneXpert MTB/RIF as the reference test.*

DISCUSSION:

In this retrospective analysis of 643 patients with presumptive pulmonary tuberculosis, ZN smear microscopy showed high specificity (100%) and PPV (100%) but only moderate sensitivity (68.85%) compared with GeneXpert MTB/RIF, missing approximately one-third of GeneXpert-positive cases, mostly at lower bacillary loads. This pattern of high specificity with more limited sensitivity is consistent with Umair et al.,[9] who reported 100% specificity but lower sensitivity (60%) for ZN against GeneXpert in Pakistan. However, our findings contrast with Elbrolosy et al.,[6] who reported lower specificity (86.9%) alongside higher sensitivity (90.2%) for smear microscopy in Egypt, likely reflecting differences in population case mix, smear reading practices, and quality assurance procedures. The sensitivity observed here falls within the range reported across comparative studies,[9–11] supporting the generalizability of ZN's principal limitation: reduced detection of paucibacillary disease across diverse settings.

These findings align with other Nepalese studies. Ojha et al.[18] in Biratnagar reported ZN sensitivities of 55.9–60.0% with 100% specificity, comparable to our findings; rifampicin resistance was concentrated among retreatment cases (66.7% vs. 1.3%). Rimal et al.[19] and Lama et al.[20] at the National Tuberculosis Centre, Bhaktapur, similarly found GeneXpert substantially improved detection among smear-negative specimens (sensitivities 74.3% and 73%), supporting our finding that GeneXpert identified 19 additional cases missed by ZN alone. Pandey et al.[7] likewise demonstrated GeneXpert's value for drug-resistant TB in Kathmandu. Regionally, Van Deun et al.[21] argued smear microscopy and GeneXpert are complementary rather than competing tools, a view supported by Burger et al.,[22] who found GeneXpert increased Myanmar's national case detection by 40%. Given that the WHO South-East Asia Region bore 45% of the global TB burden in 2023, with Nepal among its high MDR/RR-TB countries,[1] these findings support continued or expanded regional GeneXpert deployment.

The ROC curve analysis (**Fig 2**) yielded an AUC of 0.844 for ZN smear grade against GeneXpert, within the range considered to reflect good diagnostic discrimination.[23] The curve's steep rise at a 0.00% false positive rate confirms that discrimination was limited by sensitivity rather than specificity. The complete absence of false-positive ZN results suggests a positive ZN smear can be regarded as highly reliable evidence of disease; conversely, the 19 ZN-negative, GeneXpert-positive cases illustrate the well-documented gap left by smear microscopy in paucibacillary and early disease. The close correspondence between ZN smear grade and GeneXpert bacillary load category (**Table 4**) supports the biological basis of this threshold effect and reinforces GeneXpert's semi-quantitative output as a useful internal check on smear quality.

Rifampicin resistance was detected in only 1 of 61 (1.64%) GeneXpert-positive samples, with a further 9 (14.75%) indeterminate results, the latter typically reflecting a very low bacillary load insufficient for reliable resistance determination.

This low but non-zero resistance rate is broadly consistent with regional and national drug-resistance surveillance data and underscores the added clinical value of GeneXpert beyond diagnosis alone, consistent with its role in guiding treatment regimen selection.[7,8] Male sex was significantly associated with GeneXpert positivity, and GeneXpert-positive participants more often reported fever, weight loss, night sweats, and hemoptysis. Both patterns reflect the more advanced or classically symptomatic disease typically seen in bacteriologically confirmed TB and may help clinicians prioritize patients for GeneXpert testing where capacity is limited.

The catchment characteristics of the study population offer context for interpreting these findings. The geographic distribution (**Supplementary Table S1**) shows that this study's catchment was drawn overwhelmingly from Palpa district (549, 85.38%), with smaller numbers from neighbouring hilly districts and only isolated participants from more distant areas. This pattern is consistent with LMCTH's role as a district-level rather than wide regional referral centre. This limits generalizability, since centres with a different rural-urban or hill-Terai case-mix could see different ZN performance. The modestly higher GeneXpert positivity in Syangja (13.89% vs. 9.65% in Palpa) should not be read as true geographic variation given the small Syangja sample (n=36); a prospective, multi-district study would be needed to confirm this. Sputum sample origin (**Supplementary Table S2**) showed that despite different routes into diagnosis, just over half from peripheral health posts (51.48%) and just over one-third from the LMCTH FAST corner (36.86%), GeneXpert positivity was similar between the two (9.67% vs. 8.86%), suggesting case-finding mode did not materially bias detection.[24]

Limitations: This study has several limitations. First, its retrospective, single-centre design and reliance on secondary records limited control over data completeness. Second, GeneXpert rather than culture was used as the reference standard, so true ZN sensitivity against culture may differ. Third, the relatively small number of GeneXpert-positive cases (61/643) widened the sensitivity confidence interval. Fourth, specimen-level quality indicators (volume, character, timing) were not recorded and could not be adjusted for, potentially contributing to the moderate sensitivity observed. Fifth, HIV status was not recorded; since HIV co-infection is a recognized major confounder that reduces smear sensitivity through more frequent paucibacillary disease,[25] its distribution and potential influence on sensitivity estimates could not be assessed. Finally, as a single-centre study conducted predominantly in Palpa, these findings may not generalize to settings with different disease prevalence or laboratory practices.

CONCLUSIONS:

ZN smear microscopy remains a highly specific but moderately sensitive test for pulmonary TB, missing a substantial proportion of GeneXpert-positive cases, particularly those with low bacillary loads. GeneXpert MTB/RIF should remain the preferred initial diagnostic test where capacity allows, with ZN reserved for settings where GeneXpert is unavailable or constrained. The complementary roles of both tests should inform local diagnostic algorithms in resource-limited, high-burden settings.

Conflict of interest:
The authors declare no conflict of interest exists.

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Authors' Declaration:
Ethical issues (including plagiarism, data fabrication, and double publication) have been completely observed by the authors.

REFERENCES

1. World Health Organization. Global tuberculosis report 2024. Geneva: World Health Organization; 2024. Available from this link.
2. Frieden TR, Sterling TR, Munsiff SS, Watt CJ, Dye C. Tuberculosis. Lancet. 2003 Sep 13;362(9387):887-99. doi: 10.1016/S0140-6736(03)14333-4. PMID: 13678977. DOI: 10.1016/S0140-6736(03)14333-4
3. Abdelaziz MM, Bakr WM, Hussien SM, Amine AE. Diagnosis of pulmonary tuberculosis using Ziehl-Neelsen stain or cold staining techniques? J Egypt Public Health Assoc. 2016 Mar;91(1):39-43. doi: 10.1097/01.EPX.0000481358.12903.af. PMID: 27110859 DOI: 10.1097/01.EPX.0000481358.12903.af
4. Chandra TJ, Selvaraj R, Sharma YV. Same day sputum smear microscopy for the diagnosis of pulmonary tuberculosis: Ziehl-Neelsen versus fluorescent staining. J Family Med Prim Care. 2015 Oct-Dec;4(4):525-8. PMID: 26985410 DOI: 10.4103/2249-4863.174273
5. Slim-Saidi L, Mehiri-Zeghal E, Ghariani A, Tritar F. Nouvelles méthodes de diagnostic de la tuberculose [New methods of diagnosis in tuberculosis]. Rev Pneumol Clin. 2015 Apr-Jun;71(2-3):110-21. French. PMID: 25754128 DOI: 10.1016/j.pneumo.2015.02.002
6. Elbrolosy AM, El Helbawy RH, Mansour OM, Latif RA. Diagnostic utility of GeneXpert MTB/RIF assay versus conventional methods for diagnosis of pulmonary and extra-pulmonary tuberculosis. BMC Microbiol. 2021 May 13;21(1):144. PMID: 33980173 DOI: 10.1186/s12866-021-02210-5
7. Pandey P, Pant ND, Rijal KR, Shrestha B, Kattel S, Banjara MR et al. Diagnostic Accuracy of GeneXpert MTB/RIF Assay in Comparison to Conventional Drug Susceptibility Testing Method for the Diagnosis of Multidrug-Resistant Tuberculosis. PLoS One. 2017 Jan 12;12(1):e0169798. PMID: 28081227 DOI: 10.1371/journal.pone.0169798
8. Prakash AK, Datta B, Tripathy JP, Kumar N, Chatterjee P, Jaiswal A. The clinical utility of cycle of threshold value of GeneXpert MTB/RIF (CBNAAT) and its diagnostic accuracy in pulmonary and extra-pulmonary samples at a tertiary care center in India. Indian J Tuberc. 2018 Oct;65(4):296-302. PMID: 30522616 DOI: 10.1016/j.ijtb.2018.05.021
9. Umair M, Siddiqui SA, Farooq MA. Diagnostic Accuracy of Sputum Microscopy in Comparison With GeneXpert in Pulmonary Tuberculosis. Cureus. 2020 Nov 8;12(11):e11383. PMID: 33312784 DOI: 10.7759/cureus.11383
10. Held M, Laubscher M, Workman L, Zar HJ, Dunn R. Diagnostic accuracy of GeneXpert MTB/RIF in musculoskeletal tuberculosis: High sensitivity in tissue samples of HIV-infected and HIV-uninfected patients. S Afr Med J. 2017 Sep 22;107(10):854-858. PMID: 29022528 DOI: 10.7196/SAMJ.2017.v107i10.11186
11. Singh UB, Singh M, Sharma S, Mahajan N, Bala K, Srivastav A et al. Expedited diagnosis of pediatric tuberculosis using Truenat MTB-Rif Dx and GeneXpert MTB/RIF. Sci Rep. 2023 Apr 28;13(1):6976. PMID: 37117209 DOI: 10.1038/s41598-023-32810-2
12. Buderer NM. Statistical methodology: I. Incorporating the prevalence of disease into the sample size calculation for sensitivity and specificity. Acad Emerg Med. 1996 Sep;3(9):895-900. PMID: 8870764 DOI: 10.1111/j.1553-2712.1996.tb03538.x
13. Mase SR, Ramsay A, Ng V, Henry M, Hopewell PC, Cunningham J, Urbanczik R, Perkins MD, Aziz MA, Pai M. Yield of serial sputum specimen examinations in the diagnosis of pulmonary tuberculosis: a systematic review. Int J Tuberc Lung Dis. 2007 May;11(5):485-95. PMID: 17439669
14. Crampin AC, Floyd S, Mwaungulu F, Black G, Ndhlovu R, Mwaiyeghele E et al. Comparison of two versus three smears in identifying culture-positive tuberculosis patients in a rural African setting with high HIV prevalence. Int J Tuberc Lung Dis. 2001 Nov;5(11):994-9. PMID: 11716350
15. Warren JR, Bhattacharya M, De Almeida KN, Trakas K, Peterson LR. A minimum 5.0 ml of sputum improves the sensitivity of acid-fast smear for Mycobacterium tuberculosis. Am J Respir Crit Care Med. 2000 May;161(5):1559-62. PMID: 10806154 DOI: 10.1164/ajrccm.161.5.9908063
16. Abraham PR, Sharma VD, Shivannavar CT. Diagnosis of TB from smear & culture negative sputum specimens by IS 6110 based PCR. Indian J Med Res. 2012;135(2):249-51. PMID: 22446870
17. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977 Mar;33(1):159-74. PMID: 843571 DOI: 10.2307/2529310
18. Ojha S, Adhikari A, Adhikari S, Khanal S, Kalwar CS, Panta OP. Comparative evaluation of sputum microscopy and Xpert MTB/RIF assay for tuberculosis detection and rifampicin resistance surveillance in Biratnagar, Nepal. Microbiol Spectr. 2026 Apr 7;14(4):e0246025. PMID: 41811027 DOI: 10.1128/spectrum.02460-25
19. Rimal R, Shrestha D, Pyakurel S, Poudel R, Shrestha P, Rai KR et al. Diagnostic performance of GeneXpert MTB/RIF in detecting MTB in smear-negative presumptive TB patients. BMC Infect Dis. 2022 Apr 1;22(1):321. PMID: 35365080 DOI: 10.1186/s12879-022-07287-5
20. Lama C, Adhikari S, Sapkota S, Regmi RS, Ghimire GR, Banjara MR et al. Evaluation of Xpert MTB/RIF Assay, MTB Culture and Line Probe Assay for the Detection of MDR Tuberculosis in AFB Smear Negative Specimens. Diseases. 2022 Oct 6;10(4):82. PMID: 36278581 DOI: 10.3390/diseases10040082
21. Van Deun A, Tahseen S, Affolabi D, Hossain MA, Joloba ML, Angra PK et al. Sputum smear microscopy in the Xpert® MTB/RIF era. Int J Tuberc Lung Dis. 2019 Jan 1;23(1):12-18. PMID: 30567624 DOI: 10.5588/ijtld.18.0553
22. Burger Z, Aung HT, Seifert M, Mar TT, Harris V, Colman RE et al. Contributions of GeneXpert® to TB diagnosis in Myanmar. Int J Tuberc Lung Dis. 2022 Sep 1;26(9):875-879. PMID: 35996278 DOI: 10.5588/ijtld.22.0009
23. Swets JA. Measuring the accuracy of diagnostic systems. Science. 1988 Jun 3;240(4857):1285-93. PMID: 3287615 DOI: 10.1126/science.3287615
24. Paudel S, Padmawati RS, Ghimire A, Yonzon CL, Mahendradhata Y. Feasibility of Find cases Actively, Separate safely and Treat effectively (FAST) strategy for early diagnosis of TB in Nepal: An implementation research. PLoS One. 2021 Oct 26;16(10):e0258883. PMID: 34699542 DOI: 10.1371/journal.pone.0258883
25. Zifodya JS, Kreniske JS, Schiller I, Kohli M, Dendukuri N, Schumacher SG et al. Xpert Ultra versus Xpert MTB/RIF for pulmonary tuberculosis and rifampicin resistance in adults with presumptive pulmonary tuberculosis. Cochrane Database Syst Rev. 2021 Feb 22;2(2):CD009593. PMID: 33616229 DOI: 10.1002/14651858.CD009593.pub5