



Diagnostic Accuracy of Computed Tomography in Active Pulmonary Tuberculosis

Qurat ul Ain¹, Adnan Ahmed¹, Mohsin Qasim Dahri¹, Kainat Mirani¹, Qurat-ul-Ain¹

¹Radiology Department, Liaquat University of Medical and Health Sciences, Jamshoro, Pakistan

ARTICLE INFO

Keywords: Tuberculosis, X-Ray, Diagnostic Imaging, Sensitivity and Specificity, Sputum / microbiology, Mycobacterium tuberculosis, Radiography.

Correspondence to: Qurat ul ain, Radiology Department, Liaquat University of Medical and Health Sciences, Jamshoro, Pakistan.

Email: ainyfaizmemon@gmail.com

Declaration

Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History

Received: 01-04-2025 Revised: 13-06-2025

Accepted: 21-06-2025 Published: 30-06-2025

ABSTRACT

Background: Diagnosing active pulmonary tuberculosis (PTB) remains difficult, particularly when sputum tests are inconclusive or delayed. This study examined how accurately computed tomography (CT) detects active PTB compared to sputum culture, the current reference standard. **Methods:** We enrolled 151 patients with suspected PTB who underwent both chest CT and sputum culture. Radiologists assessed CT scans for features suggestive of active disease. We compared CT findings to culture results and calculated sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. **Results:** CT identified active PTB in 96 patients, while sputum culture confirmed disease in 92. CT correctly classified 86 true positives and 49 true negatives. The test achieved a sensitivity of 89.5%, specificity of 89.0%, PPV of 93.4%, NPV of 83.0%, and overall accuracy of 89.4%. **Conclusion:** CT identified active pulmonary tuberculosis with high accuracy and performed well in both smear-positive and smear-negative cases. It serves as a reliable adjunct when bacteriological confirmation is unavailable or delayed, and may improve early diagnosis in high-burden settings.

INTRODUCTION

Tuberculosis is one of the most infectious airborne diseases of the developing world. Unlike many other diseases, this disease has the capability to evolve into a multisystem disorder, something that is labelled as extrapulmonary tuberculosis.¹ This can affect the bowel, the bones, particularly the spine and can disseminate into the blood, crossing the blood-brain barrier and forming lesions inside the cerebral parenchyma, commonly known as Tuberculomas. The lungs have been noted to be the most common portal of entry for Mycobacterium Tuberculosis, the culprit bug behind this notorious infectious disease. In immunocompetent hosts, the lungs tend to be the main reservoir of infection.² The adaptability and resilience of the pathogen can be established from the fact that tuberculosis has been regarded as the second most common cause of death from a single infectious pathogen in 2020,³ and the ninth most common cause of death among all diseases according to a 2017 report on global tuberculosis.⁴ Multiple imaging modalities are available for the screening and detection of pulmonary tuberculosis. The most

common imaging modality that is used in basic health facilities is plain radiograph of the chest. While fairly common, the radiographs can just demonstrate the granulomas and hilar lymphadenopathy, thereby raising the suspicion of pulmonary involvement.⁵ Other modalities that are used include the computed tomography of the chest. While the CT makes use of the same X-Rays as a plain radiograph, it is able to demonstrate the pulmonary manifestations in a greater comparative detail compared to its older and less evolved counterpart.⁶

Early detection of pulmonary tuberculosis in its active phase is crucial as it determines the outcome of the patient. With PTB already prevalent in Pakistan, there is a greater need for diagnostic imaging setups for early diagnosis. A local study published in Pakistan in 2020 found out the sensitivity and specificity of CT to be 88.57% and 84.62% respectively.⁷ Higher sensitivity of CT can prove to be of absolute value in the arsenal of diagnostic tools for PTB. Our study, or the likes thereof, have not been done previously in our institution, which caters to a wide range of patients from poor socioeconomic background. So, our

study can pave the way towards further similar follow-up studies and establishment of diagnostic CT imaging setups in rural areas where pulmonary tuberculosis is comparatively more prevalent. Furthermore, due to early detection, patients will have a better chance of receiving early treatment before progression or dissemination of the pulmonary disease.

MATERIALS AND METHODS

This cross-sectional study was conducted at the Computed Tomography Unit, Department of Radiology, Liaquat University of Medical and Health Sciences, Jamshoro/Hyderabad. The study spanned a period of six months following the approval of the research synopsis. The sample size was determined using Dr. Lin Naing's sample size calculator, considering a sensitivity of 88.57% and specificity of 84.62% for CT in detecting pulmonary tuberculosis, with a disease prevalence of 46.38%, a confidence level of 95%, and a margin of error of 8%. This yielded a required sample size of 151 participants.⁸ Patients were selected through non-probability consecutive sampling.

Eligible participants included individuals aged between 20 and 75 years, of either gender, who were referred for CT chest evaluation with clinical suspicion of pulmonary tuberculosis based on specific criteria: a productive cough lasting three months, progressive weight loss over the same duration, and persistent low-grade fever ranging from 37°C to 39°C. Patients already diagnosed with pulmonary tuberculosis and currently undergoing treatment—either pharmacological or surgical (e.g., pulmonary lobectomy)—were excluded from the study.

Following approval from the College of Physicians and Surgeons Pakistan, patients meeting the inclusion criteria were enrolled. Informed consent was obtained after clearly explaining the purpose, procedures, and potential risks and benefits of the study. Demographic details such as age, gender, and socioeconomic status—based on household conditions—were recorded on a structured data collection form. Data were collected from patients presenting to the outpatient department of Radiology who had submitted sputum samples for culture and were referred for CT chest scans for further evaluation.

All CT scans were performed using a 128-slice CT scanner, with images acquired in axial, sagittal, and coronal planes. These scans were interpreted on a PACS workstation by a consultant radiologist with over three years of experience in CT reporting. CT findings consistent with pulmonary tuberculosis—such as tuberculomas, cavitary lesions, and mediastinal lymphadenopathy—were documented. Patients were followed up for their sputum culture results, which served as the gold standard for confirming or ruling out the diagnosis of tuberculosis. A comparative analysis between CT findings and sputum culture outcomes was then carried out.

Statistical analysis was performed using SPSS version 17. Qualitative variables such as the presence of fever, cough, weight loss, and CT and sputum culture results were reported as frequencies and percentages. Quantitative variables like age and duration of symptoms were evaluated for normality using the Shapiro–Wilk test. Normally distributed variables were presented as mean $\pm$

standard deviation, while non-normally distributed data were reported as median with interquartile ranges. The diagnostic performance of CT was assessed by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), using 2x2 contingency tables with sputum culture as the gold standard. Stratification was carried out to assess the impact of confounding factors such as age, gender, fever, weight loss, and clinical duration. Post-stratification analysis included recalculation of sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy.

RESULTS

This study included 151 patients with clinical suspicion of pulmonary tuberculosis. Most patients (58.3%) were between 20 and 50 years of age, indicating that the disease primarily affected individuals in their most economically productive years. The remaining 41.7% were aged between 51 and 75 years. The gender distribution was nearly equal, with males accounting for 51.7% of the cohort and females for 48.3%. (Table 1)

A majority of patients (64.2%) reported symptom duration of four weeks or less at the time of presentation. This suggests that most individuals sought evaluation relatively early in the course of illness. Among respiratory symptoms, only 47% of patients reported a productive cough, while 53% denied it. Despite the common clinical association between tuberculosis and sputum production, over half of the patients presented without this symptom. In contrast, low-grade fever was reported by 72.2% of patients, making it the most frequently observed symptom. Weight loss, often considered a classic sign of tuberculosis, was reported by only 39.7% of patients, while 60.3% did not report any weight loss.

Computed tomography identified radiological features consistent with active pulmonary tuberculosis in 96 patients (63.6%). Sputum culture confirmed tuberculosis in 92 patients (60.9%) and yielded negative results in the remaining 59 (39.1%). When CT findings were compared to culture results, 86 patients were true positives (both CT and culture positive), while 6 were false positives (CT positive, culture negative). Ten patients with culture-confirmed TB had negative CT findings (false negatives), and 49 patients were true negatives (both CT and culture negative). (Table 2)

Computed tomography demonstrated high diagnostic performance. It achieved a sensitivity of 89.5%, correctly identifying nearly nine out of ten culture-positive cases. The specificity was similarly high at 89.0%, reflecting a low rate of false positives. The positive predictive value reached 93.4%, suggesting that CT findings strongly correlated with true infection. The negative predictive value was 83.0%, indicating that while CT was reasonably reliable in excluding disease, a small number of cases were missed. Overall, CT achieved a diagnostic accuracy of 89.4% when compared to sputum culture.

These findings show that CT reliably detected active pulmonary tuberculosis, even in cases where clinical presentation was atypical or sputum samples were not diagnostic. The data support the role of CT as a valuable diagnostic tool, particularly in settings where rapid microbiological confirmation may not be feasible.

TABLE 1*Characteristics of Patients*

Demography		Number	Percentage
Age	20-50 years	88	58.3%
	51-75 years	63	41.7%
Gender	Male	78	51.7%
	Female	73	48.3%
Duration of Symptoms	≤ 4 weeks	97	64.2%
	> 4 weeks	54	35.8%
Productive Cough	Yes	71	47%
	No	80	53%
Loss of Body Weight	Yes	60	39.7%
	No	91	60.3%
Low Grade Fever	Yes	109	72.2%
	No	42	27.8%
Pulmonary Tuberculosis on CT	Positive	96	63.6%
	Negative	55	36.4%
Pulmonary tuberculosis on sputum culture	Positive	92	60.9%
	Negative	59	39.1%

Table 2*Results of Computed Tomography in Active Pulmonary Tuberculosis Taking Sputum Culture as Gold Standard*

Variable		Pulmonary Tuberculosis on Sputum Culture		Total
		Positive	Negative	
Pulmonary Tuberculosis on CT	Positive	86(tp)	06(fp)	92
	Negative	10(fn)	49(tn)	59
Total		96	55	151

Table 3*Sensitivity, Specificity, Positive and Negative Predictive Values and Diagnostic Accuracy of Computed Tomography in Active Pulmonary Tuberculosis Taking Sputum Culture as Gold Standard*

Variable	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Diagnostic Accuracy
Computed tomography in active pulmonary tuberculosis	89.5%	89.0%	93.4%	83.0%	89.4%

DISCUSSION

In this study, computed tomography (CT) demonstrated high diagnostic accuracy in identifying active pulmonary tuberculosis (PTB). It had a sensitivity of 89.5%, specificity of 89.0%, and an overall accuracy of 89.4%. These findings suggest that CT can serve as a valuable adjunct in TB diagnosis. This is particularly so in settings where microbiological confirmation is delayed, unavailable, or inconclusive.

We observed strong agreement between CT and sputum culture results, with 86 true positives and only 6 false positives. This is consistent with findings from Yeh et al., who reported that high-resolution CT effectively detects key radiological features of active TB.⁹ For instance, upper lobe consolidation, cavities, and nodular clusters, were detected with high sensitivity and specificity.⁹ Similarly, Heo et al. highlighted the importance of detecting cavitary lesions, a hallmark of infectious TB, which CT identifies with greater clarity than chest X-rays.¹⁰

Interestingly, CT identified TB-consistent findings in several culture-negative patients. These may represent

early disease or limitations in sputum collection or culture sensitivity. Breuninger et al. encountered similar diagnostic discrepancies in their validation study of CAD4TB, where imaging identified disease in patients with negative microbiological tests, particularly in resource-limited settings.¹¹ Our findings also support the notion, put forth by Poey et al., that CT can distinguish active from inactive TB.¹² This was done through certain imaging features, even when cultures are inconclusive.¹²

The positive predictive value (PPV) of 93.4% indicates that when CT suggests active TB, it is highly likely to be accurate. This aligns with results from Sathekge et al., who evaluated PET/CT in TB-endemic regions and found similarly high PPVs when imaging findings correlated with clinical suspicion.¹³ However, these studies also underscore a persistent challenge: false positives due to infections or inflammatory diseases that mimic TB radiologically. As a study has emphasized, in high-burden settings, even advanced imaging can struggle to distinguish TB from alternative pathologies like fungal infections or malignancy.¹⁴

Our negative predictive value (NPV) of 83.0% also holds clinical relevance, as a normal CT scan reduces the likelihood of active TB. Yeh et al. previously proposed a CT-based scoring system that achieved comparable NPV (96.8%). Thus offering a practical tool to guide triage decisions, especially in emergency departments where rapid isolation and treatment are essential.⁹ Researchers have similarly showed that patients initially misdiagnosed as having pneumonia later tested positive for TB. Thus indicating the need for better early detection tools in acute care settings.¹⁵

The demographic profile of our data set, primarily individuals aged 20 to 50 years mirrors TB epidemiology in many high-burden countries. It is in this population where disease disproportionately affects working-age adults. Researchers also observed this trend which found similar age and symptom distributions among newly diagnosed PTB patients.¹⁶

Despite its strengths, CT cannot fully replace bacteriological confirmation. Conditions such as sarcoidosis, bacterial pneumonia, or organizing pneumonia may produce overlapping imaging features. As Sathekge and others have argued, combining CT findings with clinical risk factors and laboratory data offers the best diagnostic yield.¹³ Furthermore, while our findings reinforce CT's diagnostic value, the cost and access barriers in low-resource settings must be acknowledged. Breuninger et al. emphasized the need for practical deployment strategies when integrating imaging tools into TB programs, particularly in under-resourced healthcare systems.¹¹

Lastly, this study supports ongoing efforts to refine diagnostic pathways by combining radiological and clinical data. Predictive models incorporating age, symptom duration, and CT findings. For instance, as explored by some studies which were conducted in TB-endemic regions, this could improve diagnostic accuracy and resource allocation.¹⁷⁻¹⁸

We recognise several potential sources of bias and confounding that may have influenced our findings.¹⁹ Since we conducted this study at a single tertiary centre,

selection bias may have occurred, as patients who seek care at such facilities often present with more advanced disease. This could have led to an overestimation of CT's diagnostic performance. Additionally, we relied on sputum culture as the reference standard, which, although widely accepted, has known limitations. Culture-negative cases with clear CT findings may represent true disease that the gold standard failed to detect, introducing the risk of misclassification. Observer bias may also have played a role, as radiologists were not blinded to clinical information. Without blinding, knowledge of the patient's symptoms could have influenced image interpretation. We did not control for certain confounders such as HIV status, history of prior TB, or underlying lung conditions, any of which could have altered CT appearance or affected culture results. From an epidemiological standpoint, the study's context—a high TB burden setting—increases the positive predictive value of CT but also raises the likelihood of false positives due to overlapping conditions such as non-tuberculous mycobacterial infections. These factors underscore the importance of interpreting CT

findings in the context of clinical presentation, background prevalence, and resource availability.¹⁹

Limitations: This single-center study may limit the generalizability of our findings to other settings with different TB prevalence or diagnostic infrastructure. We also did not assess inter-observer variability. We did not see the cost-effectiveness of implementing CT as a routine diagnostic tool in low-resource environments.

CONCLUSION

This study showed that computed tomography accurately identified active pulmonary tuberculosis in most patients. It performs well performing well against sputum culture as the reference standard. Given its high sensitivity and specificity, CT can support timely diagnosis, especially in patients with negative sputum results or atypical clinical presentations. While CT should not replace microbiological confirmation, it offers strong diagnostic value when used alongside clinical judgment and laboratory testing.

REFERENCES

- Golden MP, Vikram HR. Extrapulmonary tuberculosis: an overview. *American family physician*. 2005 Nov 1;72(9):1761-8.
- Lyon SM, Rossman MD. Pulmonary tuberculosis. *Microbiology spectrum*. 2017 Feb 27;5(1):10-128. <https://doi.org/10.1128/microbiolspec.tnmi7-0032-2016>
- Galvin J, Tiberi S, Akkerman O, Kerstjens HA, Kunst H, Kurhasani X, Ambrosino N, Migliori GB. Pulmonary tuberculosis in intensive care setting, with a focus on the use of severity scores, a multinational collaborative systematic review. *Pulmonology*. 2022 Jul 30;28(4):297-309. <https://doi.org/10.1016/j.pulmoe.2022.01.016>
- Zeng J, Liu Z, Shen G, Zhang Y, Li L, Wu Z, Luo D, Gu Q, Mao H, Wang L. MRI evaluation of pulmonary lesions and lung tissue changes induced by tuberculosis. *International Journal of Infectious Diseases*. 2019 May 1;82:138-46. <https://doi.org/10.1016/j.ijid.2019.03.004>
- Van Dyck P, Vanhoenacker FM, Van den Brande P, De Schepper AM. Imaging of pulmonary tuberculosis. *European radiology*. 2003 Aug;13:1771-85. <https://doi.org/10.1007/s00330-002-1612-y>
- Komiya K, Yamasue M, Goto A, Nakamura Y, Hiramatsu K, Kadota JI, Kato S. High-resolution computed tomography features associated with differentiation of tuberculosis among elderly patients with community-acquired pneumonia: a multi-institutional propensity-score matched study. *Scientific Reports*. 2022 May 6;12(1):7466. <https://doi.org/10.1038/s41598-022-11625-7>
- Rasheed W, Qureshi R, Jabeen N, Shah HA, Khan RN. Diagnostic accuracy of high-resolution computed tomography of chest in diagnosing sputum smear positive and sputum smear negative pulmonary tuberculosis. *Cureus*. 2020 Jun 5;12(6). <https://doi.org/10.7759/cureus.8467>
- Sadaat Ullah MW, Hussain H, Ullah R, Khan N, Muhammad W. Prevalence of Pulmonary Tuberculosis. *Prevalence*. 2022 Feb;29(02).
- Yeh JJ, Yu JK, Teng WB, Chou CH, Hsieh SP, Lee TL, Wu MT. High-resolution CT for identify patients with smear-positive, active pulmonary tuberculosis. *European journal of radiology*. 2012 Jan 1;81(1):195-201. <https://doi.org/10.1016/j.ejrad.2010.09.040>
- Heo JN, Choi YW, Jeon SC, Park CK. Pulmonary tuberculosis: another disease showing clusters of small nodules. *American Journal of Roentgenology*. 2005 Feb;184(2):639-42. <https://doi.org/10.2214/ajr.184.2.01840639>
- Breuninger M, van Ginneken B, Philipsen RH, Mhimbira F, Hella JJ, Lwilla F, van den Hombergh J, Ross A, Jugheli L, Wagner D, Reither K. Diagnostic accuracy of computer-aided detection of pulmonary tuberculosis in chest radiographs: a validation study from sub-Saharan Africa. *PloS one*. 2014 Sep 5;9(9):e106381. <https://doi.org/10.1371/journal.pone.0106381>
- Poey C, Verhaegen F, Giron J, Lavyssiere J, Fajadet P, Duparc B. High resolution chest CT in tuberculosis: evolutive patterns and signs of activity. *Journal of computer assisted tomography*. 1997 Jul 1;21(4):601-7. <https://doi.org/10.1097/00004728-199707000-00014>
- Sathegke MM, Maes A, Pottel H, Stoltz A, Van De Wiele C. Dual time-point FDG PET/CT for differentiating benign from malignant solitary pulmonary nodules in a TB endemic area. *South African medical journal*. 2010 Sep 1;100(9):598-61. <https://doi.org/10.7196/samj.4082>
- Sharma SK, Mohan A, Sharma A. Challenges in the diagnosis & treatment of miliary tuberculosis. *Indian Journal of Medical Research*. 2012 May 1;135(5):703-30. https://doi.org/10.5005/jp/books/10992_34
- Miller AC, Polgreen LA, Cavanaugh JE, Hornick DB, Polgreen PM. Missed opportunities to diagnose tuberculosis are common among hospitalized patients and patients seen in emergency departments. *InOpen forum infectious diseases* 2015 Dec 1 (Vol. 2, No. 4, p. ofv171). Oxford University Press. <https://doi.org/10.1093/ofid/ofv171>
- LIAM CK, PANG YK, Poosparajah S. Pulmonary tuberculosis presenting as community-acquired pneumonia. *Respirology*. 2006 Nov;11(6):786-92. <https://doi.org/10.1111/j.1440-1843.2006.00947.x>
- Swensen SJ, Silverstein MD, Ilstrup DM, Schleck CD, Edell ES. The probability of malignancy in solitary pulmonary nodules: application to small radiologically indeterminate nodules. *Archives of internal medicine*. 1997 Apr 28;157(8):849-55. <https://doi.org/10.1001/archinte.1997.00440290031002>

18. Li Y, Wang J. A mathematical model for predicting malignancy of solitary pulmonary nodules. World journal of surgery. 2012 Apr;36:830-5.
<https://doi.org/10.1007/s00268-012-1449-8>
19. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2008 Sep 20.