


**INCIDENTAL RADIOLOGICAL PROFILE OF TUBERCULOSIS IN CHEST
TOMOGRAPHY EXAMS FROM AN IMAGING SERVICE IN SÃO LUÍS**

**PERFIL RADIOLÓGICO INCIDENTAL DE TUBERCULOSE EM EXAMES DE
TOMOGRAFIA DE TORÁX DE UM SERVIÇO DE IMAGEM DE SÃO LUÍS**

**PERFIL RADIOLÓGICO INCIDENTAL DE TUBERCULOSIS EN EXÁMENES DE
TOMOGRFÍA DE TÓRAX DE UN SERVICIO DE IMAGENOLÓGÍA DE SÃO LUÍS**

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ABSTRACT

That tuberculosis (TB) is one of the infectious diseases with a great impact on global and Brazilian public health, posing a constant challenge in low- and middle-income regions due to socioeconomic conditions and limited access to healthcare services. The research aims to describe the findings suggestive of tuberculosis infection/co-infection, as well as associated variables, reinforcing the clinical-laboratory-radiological diagnostic criteria to optimize resources. For this purpose, a retrospective cross-sectional analysis was performed on 173 chest CT scan reports of patients over 18 years old under outpatient investigation or treatment for respiratory syndrome, from March 2020 to March 2024, in São Luís. The sample was one of convenience, with statistical analysis performed using STATA 15.0 software. Thus, it is observed that the prevalent population was between 50 and 69 years old (37.57%), male (60.12%), and predominantly attended by the SUS (Brazilian Public Healthcare System) (54.91%). The majority of patients did not undergo previous X-ray examinations (82.66%). The most frequent radiological findings were excavated lesions or cavitations (59.54%) and tree-in-bud patterns (73.99%). Although 67.05% presented signs of infection, 93.64% of the findings also indicated risk for COVID-19. This allows concluding that radiological signs suggestive of pulmonary tuberculosis were frequent,

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demonstrating the importance of active diagnosis and treatment according to Ministry of Health guidelines, making professional training crucial for adequate identification and clinical management of tuberculosis.

Keywords: Pulmonary Tuberculosis. Radiography. Tomography.

RESUMO

A Tuberculose (TB) é uma das doenças infecciosas com grande impacto na saúde pública global e brasileira, sendo um desafio constante em regiões de baixa e média renda devido às condições socioeconômicas e à limitação de acesso aos serviços de saúde. A pesquisa objetiva descrever os achados sugestivos de infecção/co-infecção de tuberculose, bem como as variáveis associadas, reforçando os critérios de diagnóstico clínico-laboratorial-radiológico para otimizar recursos. Para tanto, procede-se à análise retrospectiva transversal de 173 laudos de tomografia de tórax de pacientes maiores de 18 anos em investigação ambulatorial ou tratamento de síndrome respiratória no período de março de 2020 a março de 2024, em São Luís. A amostra foi por conveniência, com análise estatística no software STATA 15.0. Desse modo, observa-se que a população prevalente foi de 50 a 69 anos (37,57%), sexo masculino (60,12%) e atendida majoritariamente pelo SUS (54,91%). A maioria dos pacientes não realizou exames prévios de raio-x (82,66%). Os achados radiológicos mais frequentes foram lesões escavadas ou cavitações (59,54%) e padrões em árvore em brotamento (73,99%), sendo que 67,05% apresentaram sinais de infecção, mas 93,64% dos achados também apresentavam risco para COVID-19. O que permite concluir que os sinais radiológicos sugestivos de tuberculose pulmonar foram frequentes, demonstrando a importância do diagnóstico e tratamento ativo segundo as diretrizes do Ministério da Saúde, sendo crucial o treinamento profissional para a identificação e manejo clínico adequados da tuberculose.

Palavras-chave: Tuberculose Pulmonar. Radiografia. Tomografia.

RESUMEN

A pesquisa que la tuberculosis (TB) es una de las enfermedades infecciosas con gran impacto en la salud pública global y brasileña, lo que representa un desafío constante en regiones de ingresos bajos y medianos debido a las condiciones socioeconómicas y a la limitación en el acceso a los servicios de salud. La investigación tiene como objetivo describir los hallazgos sugestivos de infección/coinfección de tuberculosis, así como las variables asociadas, reforzando los criterios de diagnóstico clínico-laboratorial-radiológico para optimizar recursos. Para ello, se procede al análisis retrospectivo transversal de 173 informes de tomografía de tórax de pacientes mayores de 18 años en investigación ambulatoria o tratamiento de síndrome respiratorio en el período de marzo de 2020 a marzo de 2024, en São Luís. La muestra fue por conveniencia, con análisis estadístico realizado con el software STATA 15.0. De este modo, se observa que la población prevalente fue de 50 a 69 años (37,57%), sexo masculino (60,12%) y atendida mayoritariamente por el SUS (Sistema Único de Salud de Brasil) (54,91%). La mayoría de los pacientes no se sometió a exámenes previos de rayos X (82,66%). Los hallazgos radiológicos más frecuentes fueron lesiones excavadas o cavitaciones (59,54%) y patrones en árbol en brote (73,99%). Si bien el 67,05% presentó signos de infección, el 93,64% de los hallazgos también presentaban riesgo de COVID-19. Lo que permite concluir que los signos radiológicos sugestivos de tuberculosis pulmonar fueron frecuentes, demostrando la importancia del diagnóstico y tratamiento activo de acuerdo con las directrices del Ministerio de Salud, siendo crucial la

capacitación profesional para la identificación y el manejo clínico adecuados de la tuberculosis.

Palabras clave: Tuberculosis Pulmonar. Radiografía. Tomografía.

1 INTRODUCTION

Tuberculosis (TB) is one of the most prevalent infectious diseases with the greatest global impact, predominantly affecting low-and middle-income countries, where socioeconomic conditions and limited access to health services make it difficult to control the disease (Silva, M. L. B. da et al., 2021).

The distribution of TB in Brazil is marked by regional disparities that reflect differences in economic levels and access to health services. The North and Northeast regions have the highest incidence rates, while the South and Southeast have better results in controlling the disease. In the Northeast, the state of Maranhão, in particular, and its capitals, São Luís, face high rates of TB, especially among vulnerable populations, such as those with poor housing conditions and low incomes. In these contexts, access to health services is limited, and the continuity of treatment faces several barriers, highlighting the importance of specific public policies that consider local needs and characteristics for more effective TB control (Aragão et al., 2024).

Computed tomography (CT) is an imaging tool that enables detailed visualization of lung lesions associated with TB, such as cavities and nodules, and has been widely used to complement clinical and laboratory diagnoses. However, more accessible examinations, such as chest radiography, combined with clinical evaluation and laboratory testing, are often sufficient to confirm the disease. Therefore, CT should be used judiciously, particularly in resource-limited settings, and reserved for complex cases or for diagnosing complications that cannot be detected by conventional methods. This approach reduces costs and minimizes patients' exposure to unnecessary radiation (Ribeiro et al., 2023).

With the onset of the COVID-19 pandemic, the use of CT increased for monitoring pulmonary complications. This practice persisted in the post-pandemic period, leading to a rise in requests for CT scans to diagnose TB, particularly in patients with suspected co-infection or disease reactivation resulting from COVID-19-induced immunosuppression. The overlap of symptoms and tomographic findings between TB and COVID-19 underscores the importance of a careful and differentiated diagnostic approach, especially in regions where health systems already struggle to meet the population's basic needs (Mançano; Zanetti; Marchiori, 2022).

Studies have shown that coinfection with TB and COVID-19 can worsen patients' clinical status and lead to a poorer prognosis, particularly in resource-limited settings. In Brazil, the pandemic has contributed to a decline in TB diagnoses and an increase in

mortality associated with the disease, mainly due to the overburdening of health systems and the interruption of treatment. These circumstances underscore the importance of regional studies that investigate the radiological features of TB and provide evidence to support the improvement of diagnostic and therapeutic practices (Teixeira, 2025).

In Brazil, TB represents an ongoing public health challenge, with thousands of new cases diagnosed each year. Despite the implementation of several initiatives, the country remains among those with a high TB incidence, underscoring the need to strengthen control policies and strategies (Silva, M. L. B. da *et al.*, 2021).

This study aims to describe findings suggestive of tuberculosis infection or co-infection, as well as associated variables, reinforcing clinical, laboratory, and radiological diagnostic criteria to optimize the use of CT resources in TB patients evaluated at imaging services in Northeast Brazil, with particular focus on the state of Maranhão and the city of São Luís. By characterizing the specific radiological patterns of TB in this region, the study seeks to contribute to the improvement of diagnostic practices, promote more effective clinical management, and support the development of public policies better aligned with local needs. The findings are expected to inform strategies that reduce TB-related mortality and strengthen disease control in Maranhão and throughout Northeast Brazil.

2 METHODOLOGY

This is a cross-sectional analytical study conducted between March 2020 and March 2024 in the municipality of São Luís, Maranhão. Data were collected from an imaging center where chest tomography reports from both the Brazilian Unified Health System (SUS) and the private sector were analyzed. The analysis focused on radiological descriptors related to tuberculosis, as well as additional associated findings.

The target population included patients over 18 years of age who underwent chest CT scans for the investigation of respiratory syndromes. The sample consisted of 173 chest CT scan reports analyzed retrospectively. Based on this preliminary estimate, the sample size calculation was performed using the statistical program STATA 15.0 (Stata Corp., College Station, Texas, USA). A significance level (α) of 5%, a test power of 80%, a tolerable error of 4%, plus 10% for possible losses, was applied in this study.

The inclusion criteria comprised patients over 18 years of age with complete chest CT scan reports performed during the study period, excluding exams performed outside the specified period. Data were extracted from reports and findings issued by the imaging

service. The variables analyzed included demographic characteristics, radiological findings, and relevant clinical history.

The data were analyzed using STATA 15.0 software (Stata Corp, College Station, Texas, USA). In descriptive statistics, the categorical qualitative variables were analyzed by calculating absolute and relative frequencies (percentages). In analytical statistics, the association between the explanatory variables (Incidental Radiological Profile of Tuberculosis) and the response variable (Radiological Findings) was assessed using the Chi-square test.

The study was approved by the research ethics committee of CEUMA University, in accordance with opinion No. 4,407,369. The right to confidentiality of research data was ensured in accordance with the guidelines and regulatory standards for research involving human subjects established by the National Health Council, resolution 466/2012.

3 RESULTS

Analysis of the radiological findings of chest CT scans revealed distinct patterns among the patients evaluated (Table 1). The age group between 50 and 69 years had the highest percentage (65, or 37.57%) for males (104, or 60.12%), with most procedures being elective (122, or 70.52%) and performed in the SUS service (95, or 54.91%). Most patients had not previously undergone X-rays (143, or 82.66%) or contrast examinations (168, or 97.11%) and presented with excavated lesions or cavitations (59.54%).

Table 1

Description of socioeconomic, demographic, and clinical variables of radiological findings related to tuberculosis in chest CT scans at an imaging service in São Luís, Maranhão, from 03/2020 to 03/2024

Variables	n	%
Age		
18 to 29	32	18,49
30 to 49	38	21,97
50 to 69	65	37,57
> 70	38	21,97
Gender		
Male	104	60,12
Female	69	39,88
Aplicant		
Elective	122	70,52
Hospital	51	29,48
Origin		
SUS	95	54,91
Private	62	35,84
Medical Insurance	16	09,25
X-ray		
Yes	30	17,34
No	143	82,66
Contrast		
Yes	05	02,89
No	168	97,11
Has Excavated lesions or Cavitations		
No	70	40,46
Yes	103	59,54
Tree-in-Budd Patterns		
No	45	26,01
Yes	128	73,99
Peribronchial Thickening or Bronchiectasis		
No	91	52,6
Yes	82	47,4
Micronodules Random Distribution (Miliary TB)		
No	172	99,42
Yes	01	00,58
Infectious/ Inflammatory (Ground-glass/ Consolidation)		
No	57	32,95
Yes	116	67,05
Neoplastic (Expansive Formation)		
No	165	95,38
Yes	08	04,62
Scars		
No	92	53,18
Yes	81	46,82
Cardiovascular		
No	112	64,74
Yes	61	35,26
MSK		
No	142	82,08
Yes	31	17,92
Pleural Changes		
No	143	82,66
Yes	30	17,34

Lymph Node Changes			
No		120	69,36
Yes		53	30,64
Congenital Changes (<i>Situs Inversus Totalis</i>)			
No		173	100
Yes		-	-
Covid Risk			
No		162	93,64
Yes		11	06,36

Source: Sourvey data for the period from 03/2020 to 03/2024.

In Table 2, the variables that showed statistical significance were those related to Excavated Lesions or Cavitations, with a higher frequency for those with the tree-in-bud pattern, with 66 (51.56%), showing strong statistical significance ($p=0.001$); the variable Peribronchial Thickening or Bronchiectasis showed a higher percentage for 71 (55.47%) with strong statistical significance ($p=0.001$); those referring to the variable Random Distribution Micronodules (Miliary TB), most radiological findings showed low frequency with 128 (100%) and statistical significance ($p=0.051$); the variable MSK showed a higher prevalence for 1109 (85.16%) with statistical significance ($p=0.055$) of degenerative lesions; Lymph node alterations showed a higher prevalence of reactive changes to underlying processes with 84 (65.62%) and with statistical significance ($p=0.052$), and finally, risk for COVID-19 with a higher prevalence of viral pneumonia/flu-like syndrome 124 (96.88%) and with statistical significance ($p=0.003$).

Table 2

Description of radiological findings related to tuberculosis in chest CT scans from an imaging service in São Luís-MA, Brazil, between March 03/2020 to 03/2024.

VARIABLES	TREE-IN-BUD		p*
	Absence	Presence	
Age			0,510
18 to 29	5(11,1)	27(21,09)	
30 to 49	10(22,22)	28(21,88)	
50 to 69	19(42,23)	46(35,94)	
>70	11(24,44)	27(21,09)	
Gender			0,985
Male	27(60,00)	77(60,16)	
Female	18(40,00)	51(39,84)	
Apliccant			0,299
Elective	29(64,44)	93(72,66)	
Hospital	16(35,56)	35(27,34)	
Origin			0,494
SUS	28(62,22)	67(52,34)	
Private	14(31,11)	48(37,50)	

Medical Insurance	3(6,67)	13(10,16)	
X-ray			0,713
Yes	7(15,56)	23(17,97)	
No	38(84,44)	105(82,03)	
Contrast			0,756
Yes	1(2,22)	4(3,12)	
No	44(97,78)	124(96,88)	
Has Excavated lesions or Cavitations			0,001
No	8(17,78)	62(48,44)	
Yes	37(82,22)	66(51,56)	
Peribronchial Thickening or Bronchiectasis			0,001
No	34(75,56)	57(44,53)	
Yes	11(24,44)	71(55,47)	
Micronodules Random Distribution (Miliary TB)			0,051
No	44(97,78)	128(100,00)	
Yes	1(2,22)	0(0,00)	
Infectious/ Inflammatory (Ground-glass/ Consolidation)			0,665
No	16(35,56)	41(32,03)	
Yes	29(64,44)	87(67,97)	
Neoplastic (Expansive Formation)			0,448
No	42(93,33)	123(96,09)	
Yes	3(6,67)	5(3,91)	
Scars			0,981
No	24(53,33)	68(53,12)	
Yes	21(46,67)	60(46,88)	
Cardiovascular			0,439
No	27(60,00)	85(66,41)	
Yes	18(40,00)	43(33,59)	
MSK			0,055
No	33(73,33)	109(85,16)	
Yes	12(26,67)	19(14,84)	
Pleural Changes			0,928
No	37(82,22)	106(82,81)	
Yes	8(17,78)	22(17,19)	
Lymph Node Changes			0,052
No	36(80,00)	84(65,62)	
Yes	9(20,00)	44(34,38)	
Covid Risk			0,003
No	38(84,44)	124(96,88)	
Yes	7(15,56)	4(3,12)	

Source: Sourvey data for the period from 03/2020 to 03/2024.

In Table 3, the unadjusted analysis, whose variables were included in the final model, showed statistical significance for Excavated Lesions or Cavitations ($p \leq 0.01$); the variable Peribronchial Thickening or Bronchiectasis ($p \leq 0.01$); those referring to the variable Random Distribution Micronodules (Miliary TB) ($p \leq 0.01$); Lymph Node Alterations ($p = 0.031$); and finally, risk for COVID-19 with statistical significance ($p \leq 0.05$). The adjusted analysis, whose variables were included in the final model, showed statistical significance for Excavated

Lesions or Cavitations ($p \leq 0.01$); the variable Peribronchial Thickening or Bronchiectasis ($p = 0.003$); and those referring to the variable Random Distribution Micronodules (Miliary TB) ($p \leq 0.01$). Lymph node changes ($p = 0.041$) and finally, risk for COVID-19 with statistical significance.

Table 3

Unadjusted and adjusted analyses of tuberculosis-related radiological findings described in chest CT scans from an imaging center in São Luís, Maranhão, between 03/2020 to 03/2024.

VARIABLES	UNADJUSTED ANALYSIS			ADJUSTED ANALYSIS ($p \leq 0,01$)		
	RP	IC	P*	RP	IC	P*
Has Excavated lesions or Cavitations			0,000			
No	1	1	-	1	1	-
Yes	0,717	0,609-0,844	0,000	0,734	0,630-0,855	0,000
Peribronchial Thickening or Bronchiectasis			0,000			
No	1	1	-	1	1	-
Yes	1,392	1,168-1,660	0,000	1,276	1,084-1,502	0,003
Micronodules Random Distribution (Miliary TB)			0,000			
No	1	1	-	1	1	-
Yes	2,320	3,24-1,66	0,000	1,28	1,79-9,22	0,000
MSK			0,353			
No	1	1	-	-	-	-
Yes	0,799	0,492-1,298	0,366	-	-	-
Lymph Node Changes			0,031			
No	1	1	1	1	1	-
Yes	1,197	1,016-1,411	0,031	1,168	1,00-1,355	0,041
Covid Risk			0,058			0,057
No	1	1	-	1	1	-
Yes	0,475	0,175-1,286	0,143	0,512	0,250-1,048	0,057

Source: Sourvey data for the period from 03/2020 to 03/2024.

4 DISCUSSION

Tuberculosis remains a significant public health problem, requiring an integrated approach that includes early diagnosis, epidemiological control strategies, and health education. In addition to disseminating technical information on TB transmission and treatment, it is essential to emphasize the importance of accurate diagnosis, particularly in primary health care. TB assessment should follow the guidelines of the Ministry of Health, prioritizing clinical and laboratory evaluation as well as chest radiography, while avoiding exclusive reliance on computed tomography as an initial diagnostic tool (BRASIL, 2011). This study addresses an important issue: regional inequality in TB control in Brazil. The

specific focus on Maranhão contributes to a better understanding of regional particularities that hinder effective disease control.

The data presented in this study reveal two distinct radiological associations: the tree-in-bud pattern, which is strongly associated with peribronchial thickening/bronchiectasis ($p \leq 0.01$); and cavitation, which was more frequent in the absence of the tree-in-bud pattern ($p \leq 0.01$). These findings are consistent with the understanding that the tree-in-bud pattern represents an airway-centered distribution (endobronchial/bronchiolar dissemination), whereas cavitation reflects a necrotizing phenotype of lung disease. The low association with “COVID risk” aligns with the known pathophysiology of COVID-19, which predominantly affects the lung parenchyma. Etiological confirmation and causal inference require microbiological correlations and multivariate analyses (Mançano, Zanetti, Marchiori, 2022).

The prevalence in the gender variable in the study by Feitosa (2022), conducted in the state of Paraíba in the municipality of Lagarto (SE), shows data similar to those found in the present study, with the first result recording 65.0% of cases in men and the second, 65.4%. According to (Pp; K; Sm, 2017), the higher prevalence of illness among males may indicate greater vulnerability associated with the behaviors this sex exhibits regarding their health, as well as their perception of the health-disease process, which may contribute to delays in seeking care and, consequently, to the worsening of signs and symptoms (Feitosa et al., 2022).

The historical series study by Silva et al. (2021) conducted in Ouro Preto (MG), which studied the periods between 1999 and 2015, including individuals aged 1 to 92 years, found that the most affected age group was 40.3 ± 16.4 years. Different results obtained for this variable indicate that the average age of the 756 cases of tuberculosis reported between 2014 and 2016 was 38 years (± 16 years).

Most patients presented a tree-in-bud pattern, with 128 (73.99%) showing no peribronchial thickening or bronchiectasis, 91 (52.60%) showing no randomly distributed micronodules, and 172 (99.42%) showing no miliary TB. Regarding the Infectious/Inflammatory variable (ground-glass opacity/consolidation), a higher percentage showed the presence of infection [116 (67.05%)]. Neoplastic lesions (expansive formations) were observed in 165 (95.38%) of cases, cicatricial changes in 92 (53.18%), and absence of cardiovascular problems in 112 (64.74%). In the study by Soares et al. (2024), radiological findings suggestive of inflammatory etiology were more prevalent in chest CT scans than traumatic findings in examinations from the hospital emergency department. The main

alterations observed were pneumonia (23.7%), pleural effusion (12.9%), pulmonary contusion (5.4%), and bone fracture (4.3%).

The MSK variable showed the highest percentage of cases without abnormalities in the test results 142 (82.08%), as well as no pleural abnormalities 143 (82.66%), lymph node abnormalities, or congenital abnormalities (situs inversus totalis) 173 (100%). However, most radiological findings indicated a risk for COVID-19, with 162 (93.64%) cases. In the study by Soares et al. (2024), MSK findings were infrequent on chest CT scans, consisting mainly of traumatic findings such as bone fractures (4.3%).

The prevalence study of TB cases in Rio de Janeiro among patients with respiratory symptoms seeking care at health facilities found that 10.7% had a cough lasting more than one week, and among them, the prevalence of pulmonary TB was 2.7% (12). Although few studies have been conducted in Brazil on the prevalence of respiratory symptomatic individuals identified in the community, the results of the cited study are consistent with those found in studies conducted in health facilities (Brasil, 2011).

Regarding imaging tests, most patients had suspicious results for tuberculosis, and 13.3% had normal X-rays. It is worth noting that chest X-rays are an inexpensive, accessible, and safe method and are the method of choice for initial patient assessment. Radiological changes are present in up to 90% of cases (Silva, D. J. da et al., 2021).

Chest radiography is a diagnostic method of great importance in the investigation of tuberculosis and is essential for analyzing suspected cases of pulmonary tuberculosis and ruling out other pulmonary diseases (Brasil, 2011). This applies to the present study, since 59.09% of pulmonary tuberculosis cases showed radiographic findings suggestive of tuberculosis. Regarding imaging examinations, most presented results suggestive of tuberculosis, while 13.3% had normal radiographs. The study by Ribeiro et al. (2021) emphasizes that chest radiography is an inexpensive, accessible, and safe method, and it is the method of choice for the initial evaluation of patients, with radiological abnormalities present in up to 90% of cases.

In the chest radiography variable, most cases showed suspicious results 70 (55.56%), with the highest prevalence observed among patients with pulmonary tuberculosis 60 (57.69%) (Silva, M. L. B. da et al., 2021). The initial assessment of patients with respiratory diseases includes imaging methods, represented by chest radiography and computed tomography (CT). These methods are considered essential, as they provide relevant information regarding the disease presentation, its extent, and its progression

during treatment. With regard to tuberculosis, chest radiography—due to its ease of execution, accessibility, low cost, and low radiation dose—is the method of choice for the initial evaluation.

Although it has low specificity, chest radiography plays an important role in the diagnosis and follow-up of cases suggestive of the disease; however, when used alone, it is not sufficient for the diagnosis of TB.

5 CONCLUSION

This study highlights key concerns about the need to prevent medical errors related to diagnostic imaging, ensuring that the interpretation of examinations is performed with technical rigor and that reports are prepared by qualified professionals. Emphasizing the rational use of chest radiography not only improves diagnostic accuracy but also helps prevent errors that could lead to inappropriate treatments.

Investment in imaging technologies must be accompanied by professional training, particularly in the management of patients with suspected tuberculosis. Chest radiography, in addition to being an accessible examination, plays a crucial role in the early detection of tuberculosis. This study underscores the need for increased investment in the expansion and modernization of radiography services, ensuring that all healthcare units are equipped with appropriate equipment and staffed by trained professionals capable of accurately interpreting radiological findings.

Public education is a critical component in the management of tuberculosis. Raising awareness among the population about the importance of early diagnosis and appropriate treatment can directly impact disease control. It is essential that public health strategies incorporate educational campaigns that inform people about TB symptoms, the available diagnostic tests, and the importance of seeking medical care when presenting with suspicious symptoms.

The role of management in expanding access to imaging tests should be a priority in public health policies. Implementing investments aimed at improving diagnostic infrastructure, especially in primary care, can optimize TB detection and reduce rates of underdiagnosis and transmission of the disease.

Considering the factors outlined above, this study emphasizes the need for tiered diagnostic guidelines that integrate accessible tests, advanced technologies, and a tailored

epidemiological approach for the effective control of tuberculosis, thereby ensuring a positive impact on public health.

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