

**American College of Radiology
End User License Agreement**

ACR Appropriateness Criteria is a registered trademark of the American College of Radiology. By accessing the ACR Appropriateness Criteria®, you expressly agree and consent to the terms and conditions as described at: <http://www.acr.org/~media/ACR/Documents/AppCriteria/TermsandConditions.pdf>

Personal use of material is permitted for research, scientific and/or information purposes only. You may not modify or create derivative works based on American College of Radiology material. No part of any material posted on the American College of Radiology Web site may be copied, downloaded, stored in a retrieval system, or redistributed for any other purpose without the expressed written permission of American College of Radiology.

**American College of Radiology
ACR Appropriateness Criteria®
Imaging of Possible Tuberculosis**

Variant 1: Suspect active tuberculosis.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9		⊕
CT chest without IV contrast	7	This procedure is recommended if x-ray is equivocal.	⊕ ⊕ ⊕
CT chest with IV contrast	6		⊕ ⊕ ⊕
CT chest without and with IV contrast	3		⊕ ⊕ ⊕
MRI chest without IV contrast	3		○
MRI chest without and with IV contrast	3		○
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Newly positive PPD or IGRA OR positive PPD or IGRA with unknown prior status. No clinical symptoms.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9		⊕
CT chest with IV contrast	4		⊕ ⊕ ⊕
CT chest without IV contrast	3		⊕ ⊕ ⊕
MRI chest without IV contrast	2		○
MRI chest without and with IV contrast	2		○
CT chest without and with IV contrast	1		⊕ ⊕ ⊕
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 3: PPD not available. Placement in group home or skilled nursing facility. No clinical symptoms.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9		⊕
CT chest with IV contrast	2		⊕ ⊕ ⊕
CT chest without IV contrast	2		⊕ ⊕ ⊕
MRI chest without IV contrast	2		○
CT chest without and with IV contrast	1		⊕ ⊕ ⊕
MRI chest without and with IV contrast	1		○
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

IMAGING OF POSSIBLE TUBERCULOSIS

Expert Panel on Thoracic Imaging: James G. Ravenel, MD¹; Jonathan H. Chung, MD²; Jeanne B. Ackman, MD³; Patricia M. de Groot, MD⁴; Geoffrey B. Johnson, MD, PhD⁵; Clinton Jokerst, MD⁶; Fabien Maldonado, MD⁷; Barbara L. McComb, MD⁸; Robert M. Steiner, MD⁹; Tan-Lucien H. Mohammed, MD.¹⁰

Summary of Literature Review

Introduction/Background

Pulmonary tuberculosis (TB) predominantly results from the transmission of aerosolized mycobacterium TB to susceptible hosts [1]. In the vast majority of cases, this results in subclinical disease with the immune system isolating the organism. In this setting, a person has latent TB and does not pose a risk to the community at large. The development of active infection within 1 year following exposure is termed primary TB and is classically described as a lobar pneumonia and/or mediastinal and hilar adenopathy. This pattern is most often seen in children and severely immunocompromised individuals. If active infection develops later than 1 year after initial exposure, it is considered to be reactivation TB, often presenting with apical posterior upper-lobe or superior-segment lower-lobe fibrocavitary disease and endobronchial spread through the airways.

With modern molecular techniques it has been shown that radiographic patterns of primary and reactivation TB overlap, and thus the preferred terminology for TB infection is active TB [2]. The important public health issue is that both primary and reactivation TB present a risk of exposing the general population to TB infection.

A high level of suspicion should be maintained in immunocompromised hosts, particularly those with AIDS, as imaging manifestations may not fit a classic primary or reactivation pattern; instead, these patients may present with mediastinal lymphadenopathy alone or a deceptively normal chest radiograph.

Overview of Imaging Modalities

Chest radiograph

The chest radiograph is usually the first study performed in patients suspected of having TB. Although frontal and lateral radiographs are often performed in this setting, it has been shown that the lateral radiograph does not improve the detection of findings related to TB [3]. In those with signs or symptoms of disease, the radiographic pattern of upper-lobe or superior-segment lower-lobe fibrocavitary disease in the appropriate clinical setting is sufficient to warrant respiratory isolation and sputum culture for definitive diagnosis. Using radiographs in combination with clinical evaluation results in a high sensitivity for the diagnosis but a relatively low specificity for both latent [4] and active TB [5]. In addition, radiographs may reveal ancillary findings of TB such as pleural effusion or spondylitis. For immunocompromised hosts, particularly those with a low CD4 count, computed tomography (CT) should be considered.

Computed tomography

The major advantage of CT is increasing the specificity of the diagnosis of TB; therefore, CT is often not necessary in the acute setting, particularly when the disease is already suspected and appropriate precautions and testing are already underway. CT may be able to better show distinct findings such as cavitation or endobronchial spread with tree-in-bud nodules and may be helpful in cases in which the chest radiograph does not show “classic” findings of TB [6]. CT findings can also be helpful in predicting acid-fast bacilli smear positivity [7-9]. Even in acid-fast bacilli smear-negative patients, CT may suggest the risk that a patient will be TB culture positive when findings consistent with active TB are present [10]. CT may be of value in the severely immunocompromised patient with a normal or near-normal radiograph by revealing abnormal lymph nodes or subtle parenchymal disease. Finally, CT may also have a role in identifying patients with latent TB who will be at risk for reactivation disease [4,11].

¹Principal Author and Panel Chair, Medical University of South Carolina, Charleston, South Carolina. ²Panel Vice-chair, National Jewish Health, Denver, Colorado. ³Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts. ⁴University of Texas MD Anderson Cancer Center, Houston, Texas. ⁵Mayo Clinic, Rochester, Minnesota. ⁶Mayo Clinic, Phoenix, Arizona. ⁷Vanderbilt University Medical Center, Nashville, Tennessee, American College of Chest Physicians. ⁸Mayo Clinic, Jacksonville, Florida. ⁹Columbia University Medical Center New York and Temple University Health System, Philadelphia, Pennsylvania. ¹⁰Specialty Chair, University of Florida College of Medicine, Gainesville, Florida.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: publications@acr.org

Magnetic resonance imaging

Only 1 study has been performed evaluating magnetic resonance imaging (MRI) for suspected TB. In this study the accuracy of MRI was similar to CT in describing findings related to culture-positive patients [12]. Inferential data regarding the value of MRI can also be derived from its role in cystic fibrosis and the observation in other settings that MRI correlates well with CT for parenchymal findings including bronchiectasis, cavitation, and tree-in-bud nodules [13]. Although MRI is technically feasible and described in the literature, MRI has not been specifically evaluated as a primary imaging modality for patients with suspected or proven TB.

Nuclear scintigraphy

Several nuclear radiopharmaceuticals have been employed for the purpose of evaluating possible TB, particularly for differentiating active from inactive tuberculomas and distinguishing tuberculomas from neoplasms. In small studies, Tc-99m methoxyisobutylisonitrile has shown higher activity over background in active tuberculomas compared with inactive tuberculomas [14,15]. Similarly, metabolic activity measured by fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) is higher in active tuberculomas. Dual-time-point FDG-PET imaging (1 and 2 hours postinjection) can also help differentiate active tuberculomas from neoplasms, owing to the longer retention of FDG in benign lesions [16]. Gallium 67 has been used to follow patients for disease activity and correlates with the number of organisms on sputum smears [17]. Evidence for the use of nuclear imaging to diagnose active TB is limited to either small single-site studies or several small studies, and the impact on clinical practice and patient care at this time is minimal.

Discussion of the Imaging Modalities by Variant

Variant 1: Suspect active tuberculosis.

The initial suspicion of active TB should be made based on clinical symptoms and demographics. Those at particular risk include those in close contact with patients having active TB, spending time in a TB-endemic country, or working/spending time in sites where TB is more prevalent, such as prisons, homeless shelters, and long-term care facilities. Those who are immunocompromised are at particular risk. Included in this category are also individuals with a newly positive purified protein derivative (PPD) skin test or a positive interferon-gamma release assay (IGRA) and who have symptoms that could be related to active TB. Clinical symptoms of active TB may include unexplained weight loss, night sweats, fever, prolonged cough, hemoptysis, and fatigue.

Chest radiography

Identified individuals should undergo chest radiography as the initial test. Chest radiographs have been shown to have a high sensitivity for detecting manifestations of active TB [5]. Chest radiography has a high sensitivity but relatively poor specificity owing to the overlap of findings with nontuberculous pulmonary infection. The yield of chest radiographs in high-risk patients ranges from 1% to 7%, although it is not clear how many of these cases would have been suspected based on clinical symptoms alone [18,19].

In particular, lobar pneumonia with associated hilar and/or mediastinal adenopathy or cavitary air space disease involving the apical posterior segments of the upper lobe or superior segment of the lower lobe should raise particular concern [20]. When a chest radiograph confirms the clinical suspicion of active TB, it is sufficient to warrant respiratory isolation pending sputum cultures. However, in patients who are immunocompromised, particularly those with AIDS and very low CD4 counts, chest radiographs may be deceptively normal.

Computed tomography

The role of CT remains less clear, but it should be considered for those with equivocal chest radiographic findings and may be efficacious in excluding active TB owing to its higher specificity. High-risk acid-fast bacilli smear-negative patients may also benefit from CT. AIDS patients with low CD4 counts and those taking anti-tumor necrosis factor medications have sufficient risk to warrant CT in the setting of high clinical suspicion for active TB and an unrevealing chest radiograph.

Magnetic resonance imaging

MRI is a reasonable consideration for use in select patients for whom there is a desire to avoid ionizing radiation.

Variant 2: Newly positive PPD or IGRA OR positive PPD or IGRA with unknown prior status. No clinical symptoms.

Chest radiography

One key principal of PPD testing is application in those at high risk for developing latent TB infection. This may include those who work in settings where contact with active TB is possible and those coming from regions where

TB is endemic. Although screening of low-risk individuals is discouraged, it is recommended for those whose future activity will place them at high risk for exposure or reactivation. The rationale behind performing chest radiography following a positive PPD is to distinguish latent TB from active TB, as these are managed differently. However, in patients without clinical symptoms the yield of radiographs for active TB (that would change management) is negligible [21]. Furthermore, parenchymal findings of latent TB are relatively poor predictors of future reactivation. If a chest radiograph is performed, a frontal view is sufficient [3].

Computed tomography

CT should be reserved for the rare case in which a chest radiograph may be equivocal for active TB and cases for which knowledge of latent TB abnormalities may inform future care, such as patients undergoing solid organ transplantation and biologic therapy for rheumatologic disease [4,11].

Magnetic resonance imaging

Like CT, there is a very limited role for MRI, although it may be considered when cross-sectional imaging is deemed necessary in a patient for whom there is a desire to avoid ionizing radiation.

Variant 3: PPD not available. Placement in group home or skilled nursing facility. No clinical symptoms.

Chest radiography

Low-risk screening also frequently occurs in patients being transferred to correctional institutions, group homes, and skilled nursing facilities. Because of time constraints related to placing and interpreting a PPD, chest radiography has emerged as a surrogate measure. A meta-analysis of homeless populations suggests that using chest radiography as a screening measure is sufficient and can lead in some cases to a decline in the incidence of TB over time [19]. This study, however, did not compare chest radiography screening to other screening strategies in terms of efficacy. Screening procedures vary from one prison site to another. There does not appear to be a large discrepancy in TB incidence regardless of screening technique (symptom survey, PPD, or chest radiograph) [22]. There is no evidence regarding the performance of routine radiography in low-risk patients who did not receive other TB screening before transfer to a group home or nursing facility.

Computed tomography

CT should be reserved for the rare case in which a chest radiograph is equivocal for active TB and more definitive testing such as sputum culture is impractical.

Magnetic resonance imaging

Like CT, there is a very limited role for MRI, although it might be considered when cross-sectional imaging is deemed necessary in a patient for whom there is a desire to avoid ionizing radiation.

Summary of Recommendations

- Chest radiography is the first recommended test in patients with suspected tuberculosis.
- Chest radiography is generally appropriate for patients with new evidence of exposure or at high risk for development of tuberculosis, although it may be of low yield in patients who have no clinical symptoms.
- Chest CT is appropriate when tuberculosis is suspected and radiography is nonrevealing or nondiagnostic.

Summary of Evidence

Of the 22 references cited in the *ACR Appropriateness Criteria® Imaging of Possible Tuberculosis* document, all are categorized as diagnostic references, including 1 well-designed study, 10 good-quality studies, and 2 quality studies that may have design limitations. There are 8 references that may not be useful as primary evidence. There is 1 reference that is a meta-analysis study.

The 22 references cited in the *ACR Appropriateness Criteria® Imaging of Possible Tuberculosis* document were published from 2004 through 2015.

Although there are references that report on studies with design limitations, 11 well-designed or good-quality studies provide good evidence.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposure associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate

population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
⊛	<0.1 mSv	<0.03 mSv
⊛ ⊛	0.1-1 mSv	0.03-0.3 mSv
⊛ ⊛ ⊛	1-10 mSv	0.3-3 mSv
⊛ ⊛ ⊛ ⊛	10-30 mSv	3-10 mSv
⊛ ⊛ ⊛ ⊛ ⊛	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies”.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

- LoBue PA, Enarson DA, Thoen TC. Tuberculosis in humans and its epidemiology, diagnosis and treatment in the United States. *Int J Tuberc Lung Dis.* 2010;14(10):1226-1232.
- Rozenshtein A, Hao F, Starc MT, Pearson GD. Radiographic appearance of pulmonary tuberculosis: dogma disproved. *AJR Am J Roentgenol.* 2015;204(5):974-978.
- Eisenberg RL, Romero J, Litmanovich D, Boiselle PM, Bankier AA. Tuberculosis: value of lateral chest radiography in pre-employment screening of patients with positive purified protein derivative skin test results. *Radiology.* 2009;252(3):882-887.
- Piccazzo R, Paparo F, Garlaschi G. Diagnostic accuracy of chest radiography for the diagnosis of tuberculosis (TB) and its role in the detection of latent TB infection: a systematic review. *J Rheumatol Suppl.* 2014;91:32-40.
- Wisnivesky JP, Henschke C, Balentine J, Willner C, Deloire AM, McGinn TG. Prospective validation of a prediction model for isolating inpatients with suspected pulmonary tuberculosis. *Arch Intern Med.* 2005;165(4):453-457.
- Yeh JJ, Yu JK, Teng WB, et al. High-resolution CT for identify patients with smear-positive, active pulmonary tuberculosis. *Eur J Radiol.* 2012;81(1):195-201.
- Matsuoka S, Uchiyama K, Shima H, et al. Relationship between CT findings of pulmonary tuberculosis and the number of acid-fast bacilli on sputum smears. *Clin Imaging.* 2004;28(2):119-123.
- Ors F, Deniz O, Bozlar U, et al. High-resolution CT findings in patients with pulmonary tuberculosis: correlation with the degree of smear positivity. *J Thorac Imaging.* 2007;22(2):154-159.
- Yeh JJ, Neoh CA, Chen CR, Chou CY, Wu MT. A high resolution computer tomography scoring system to predict culture-positive pulmonary tuberculosis in the emergency department. *PLoS One.* 2014;9(4):e93847.
- Nakanishi M, Demura Y, Ameshima S, et al. Utility of high-resolution computed tomography for predicting risk of sputum smear-negative pulmonary tuberculosis. *Eur J Radiol.* 2010;73(3):545-550.
- Lyu J, Lee SG, Hwang S, et al. Chest computed tomography is more likely to show latent tuberculosis foci than simple chest radiography in liver transplant candidates. *Liver Transpl.* 2011;17(8):963-968.
- Rizzi EB, Schinina V, Cristofaro M, et al. Detection of Pulmonary tuberculosis: comparing MR imaging with HRCT. *BMC Infect Dis.* 2011;11:243.

13. Barreto MM, Rafful PP, Rodrigues RS, et al. Correlation between computed tomographic and magnetic resonance imaging findings of parenchymal lung diseases. *Eur J Radiol.* 2013;82(9):e492-501.
14. Ahmadihosseini H, Sadeghi R, Zakavi R, Kakhki VR, Kakhki AH. Application of technetium-99m-sestamibi in differentiation of active from inactive pulmonary tuberculosis using a single photon emission computed tomography method. *Nucl Med Commun.* 2008;29(8):690-694.
15. Razieli G, Masjedi MR, Fotouhi F, et al. The role of 99mTc-MIBI scintigraphy in the management of patients with pulmonary tuberculosis. *Eur Rev Med Pharmacol Sci.* 2012;16(5):622-629.
16. Kaneko K, Sadashima E, Irie K, et al. Assessment of FDG retention differences between the FDG-avid benign pulmonary lesion and primary lung cancer using dual-time-point FDG-PET imaging. *Ann Nucl Med.* 2013;27(4):392-399.
17. Liu SF, Liu JW, Lin MC, Lee CH, Huang HH, Lai YF. Monitoring treatment responses in patients with pulmonary TB using serial lung gallium-67 scintigraphy. *AJR Am J Roentgenol.* 2007;188(5):W403-408.
18. Liu Y, Weinberg MS, Ortega LS, Painter JA, Maloney SA. Overseas screening for tuberculosis in U.S.-bound immigrants and refugees. *N Engl J Med.* 2009;360(23):2406-2415.
19. Paquette K, Cheng MP, Kadatz MJ, Cook VJ, Chen W, Johnston JC. Chest radiography for active tuberculosis case finding in the homeless: a systematic review and meta-analysis. *Int J Tuberc Lung Dis.* 2014;18(10):1231-1236.
20. Jeong YJ, Lee KS. Pulmonary tuberculosis: up-to-date imaging and management. *AJR Am J Roentgenol.* 2008;191(3):834-844.
21. Eisenberg RL, Pollock NR. Low yield of chest radiography in a large tuberculosis screening program. *Radiology.* 2010;256(3):998-1004.
22. Vinkeles Melchers NV, van Elstrand SL, Lange JM, Borgdorff MW, van den Hombergh J. State of affairs of tuberculosis in prison facilities: a systematic review of screening practices and recommendations for best TB control. *PLoS One.* 2013;8(1):e53644.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.