

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Suspected Infective Endocarditis

Radiologic Procedure	Rating	Comments	RRL*
US echocardiography transthoracic resting	9	This is the preferred modality.	O
X-ray chest	8	This procedure is useful for monitoring cardiopulmonary status.	⊕
US echocardiography transesophageal	8	This invasive procedure is used when better definition of anatomy is required.	O
CT heart function and morphology with IV contrast	6	This procedure is used mainly in the setting of suspected paravalvular infections and to evaluate prosthetic heart valves.	⊕ ⊕ ⊕ ⊕
MRI heart function and morphology without IV contrast	6	This procedure is used mainly in the setting of suspected complications and for quantifying the volume of valvular regurgitation.	O
MRI heart function and morphology without and with IV contrast	6	This procedure is used mainly in the setting of suspected complications and for quantifying the volume of valvular regurgitation.	O
CT chest with IV contrast	5	This procedure can be helpful to evaluate pulmonary findings such as septic infarcts.	⊕ ⊕ ⊕
CTA coronary arteries with IV contrast	5	This procedure is used mainly for better definition of coronary artery origin and course prior to surgery.	⊕ ⊕ ⊕
Arteriography coronary with ventriculography	5	This procedure is used mainly for evaluation of coronary artery disease prior to surgery.	⊕ ⊕ ⊕
FDG-PET/CT skull base to mid-thigh	5	This procedure may be particularly useful in suspected prosthetic valve endocarditis.	⊕ ⊕ ⊕ ⊕
In-111 WBC scan heart	3	This procedure has largely been replaced by cross-sectional imaging techniques.	⊕ ⊕ ⊕ ⊕
Fluoroscopy heart	3	This procedure has largely been replaced by EKG-gated CTA. It may be considered for initial evaluation of prosthetic heart valves.	⊕ ⊕
CT chest without and with IV contrast	2	Noncontrast CT chest adds radiation without clear benefits.	⊕ ⊕ ⊕
CT chest without IV contrast	1	This procedure cannot be used to evaluate vascular structures for complications.	⊕ ⊕ ⊕
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

SUSPECTED INFECTIVE ENDOCARDITIS

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Summary of Literature Review

Introduction/Background

Infective endocarditis can involve a normal, abnormal, or prosthetic cardiac valve. In recent years, infective endocarditis of normal right-sided valves has become more frequent as a consequence of intravenous (IV) injection of illicit drugs, indwelling IV catheters, and implantable cardiac devices [1]. Although acute endocarditis of left-sided cardiac valves nearly invariably causes congestive heart failure, heart failure may also occur with subacute infective endocarditis. Physical examination typically reveals a new heart murmur. The diagnostic workup of patients with suspected infective endocarditis typically includes serial blood cultures and echocardiography [2].

Infective endocarditis is fundamentally a clinical diagnosis based on the presence of positive blood cultures in association with characteristic symptoms and physical findings [2]. Blood cultures may be negative in the setting of antibiotic use. Imaging is used to support the diagnosis by demonstrating vegetations of cardiac valves and, in complicated cases, paravalvular abscesses affecting native [3] and prosthetic [4] valves. Imaging is also used to assess the severity of valvular damage, identify complications, and recognize the presence and severity of heart failure.

Chest Radiograph

The chest radiograph is used to determine cardiac chamber size and the presence and severity of pulmonary venous hypertension and edema; it is necessary for the evaluation of infective endocarditis. It is used to monitor the severity of the hemodynamic consequences of valvular regurgitation caused by infective endocarditis and to assess their response to treatment. In right-sided endocarditis the chest radiograph is effective for demonstrating pulmonary infarcts and abscesses as sequelae of septic emboli.

Transthoracic and Transesophageal Echocardiography

Transthoracic echocardiography (TTE) plays an important role in the evaluation of infective endocarditis and is currently the only imaging criterion included in the modified Duke criterion used for a diagnosis of infective endocarditis [5]. It can demonstrate vegetations on cardiac valves, valvular regurgitation, and paravalvular abscess. It is the most frequently used imaging study for confirming the diagnosis of infective endocarditis. The demonstration of vegetations by echocardiography is 1 of the 2 major modified Duke criteria required for the diagnosis of a definite endocarditis [5,6].

Studies show that criteria for the diagnosis, which include the findings on TTE [6,7] and particularly on transesophageal echocardiography (TEE) [6], were significantly better than traditional criteria based on clinical and bacteriologic criteria. Although TEE has been shown to have significantly higher sensitivity than TTE for identifying vegetations [6], specificities were similar. The positive predictive value of TTE for the diagnosis has been shown to be 97%, whereas the negative predictive value was 94% [6].

Several studies evaluated the diagnostic value of TTE and TEE in relation to the pretest probability of infective endocarditis based on clinical assessment in pediatric [8] and adult [9] patients. These studies concluded that echocardiography has a lower yield in patients with low probability of endocarditis. TEE is the procedure of

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choice for patients with intermediate or high probability of endocarditis. In right-sided endocarditis, TTE and TEE performed comparably, demonstrating similar numbers of vegetations and frequency of tricuspid regurgitation [10].

The size and other characteristics of vegetations on echocardiography have been shown to be useful in predicting complications such as peripheral embolization. Increase or failure to decrease in size of vegetation on serial echocardiograms during antibiotic therapy has been shown to be predictive of a prolonged and/or complicated course of infective endocarditis [10].

TEE is indicated and increasingly used in suspected infective endocarditis for demonstrating vegetations, paravalvular abscess [11], and valvular regurgitation. It is the most sensitive imaging technique for identifying vegetations, the presence of which is the hallmark for a definitive diagnosis of infective endocarditis [6]. Using criteria for diagnosing infective endocarditis based on echocardiographic features provides better diagnostic accuracy than using clinical criteria alone [7]. TEE has better sensitivity than TTE for detecting vegetations [6]. Authors of a review claimed that, in experienced hands, TEE has >90% sensitivity and specificity for detecting intracardiac lesions associated with infective endocarditis [6]. This [6] and another [12] review also concluded that a negative TEE almost always means a very low probability of infective endocarditis.

TEE has been shown to be very effective for monitoring the size and other characteristics of vegetation and for detecting complications such as paravalvular abscesses [6]. TEE has better sensitivity and accuracy than TTE for identifying paravalvular abscesses [6]. TEE is indicated for suspected infective endocarditis of prosthetic valves; it is significantly more accurate than TTE [6]. Furthermore, monitoring the size of vegetations during treatment contributes information concerning prognosis and risk of complication [13], although the usefulness of repeated TTE for altering patient management decreases with the number of repetitions [14].

TTE was found to be the more cost-effective test in patients with intermediate or high pretest probability of infective endocarditis [15].

TEE is indicated in many patients with suspected infective endocarditis, especially those in whom TTE is inconclusive or those with suspected paravalvular abscess.

If the initial echo is negative and the clinical suspicion is high or if the pathogen is a virulent organism such as *staph aureus*, a repeat TTE in 7–10 days may be considered. This follow-up study can in some instances be a TEE study (especially if the quality of the TTE is not optimal) [5,16].

Radioisotope Scanning

Although largely replaced by cross-sectional imaging techniques in clinical practice, radioisotope scanning may be used in some instances in the evaluation of suspected infective endocarditis. Several types of radioisotope scans may be used for identifying and localizing infected vegetations and paravalvular abscesses, such as Gallium 67 and indium111-labeled white cells [17]. Although these techniques are useful in isolated patients, they have a low sensitivity and add little to the usual diagnosis of infective endocarditis.

Immunoscintigraphy using technetium 99m-labeled anti-NCA-95 antigranulocyte antibodies has been proposed as a method of localization [18–20]. In one study, this scan had a sensitivity of 79% and specificity of 82% compared to echocardiography, which had a sensitivity of 88% and specificity of 97% [19]. However, the combination of echocardiography and immunoscintigraphy has a sensitivity of 100% and specificity of 82%.

Some recent studies have shown potential clinical value of fluorine-18-2-fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET)/CT in infective endocarditis. One study showed that FDG-PET/CT detected clinically unsuspected sites of extracardiac infection in up to 24% of cases [21]. In cases where TTE and TEE were normal or equivocal, 2 studies showed that FDG-PET/CT was able to detect periprosthetic abscesses [22,23]. This situation has been shown to occur in nearly 30% of cases [11]. A larger prospective study with 72 patients showed that adding abnormal FDG uptake around a prosthetic valve to the modified Duke criteria at admission increased the sensitivity for the diagnosis of prosthetic valve endocarditis to 97% from 70% [24]. However, when looking at a cohort of patients with native and prosthetic valves, one study showed a relatively low sensitivity of 39% for the diagnosis of infectious endocarditis [25]. Although early data for the use of FDG-PET/CT in the diagnosis of infectious endocarditis are encouraging, particularly in patients with prosthetic valves, further studies are needed to firmly establish the role of FDG-PET/CT in the imaging evaluation of infective endocarditis.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) may be indicated in some instances for evaluating infective endocarditis [26]. However, its use is primarily for evaluation of complications such as paravalvular and myocardial abscesses and infectious pseudoaneurysms. It is less accurate than TTE and TEE for identifying valvular vegetations. Cine MRI and velocity-encoded cine MRI can be used for quantifying the volume of valvular regurgitation [27]. Contrast material may not be necessary but can be helpful for evaluation of abscesses.

Computed Tomography

There is limited evidence in the literature for routine use of computed tomography (CT) for assessing patients with suspected endocarditis. CT is less accurate than TTE and TEE for identifying valvular vegetation. Consequently, the primary role of CT, like MRI, is in evaluating complications of infective endocarditis.

Routine non-ECG-gated CT chest with contrast may have difficulties identifying vascular complications such as paravalvular abscess due to cardiac motion artifacts. Noncontrast CT chest is even less helpful given that vascular structures will not be opacified. However, routine CT chest can be helpful in right-sided endocarditis for demonstrating septic pulmonary infarcts and abscesses.

With the development of retrospectively ECG-gated multidetector-row CT (CT heart function and morphology with contrast) the identification of paravalvular and myocardial abscesses and infective pseudoaneurysms can be possible [28-30]. In depicting aortic valve pseudoaneurysms, one study showed a sensitivity, specificity, positive predictive value, and negative predictive value of 100%, 87.5%, 91.7%, and 100%, respectively [29]. The primary weakness of CT is in detecting aortic valve vegetations <1 cm in size for which the negative predictive value was 55.5%. However, the sensitivity, specificity, positive predictive value, and negative predictive value were all 100% for vegetations >1 cm in size. In addition, CT may assist in the assessment of prosthetic valve leaflets to evaluate leaflet pannus, thrombus, or other reasons for prosthesis failure [31].

Coronary CT angiography (CCTA) may also have a role in preoperative planning and exclusion of coronary artery disease before surgery [30], where the risks of selective coronary angiography may be considerable. Given the well-established high negative predictive value of CCTA, its use for the presurgical exclusion of significant coronary artery disease allows for a noninvasive alternative to cardiac catheterization [32,33]. However, one limitation is that patients with endocarditis have a higher heart rate, which may limit the accuracy of coronary CTA.

Recent advances in cardiac CT imaging technology allow for further radiation dose reduction in CCTA examinations [34]; new and available dose-reducing techniques include prospective triggering [35-37], adaptive statistical iterative reconstruction [38], and high-pitch spiral acquisition [39]. However, these newer low-dose techniques may not be appropriate in all patients due to their dependency on a combination of factors, including heart rate, rhythm, and large body size. Thus, although these techniques are promising in terms of reducing patient radiation dose, there may be patients for whom these radiation dose techniques are not optimal, such as an obese, elderly patient with an arrhythmia who might best benefit from retrospective gating in order to allow assessment of the coronary arteries at multiple phases of the cardiac cycle. In addition, not all scanners are capable of all radiation dose reduction techniques. In all cases, the imaging physician must select the appropriate combination of imaging parameters to acquire a diagnostic examination at a radiation dose that is as low as reasonably achievable (ALARA).

Catheterization and Ventricular Angiography

Catheterization and ventriculography have limited roles in the setting of infective endocarditis with congestive heart failure. It may be used to assess the severity of valvular dysfunction and ventricular function prior to surgery [40], although the role of these invasive tests in the setting of infective endocarditis is not formally defined. The primary indication is for presurgical evaluation of coronaries. These tests are not indicated for patients with uncomplicated endocarditis on native valves in whom surgical intervention is not contemplated. Catheterization and ventriculography may be indicated for endocarditis of prosthetic valves when echocardiographic results are equivocal or in the evaluation of suspected mycotic aneurysms.

Cardiac Fluoroscopy

In rare occasions, cardiac fluoroscopy may be indicated for evaluating prosthetic cardiac valves afflicted with endocarditis [41]. Valve fluoroscopy is used to detect excess mobility of the prosthetic valve during the cardiac cycle (a finding highly suggestive of valve dehiscence caused by infective endocarditis), or to detect immobility

of prosthetic valve leaflets secondary to infected pannus or thrombus. More recently, EKG-gated CTA focusing on the prosthetic valve has come to replace this modality [31].

Summary

- In most clinical scenarios, ultrasound echocardiography using a transthoracic or transesophageal technique is the most appropriate strategy for the initial evaluation and surveillance of patients with suspected infective endocarditis.
- The chest radiograph remains one of the most appropriate cornerstones for determining the severity of the hemodynamic consequences of infective endocarditis and to assess patients' response to treatment.
- Cardiac MRI may be appropriate in the evaluation of infective endocarditis, mainly in the setting of suspected complications and for quantifying the volume of valvular regurgitation.
- Cardiac CT has emerged as a probably appropriate tool for evaluating infective endocarditis, mainly in the settings of suspected complications, for evaluating prosthetic heart valves, and for preoperative planning and exclusion of coronary artery disease before surgery.
- Radioisotope scanning for identifying and localizing infected vegetations and paravalvular abscesses can be considered in rare instances, but it has been largely replaced in clinical practice by cross-sectional imaging modalities.
- In rare instances, cardiac fluoroscopy may be considered for evaluating prosthetic cardiac valves afflicted with endocarditis, but it has been largely replaced in clinical practice by cross-sectional imaging modalities, mainly cardiac CT.

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 exposures 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
○	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.

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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.