

**American College of Radiology  
ACR Appropriateness Criteria®**

**Preprocedural Planning for Left Atrial Procedures in Atrial Fibrillation**

**Variant: 1 Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	○
MRA chest without and with IV contrast	Usually Appropriate	○
MRI heart function and morphology without and with IV contrast	Usually Appropriate	○
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
MRA chest without IV contrast	May Be Appropriate	○
MRI heart function and morphology without IV contrast	May Be Appropriate	○
US echocardiography transthoracic resting	Usually Not Appropriate	○
Arteriography coronary	Usually Not Appropriate	☢☢☢
Catheter venography pulmonary	Usually Not Appropriate	☢☢☢☢
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
MRA coronary arteries without IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

**Variant: 2 Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	○
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
MRA chest without and with IV contrast	May Be Appropriate	○
MRI heart function and morphology without and with IV contrast	May Be Appropriate	○
US echocardiography transthoracic resting	Usually Not Appropriate	○
Arteriography coronary	Usually Not Appropriate	☢☢☢
Catheter venography pulmonary	Usually Not Appropriate	☢☢☢☢
MRA chest without IV contrast	Usually Not Appropriate	○
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
MRA coronary arteries without IV contrast	Usually Not Appropriate	○
MRI heart function and morphology without IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢

CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

### **Variant: 3 Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	○
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
MRI heart function and morphology without and with IV contrast	May Be Appropriate	○
US echocardiography transthoracic resting	Usually Not Appropriate	○
Arteriography coronary	Usually Not Appropriate	☢☢☢
Catheter venography pulmonary	Usually Not Appropriate	☢☢☢☢
MRA chest without and with IV contrast	Usually Not Appropriate	○
MRA chest without IV contrast	Usually Not Appropriate	○
MRA coronary arteries without and with IV contrast	Usually Not Appropriate	○
MRA coronary arteries without IV contrast	Usually Not Appropriate	○
MRI heart function and morphology without IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

### **Panel Members**

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### **Summary of Literature Review**

#### **Introduction/Background**

Atrial fibrillation (AF) is the most common cardiac arrhythmia, affecting 3% of the population [1,2], predisposing to circulatory stasis and formation of left atrial (LA) thrombi, mostly in the LA appendage (LAA) [1,3,4].

Endovascular treatment of AF continues to evolve, with favorable outcomes. Catheter ablation eliminates the electrical connection between the left atrium and ectopic pulmonary venous arrhythmogenic foci [5] and can be used to eliminate substrate for reentry within or adjacent to areas of LA fibrosis [6]. Imaging for preprocedural planning for LA ablation has been shown to improve success rate of procedures, minimize complications, exclude contraindications for the

procedure, and minimize the risk of AF recurrence [7]. Endovascular device occlusion/closure of the LAA is used to reduce LAA thrombi from embolizing into the systemic circulation [8-10]. Cardioversion aims to restore a patient to normal sinus rhythm, and in such patients, precardioversion imaging is used to exclude the presence of LAA thrombus because up to 7% of patients have atrial thrombi despite anticoagulation regimens [7].

The document discusses imaging guidelines for the following preprocedural clinical tasks in patients needing endovascular treatment or cardioversion of AF: 1) before catheter ablation, to determine the anatomy of the pulmonary veins, the size of their ostia if using balloon technology, and to determine the relationship of the left atrium to adjacent structures (such as the esophagus) to minimize complications and exclude thrombi; 2) before LAA occlusion to assess LAA morphology and dimensions for device selection, exclude LAA thrombi, assess LAA relationship to adjacent cardiac, and extracardiac structures to aid in determining feasibility and preprocedural planning; and 3) before cardioversion, to exclude LA/LAA thrombi.

This document does not provide guidance for the diagnosis or management of AF and presumes that patients considered for LA/LAA procedures are eligible candidates. To this end, diagnosis and assessment of cardiac disease needed in addition to specific preprocedural planning, the reader is referred to the ACR Appropriateness Criteria® topics on "[Nonischemic Myocardial Disease with Clinical Manifestations \(Ischemic Cardiomyopathy Already Excluded\)](#)" [11] and "[Suspected New-Onset and Known Nonacute Heart Failure](#)" [12], valvular heart disease, arrhythmia, and pericardial pathology and the ACR Appropriateness Criteria® topic on "[Chronic Chest Pain-High Probability of Coronary Artery Disease](#)" [13]. Also, the panel does not discuss imaging performed at the time of the proposed procedures (ie, intracardiac echocardiography), nor does it discuss investigation of postprocedural complications.

## Special Imaging Considerations

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the [ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography \(CTA\)](#) [14]:

*"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial and/or venous enhancement, depending on the vascular structures to be analyzed. The resultant volumetric data set is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and reconstructions/reformats. Only in CTA, however, is 3-D rendering a **required** element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

For the purposes of the document, CTA chest may be performed with electrocardiogram (ECG) gating, triggering, high pitch dual source acquisition, or nongated acquisition depending on site technology and experience. This is in distinction to CT heart, which is routinely performed with ECG gating and is often limited in z-axis to only cover the heart. Similarly, MR angiography (MRA) chest may be an ECG-gated or nongated acquisition and may be performed with or without contrast. The 3-D reconstructions and renderings are an essential element for MRA.

## **Discussion of Procedures by Variant**

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **A. Arteriography Coronary**

Invasive coronary arteriography provides assessment of coronary artery disease. There is no relevant literature to support the use of routine coronary arteriography to guide preprocedural planning before LA ablation procedure.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **B. Catheter Venography Pulmonary**

Catheter venography provides assessment of the pulmonary veins. There is little evidence in the literature supporting the use of catheter venography for routine preprocedural planning for atrial arrhythmia ablation. One retrospective review evaluated periprocedural 3-D rotational angiography in 547 consecutive patients undergoing ablation via direct contrast injection into either the right or left atrium, with or without simultaneous oral contrast administration for esophageal mapping [15]. With the availability of electroanatomic mapping systems, there is no added benefit or literature supporting the use of catheter venography during atrial arrhythmia ablation.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **C. CT Chest With IV Contrast**

There is no relevant literature to support the use of CT chest with intravenous (IV) contrast to guide preprocedural planning before LA ablation.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **D. CT Chest Without and With IV Contrast**

There is no relevant literature to support the use of CT chest without and with IV contrast to guide preprocedural planning before LA ablation.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **E. CT Chest Without IV Contrast**

A single prospective study of 50 patients evaluated with unenhanced chest CT found no statistically significant difference in procedural times and ablation success rate [16]. This is limited by the population size and paucity of additional supporting data. Integration of unenhanced CT with electroanatomic mapping cannot be adequately performed [16], and evaluation for contraindications such as thrombus is not possible.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

### **F. CT Heart Function and Morphology With IV Contrast**

ECG-gated cardiac multidetector CT (MDCT) can assess left atrium, LAA, and pulmonary venous

anatomy. In a study including 1,040 consecutive patients who underwent pulmonary vein catheter ablation, cardiovascular anatomic variants were identified on gated-CT in 18.7% of cases [5]. For patients undergoing repeat ablation procedures, CT can assess sites of pulmonary vein stenosis or occlusion caused by a prior procedure. It also provides information on adjacent thoracic structures, including the esophagus, and facilitates electroanatomic mapping for preprocedural planning for ablation.

CT heart has also been evaluated in assessing thrombi before various LA procedures. With specific regard to the preablation setting, the specificity and negative predictive value (NPV) of a single acquisition CT (without delayed or prone imaging) have been reported to be 88% and 100%, respectively, based on a study of 51 patients when compared with transesophageal echocardiography (TEE) [17]. The diagnostic accuracy of CT for thrombus can be further improved by using a delayed phase or prone position [18]. In a small study of 70 patients, the specificity and positive predictive value of CT increased from 84% and 15% to 100% and 100%, respectively, by adding a delayed phase [19]. The high NPV can be used to decrease the usefulness of TEE, so that it is selectively used only when CT is positive. Hong et al [20] found that patients who underwent cardiac MDCT followed by routine TEE had no significant difference in periprocedural stroke incidence when compared with selective TEE (0.2% incidence in each group,  $P > .99$ ); the sensitivity and NPV of CT were 100% and 100%, respectively, in this study. This strategy of selective use of TEE was also assessed during the COVID-19 pandemic, and the study showed no significant difference in periprocedural thromboembolic events between routine TEE versus selective use of TEE guided by CT (0% versus 0.4%,  $P = .33$ ,  $n = 637$ ) [21].

Cardiac CT can assess LA size, which may help guide patient management as increased LA volume is an independent predictor of arrhythmia recurrence ( $n = 103$ ; hazard ratio [HR], 1.011/mL; 95% confidence interval [CI], 1.003-1.020;  $P = .002$ ) [22].

### **Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **G. CTA Chest With IV Contrast**

CTA of the chest can allow for assessment of the left atrium, LAA, and pulmonary venous anatomy as an alternative to CT heart. A prospective study comparing ECG-gated and non-ECG-gated CTA in 62 patients showed significant decrease in dose using the non-ECG-gated protocol ( $P < .0001$  for CT dose index-volume, dose length product, and effective dose), without significant difference in the visual quality of the images, catheter ablation parameters, and AF recurrence rate [23]. Another study randomizing 60 patients to ECG-gated 64-slice MDCT, ECG-gated 128-dual-source CT, and nongated 128-dual-source CT showed that overall using dual-source CT compared with MDCT required less contrast medium, and the dosimetric variables were lower. For the nongated dual-source CT, total scan time was significantly lower than both the gated MDCT and gated dual-source CT ( $P < .001$ ), and there were no significant differences in electroanatomic map integration and procedural parameters among the 3 groups [24].

In addition, a prospective study evaluating the role of delayed contrast imaging for thrombus detection in 320 patients with AF used non-ECG-gated CTA as part of the standard preablation protocol. The sensitivity and NPV for LAA thrombus detection (with the integrated delayed phase imaging) were both 100% and the specificity was 98% when compared with intraprocedural intracardiac echocardiography and preprocedural TEE. More importantly, no patients with a negative CTA or equivocal CTA combined with TEE suffered cerebrovascular complications [25].

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **H. CTA Coronary Arteries With IV Contrast**

CTA coronary arteries is used to assess coronary arterial disease. There is no relevant literature supporting the routine use of CTA coronary arteries with IV contrast to guide preprocedural planning before LA ablation. This can also be technically challenging due to irregular heart rhythm in these patients. Although not routinely recommended, if the specific clinical scenario requires coronary arterial evaluation in addition to preablation planning, the study may be performed as a CTA coronary examination and left atrium and pulmonary veins can be assessed simultaneously.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **I. MRA Chest Without and With IV Contrast**

MRA without and with IV contrast can assess LA size, pulmonary venous anatomy, and thrombus. Both standard contrast-enhanced and dynamic time-resolved contrast-enhanced MRA (the latter performed with a lower gadolinium agent contrast dose) can assess the LA and pulmonary venous anatomy [26,27]. A recent comparison of these 2 acquisitions in 50 patients showed that time-resolved MRA has significantly higher overall image quality ( $P < .0001$ ) [27]. MRA with IV contrast can identify LA/LAA thrombi with an accuracy of 94.3%, a sensitivity of 66.7%, and a specificity of 95.2% compared with TEE [28].

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **J. MRA Chest Without IV Contrast**

Noncontrast enhanced MRA using 2-D and 3-D balanced steady-state free-precession (b-SSFP) can assess LA size and pulmonary venous anatomy, although it cannot reliably assess for thrombus. It may be a feasible alternative for preablation planning in patients who cannot receive IV contrast [29,30]. Despite an overall lower image quality, 2-D b-SSFP MRA yielded adequate LA and pulmonary vein anatomical information and adequate electroanatomic integration when compared with contrast-enhanced CT in 54 patients, 27 scanned with each modality [29]. Further supporting data are scarce.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **K. MRA Coronary Arteries Without and With IV Contrast**

MRA coronary artery examination can assess proximal coronary artery anatomy. There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast to guide preprocedural planning before LA ablation.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **L. MRA Coronary Arteries Without IV Contrast**

MRA coronary artery examination can assess proximal coronary artery anatomy. There is no relevant literature to support the use of MRA coronary arteries without IV contrast to guide preprocedural planning before LA ablation.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

#### **M. MRI Heart Function and Morphology Without and With IV Contrast**

MRI heart with IV contrast can assess chamber size, presence of LA/LAA thrombi, and atrial fibrosis. However, for pulmonary vein anatomy and measurements, it requires a complementary procedure (ie, a simultaneous 3-D acquisition [MRA]). In a study that matched 400 patients to either preprocedural cardiac CT or cardiac MR (CMR), procedural characteristics (fluoroscopy time, procedure duration, pulmonary veins identified, targeted, and isolated) and arrhythmia recurrence rates were not significantly different [31]. In 2 studies, MRI heart was shown to have more accurate and reproducible measurements of LA volume, which, when increased, is an independent predictor of postablation recurrence [31,32]. Among various MR sequences, long inversion time-delayed enhanced CMR has the highest reported diagnostic accuracy (99.2%), sensitivity (100%), and specificity (99.2%) for thrombus assessment compared with TEE [28]. Multiple studies have shown that the identification of presence of LA fibrosis on late gadolinium enhancement imaging is an independent predictor of postablation arrhythmia recurrence [33-36]. This has led to the investigation of LA substrate-based ablation, in which these atrial fibrotic lesions are targeted in addition to the pulmonary veins to curb recurrence rates [37]. The prospective, multicenter Efficacy of Delayed Enhancement MRI-Guided Ablation vs Conventional Catheter Ablation of Atrial Fibrillation (DECAAF II) trial showed that among patients with persistent AF, MRI-guided fibrosis ablation plus pulmonary vein isolation, compared with pulmonary vein isolation catheter ablation only, resulted in no significant difference in atrial arrhythmia recurrence [6]. Other LA parameters such as LA volume, sphericity, LA volume index, LA emptying function, peak strain, and LA T1 relaxation time have also been assessed with MRI heart [32].

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

**N. MRI Heart Function and Morphology Without IV Contrast**

MRI heart without IV contrast can provide cardiac function and chamber sizes, but the role in preprocedural planning is limited and there is scant literature on this topic. Also, unlike contrast-enhanced MRI heart, it is not sensitive for thrombus and cannot be used for scar assessment.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

**O. SPECT or SPECT/CT MPI Rest and Stress**

There is no relevant literature to support the use of single-photon emission computed tomography (SPECT) or SPECT/CT myocardial perfusion imaging (MPI) rest and stress for to guide preprocedural planning before LA ablation. However, many operators use isoproterenol infusions to assess the presence of nonpulmonary vein triggers. Prior to using high doses of isoproterenol, assessment of MPI may be advisable in patients with symptoms consistent with angina or those with limited functional capacity.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural planning prior to left atrial ablation.**

**P. US Echocardiography Transesophageal**

TEE is a useful imaging technique for LA/LAA thrombus detection [38-40] and has a sensitivity of 93.3% to 100% and a specificity of 99% to 100%.

TEE cannot reliably assess pulmonary venous anatomy, pulmonary venous measurements, and extracardiac anatomic relations. Hence, alternative imaging techniques like CT and MR are being assessed to allow a more targeted use of TEE in patients with suspected thrombus.

**Variant 1: Atrial fibrillation, atrial tachycardia, or atypical atrial flutter. Preprocedural**

**planning prior to left atrial ablation.**

#### **Q. US Echocardiography Transthoracic Resting**

Although TTE is commonly used in the initial workup of patients with AF and parameters such as LA volume/volume index, left ventricular ejection fraction [41], and LA size [42] can be assessed, there is no relevant literature that describes the specific use of TTE to guide preprocedural planning before LA ablation procedure.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **A. Arteriography Coronary**

There is no relevant literature to support the use of routine coronary arteriography to guide preprocedural planning before LAA occlusion planning.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **B. Catheter Venography Pulmonary**

There is no relevant literature to support the use of catheter pulmonary venography to guide preprocedural planning before LAA occlusion.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **C. CT Chest With IV Contrast**

There is no relevant literature to support the use of CT chest with IV contrast to guide preprocedural planning before LAA occlusion.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **D. CT Chest Without and With IV Contrast**

There is no relevant literature to support the use of CT chest without and with IV contrast to guide preprocedural planning before LAA occlusion.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **E. CT Chest Without IV Contrast**

There is no relevant literature to support the use of CT chest without IV contrast to guide preprocedural planning before LAA occlusion.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

#### **F. CT Heart Function and Morphology With IV Contrast**

CT heart can assess LAA size, assess anatomy for device selection, and exclude thrombi. Accurate LAA anatomic assessment guides device selection. For device sizing, a small, randomized trial of 24 patients showed that compared with 2-D TEE, CT had a higher accuracy for first device selection (92% versus 27%,  $P = .01$ ), efficiency in device usefulness ( $1.33 \pm 0.7$  for CT versus  $2.5 \pm 1.2$  for TEE,  $P = .01$ ), and guide catheters (1 for CT versus  $1.7 \pm 0.8$  for TEE,  $P = .01$ ) and shorter procedure time ( $55 \pm 17$  min for CT versus  $73 \pm 24$  for TEE,  $P = < .05$ ) [43]. CT measurements are slightly larger



than TEE; the mild underestimation on TEE may be due to usefulness of a limited number of angles, dehydration from preprocedural fasting, and the higher spatial resolution of CT [44,45]. A single-center study showed that relying on 3-D TEE-derived length alone can incorrectly exclude 19% of patients [46]. Incremental value of CT over standalone TEE has also been shown in another study, which demonstrated a higher successful device implantation rate (98.5% versus 94.9%;  $P = .02$ ), a shorter procedural time (median, 45.5 minutes versus 51.0 minutes;  $P = .03$ ), and a less frequent change of device size (5.6% versus 12.1%;  $P = .01$ ), with no difference in the risk of major adverse events [47]. In addition, CT-based 3-D printing is being explored for procedural guidance.

An important role of CT is excluding contraindications to endovascular LAA occlusion procedures such as presence of thrombi. In a meta-analysis comparing CT and TEE for thrombus assessment, CT had a sensitivity and specificity of 96% and 92%, which increased to 100% and 99% if delayed imaging was performed [48].

#### **Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

##### **G. CTA Chest With IV Contrast**

CTA of the chest can allow for assessment of the left atrium and LAA and can be performed with various acquisition parameters (with or without ECG gating) depending on scanner and local protocols. For device sizing, ECG-gated CTA is useful, and studies have shown high accuracy for gated CTA as outlined in the preceding section on CT heart [43,49].

Depending on the exact parameters, CTA chest with IV contrast is also useful in excluding thrombi especially when combined with delayed imaging. When coupled with delayed phase it has a 100% sensitivity [48].

#### **Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

##### **H. CTA Coronary Arteries With IV Contrast**

There is no relevant literature to support the routine use of CTA coronary arteries with IV contrast to guide preprocedural planning before LAA occlusion procedures.

#### **Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

##### **I. MRA Chest Without and With IV Contrast**

MRA chest with contrast can assess LA and LAA size and patency and identify LA/LAA thrombi with an accuracy of 94.3%, a sensitivity of 66.7%, and a specificity of 95.2% compared with TEE [28]. However, there are no large studies evaluating the use of MRA chest without and with IV contrast to guide preprocedural planning before LAA occlusion.

#### **Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

##### **J. MRA Chest Without IV Contrast**

There is no relevant literature to support the use of MRA chest without IV contrast to guide preprocedural planning for LAA occlusion procedures.

#### **Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

##### **K. MRA Coronary Arteries Without and With IV Contrast**

There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast to guide preprocedural planning for LAA occlusion procedures.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**L. MRA Coronary Arteries Without IV Contrast**

There is no relevant literature to support the use of MRA coronary arteries without IV contrast to guide preprocedural planning for LAA occlusion procedures.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**M. MRI Heart Function and Morphology Without and With IV Contrast**

MRI heart can assess the patency of the left atrium and LAA. There is a small amount of data assessing contrast-enhanced CMR for detection of LA/LAA thrombus. A retrospective analysis of 97 patients showed 100% concordance in LAA thrombus detection between 3-D early postgadolinium enhancement CMR and TEE [50]. Another study comparing CMR with TEE in 261 patients showed a 99.2% diagnostic accuracy for long T1 delayed enhancement CMR in detecting LAA thrombi [28]. This diagnostic accuracy was not affected by the presence of arrhythmia during image acquisition. For the measurement of LAA, it needs to be complemented with a simultaneous 3D acquisition (ie, MRA). There are; however, no large studies to support the use of MRI in quantifying LAA size and morphology before endovascular occlusion [7]. A limitation of CMR is its lower spatial resolution and longer acquisition times when compared with CT.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**N. MRI Heart Function and Morphology Without IV Contrast**

MRI heart without IV contrast can assess the size of left atrium. There is scant data in the literature supporting the use of noncontrast CMR for detecting LAA thrombi. Kitkungvan et al [28] compared CMR with TEE for detecting LAA thrombi. Steady-state free-precession (SSFP) cine MRI had a 91.6% diagnostic accuracy, 66.7% sensitivity, and 92.5% specificity.

There is no relevant literature to support the use of nonenhanced CMR in quantifying LAA size and morphology to guide preprocedural planning for LAA occlusion procedures.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**O. SPECT or SPECT/CT MPI Rest and Stress**

There is no relevant literature to support the use of SPECT or SPECT/CT MPI rest and stress to guide preprocedural planning for LAA endovascular occlusion procedures.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**P. US Echocardiography Transesophageal**

TEE is most useful for preprocedural imaging and enables exclusion of an intracardiac thrombus, as well as the assessment of LAA size and shape for device selection and characterization of the atrial septum for transseptal puncture. Studies have shown underestimation of appendage dimensions by TEE, although this has been partly overcome by 3-D TEE [45]. A study of 53 patients showed that CT LAA maximal-width sizing was  $2.7 \pm 2.2$  mm and  $2.3 \pm 3.0$  mm larger than 2-D and 3-D TEE measurements, respectively [46], and that upsizing would be needed for 62.3% of patients with 2-D

TEE maximal-width measurements alone compared with 52.8% of patients with 3-D TEE measurements alone.

**Variant 2: Atrial fibrillation. Preprocedural planning prior to left atrial appendage endovascular occlusion.**

**Q. US Echocardiography Transthoracic Resting**

Transthoracic echocardiography TTE assesses LA parameters that can help with patient risk stratification for thromboembolic events such as LA volume/volume index, left ventricular ejection fraction [41], and LA size [42]. However, there is no relevant literature to support the use of TTE specifically for preprocedural planning to guide LAA endovascular occlusion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**A. Arteriography Coronary**

There is no relevant literature to support the use of coronary arteriography to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**B. Catheter Venography Pulmonary**

There is no relevant literature to support the use of catheter pulmonary venography to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**C. CT Chest With IV Contrast**

CT chest can, in some cases, demonstrate thrombi; however, it is not optimized for LA assessment. There is no relevant literature to support the use of CT chest with IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**D. CT Chest Without and With IV Contrast**

There is no relevant literature to support the use of CT chest without and with IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**E. CT Chest Without IV Contrast**

There is no relevant literature to support the use of CT chest without IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

**F. CT Heart Function and Morphology With IV Contrast**

There is increasing use of CT to exclude thrombus before LA procedures, especially when CT is already being performed for measurements and mapping (ie, before ablation and appendage

occlusion). However, there are no large studies assessing the role of CT before cardioversion. In terms of diagnostic accuracy, CT has shown good performance for this indication (exclusion of thrombus), with a meta-analysis showing CT to have a sensitivity and specificity of 96% and 92%, respectively, which increased to 100% and 99%, respectively, if delayed imaging was performed [48]. Other studies have shown similar results [18,19,25]. CT has the advantage of noninvasive nature with 3-D capability.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **G. CTA Chest With IV Contrast**

Depending on the exact parameters, CTA with IV contrast is useful in excluding thrombi especially when combined with delayed imaging. When coupled with delayed phase it has a 100% sensitivity and NPV [48].

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **H. CTA Coronary Arteries With IV Contrast**

There is no relevant literature to support the use of CTA coronary arteries with IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **I. MRA Chest Without and With IV Contrast**

MRA with IV contrast can identify LA/LAA thrombi with an accuracy of 94.3%, a sensitivity of 66.7%, and a specificity of 95.2% compared with TEE [28]. However, there are no large studies or relevant literature specifically evaluating the use of MRA chest without and with IV contrast for preprocedural planning before cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **J. MRA Chest Without IV Contrast**

There is no relevant literature to support the use of MRA chest without IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **K. MRA Coronary Arteries Without and With IV Contrast**

There is no relevant literature to support the use of MRA coronary arteries without and with IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **L. MRA Coronary Arteries Without IV Contrast**

There is no relevant literature to support the use of MRA coronary arteries without IV contrast to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **M. MRI Heart Function and Morphology Without and With IV Contrast**

There is emerging data that contrast-enhanced CMR is a reliable imaging modality for the detection of LA/LAA thrombus. A retrospective analysis of 97 patients showed 100% concordance in LAA thrombus detection between 3-D early postgadolinium enhancement CMR and TEE [50]. Another study comparing CMR with TEE in 261 patients showed a 99.2% diagnostic accuracy for long T1 delayed enhancement CMR in detecting LAA thrombi [28].

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **N. MRI Heart Function and Morphology Without IV Contrast**

There is limited data in the literature supporting the use of noncontrast CMR for detecting LAA thrombi. Kitkungvan et al [28] compared CMR with TEE for detecting LAA thrombi. SSFP cine MRI had a 91.6% diagnostic accuracy, a 66.7% sensitivity, and a 92.5% specificity. Flow-related breathing and inhomogeneity artifacts were the main causes for this lower yield.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **O. SPECT or SPECT/CT MPI Rest and Stress**

There is no relevant literature to support the use of SPECT or SPECT/CT MPI rest and stress to guide preprocedural planning for cardioversion.

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **P. US Echocardiography Transesophageal**

TEE can assess for LA and LAA thrombus detection with a reported 97% sensitivity and 100% specificity [38]. TEE is useful as an alternative to periprocedural anticoagulation in patients with AF of unclear onset and duration or when AF duration is >48 hours, and in patients with known thrombosis, repeat TEE is suggested after 3 to 4 weeks of anticoagulation before cardioversion by the European Society of Cardiology [51].

**Variant 3: Atrial fibrillation. Preprocedural planning prior to electrical or pharmacologic cardioversion.**

#### **Q. US Echocardiography Transthoracic Resting**

Although TTE can assess LA parameters that can help with patient risk stratification for thromboembolic events, there are no studies describing the specific usefulness of TTE before cardioversion particularly in excluding left atrial appendage thrombus.

### **Summary of Recommendations**

- **Variant 1:** US echocardiography transesophageal, or MRA chest without and with IV contrast, or MRI heart function and morphology without and with IV contrast, or CTA chest with IV contrast, or CT heart function and morphology with IV contrast is usually appropriate for patients with AF, atrial tachycardia, or atypical atrial flutter undergoing preprocedural planning before LA ablation. MRA chest without and with IV contrast and MRI heart function and morphology without and with IV contrast are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care), and performed simultaneously to assess pulmonary vein measurements in addition to chamber size and thrombi. The other procedures, US echocardiography transesophageal, or CTA chest with IV

contrast, or CT heart function and morphology with IV contrast are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

- **Variation 2:** US echocardiography transesophageal, or CTA chest with IV contrast, or CT heart function and morphology with IV contrast is usually appropriate for patients with AF undergoing preprocedural planning before LAA endovascular occlusion. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variation 3:** US echocardiography transesophageal, or CTA chest with IV contrast, or CT heart function and morphology with IV contrast is usually appropriate for patients with AF undergoing preprocedural planning before electrical or pharmacologic cardioversion. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

## Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria>.
















## Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

## 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, because of both 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 with 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	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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

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## Disclaimer

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.

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