



Zobrazovací metody | Imaging

Přehledový článek | Review article

Imaging of intracardiac thrombus

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ARTICLE INFO

Article history:

Received: 26 November 2012

Accepted: 19 February 2013

Available online: 27 February 2013

Keywords:

Cardiac thrombus
Computed tomography
Echocardiography
Magnetic resonance

Klíčová slova:

Echokardiografie
Magnetická rezonance
Trombus v srdci
Výpočetní tomografie

ABSTRACT

Intracardiac thrombus is an important clinical condition because of its potential complications. Detection of ventricular thrombi is generally performed by transthoracic echocardiography while atrial thrombi are generally evaluated by transesophageal echocardiography. Contrast-enhanced computerized tomography is more sensitive for detecting ventricular and atrial thrombi than transthoracic echocardiography, but the technique has been demonstrated to be inferior to transesophageal echocardiography for displaying atrial thrombi. Cardiac magnetic resonance imaging provides superior specificity for evaluation of tissue characteristics and helps to differentiate thrombi from other masses.

SOUHRN

Vzhledem k možnosti různých komplikací představuje přítomnost trombů v srdci závažný klinický stav. K vyhledávání trombů v pravé komoře se obvykle používá transthorakální echokardiografie, zatímco tromby v pravé síni odhalí transezofageální echokardiografie. I když výpočetní tomografie se zesíleným kontrastem vyhledává tromby v komorách i v síních spolehlivěji než transthorakální echokardiografie, nedokáže zjistit tromby v pravé síni tak přesně jako transezofageální echokardiografie. Díky své vysoké specifitě umožňuje vyšetření srdce magnetickou rezonancí určit charakteristiky srdeční tkáně a pomáhá odlišit tromby od jiných nitrosrdečních útvarů.

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Introduction

Transesophageal echocardiography (TEE) is considered to be superior to the transthoracic echocardiography (TTE) for detecting cardiovascular sources of embolism although the latter remains the cornerstone of noninvasive cardiac imaging. Imaging by means of TEE, a semi-invasive procedure, is performed within the esophagus and the gastric fundus. TEE has high sensitivity and specificity for examination of the posterior and inferior heart

territories because of their adjacency to the esophagus and stomach. The lack of intervening lung and bone, and the use of higher-frequency imaging transducers provide enhanced spatial resolution and improved detection of intracardiac thrombi and spontaneous left atrial echo contrast, a marker of blood stasis [1].

Clinical detection of ventricular thrombi is generally performed by TTE and evaluation of atrial thrombi is generally performed by TEE. Limitation of TEE is the difficulty to view some regions such as the left ventricular apex, distal ascending aorta, and proximal aortic arch. Image

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DOI: 10.1016/j.crvasa.2013.02.005

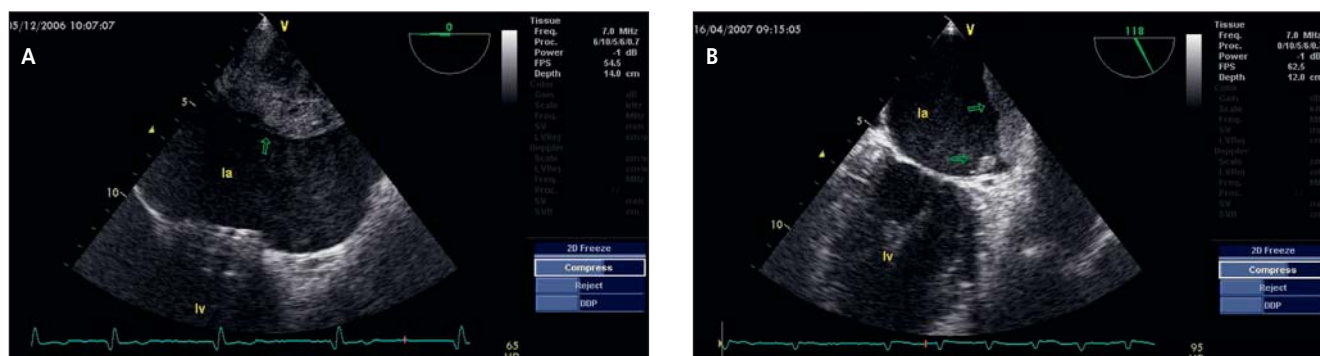


Fig. 1 – (A) and (B) Transesophageal echocardiography of two different patients with left atrial thrombus. Prosthetic mitral valve is also seen in this figure. Arrows indicate thrombi.

acquisition is limited in these areas, and other imaging modalities should be considered, e.g. helical computed tomography (CT) and cardiovascular magnetic resonance (CMR) imaging. In addition, TEE may lead to some complications which are essentially associated with esophageal intubation. These include trauma to the oropharynx, esophagus, and stomach giving rise to odynophagia, esophageal perforation, and upper gastrointestinal bleeding [2]. Therefore, the main contraindications of TEE are oropharyngeal pathology, esophageal stricture, varices, and recent upper gastrointestinal bleeding.

Left atrial thrombus

Predisposing factors for left atrial (LA) thrombus are mitral valve pathology, prosthetic mitral valve, poor left ventricular function, and abnormal LA contractile function, such as atrial fibrillation (AF). Enlarged and bifid left atrial appendage (LAA) is among the structural or anatomical risk factors. The left atrium can be visualized on two-dimensional TTE from all of the standard imaging windows. Image of the thrombi in the LA resembles intracavitary masses. The density of thrombus differs from the surrounding tissue. The thrombi usually have smooth contours and move synchronously with adjacent heart wall during the heart cycle. Scanning at least two or more different views is warranted for accurate diagnosis of thrombus. Sometimes, thrombi are visualized as an echolucent structure and are difficult to be described. In such cases, the diagnosis may be confirmed by the use of intravenous echo-contrast agent to improve the discrimination between blood and intracavitary masses [3]. Contrast echocardiography is a technique to improve endocardial border delineation and provides real time assessment of intracardiac blood flow. Unless thrombi are very large and spreading to the body of the left atrium, they are hardly identified by means of TTE because the left atrium lies in the far field of the interrogating ultrasound beam. Often they reside between the trabeculae of the LAA. The ability of TTE to identify or exclude LA or left atrial appendage thrombi is limited, with a reported sensitivity of 40–60%, due largely to poor visualization of the LAA [4]. In contrast, TEE provides detailed visualization of the body of LA and LAA from multiple imaging pla-

nes, so offers superior assessment. It is the current gold standard diagnostic method. In one intraoperative study, the sensitivity and specificity of TEE for left atrial thrombi detection (in patients among whom the left atrium was directly examined at surgery) are 93–100% and 99–100%, respectively [4]. Anecdotal reports suggest that three-dimensional (3D) TEE is also excellent, but no large comparative study has been reported. The ability to exclude LAA thrombi that are “suspected” by two-dimensional TEE is also another advantage of 3D TEE. The superiority of the 3D TEE for left atrial appendage analysis lies in the ability to differentiate the normal trabeculations of the “rough” area of the appendage from thrombi [5].

Left atrial thrombi are often multiple and vary in size and, although fasten on the atrial wall, they usually move independently to some extent (Figs. 1A and 1B). Small thrombi must be distinguished from the normal trabeculations of the LAA (pectinate muscles), and it may be difficult to distinguish larger thrombus from tumor. Myxoma is the most commonly encountered tumor in the left atrium. Myxomas are clinically important because one-half present with thromboembolism, which is thought to be the result of embolization of tumor material itself or of overlying

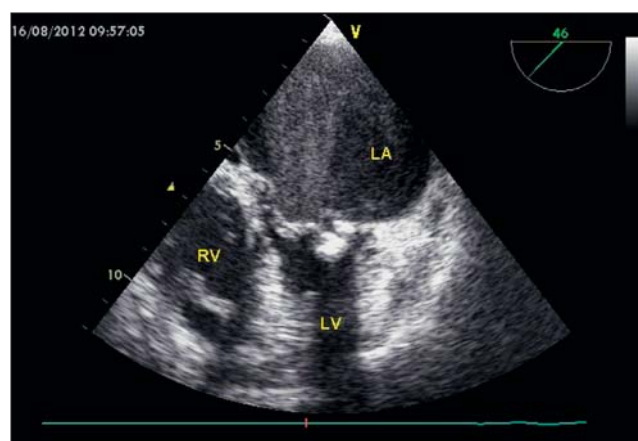


Fig. 2 – Mid-esophageal four-chamber view of the left atrium (LA), left ventricle (LV), right ventricle (RV), and calcified mitral valve. Swirling spontaneous echo contrast (or smoke) is detected by TEE in a patient with mitral stenosis.

thrombi. These benign tumors most commonly arise from the inferior limb of the fossa ovalis. The echocardiographic appearance of the left atrial tumor may resemble myxoma (especially if the tumor is encapsulated). Careful inspection of the tumor also demonstrates the stalk of attachment at its typical location along the interatrial septum. Both TTE and TEE are highly sensitive in detecting myxomas. Anatomical details provided by TEE, such as the site of attachment, may help to differentiate these tumors from the thrombi. Contrast echocardiography has been proposed to diagnose thrombi and distinguish the thrombi from tumors. Most of the malignant tumors have abnormal neovascularization, with high blood supplies, which explains why these tumors present an enhancement of mass by contrast agent. Myxomas have poor blood supplies, with partial enhancement by contrast agent. Conversely, thrombi are avascular, with no enhancement. Contrast echocardiography is more confidential than conventional echocardiography for the detection of thrombi [6].

The scene of spontaneous echo contrast (SEC) or "smoke-like" echo, which indicates the predisposing stasis, almost always accompanies thrombus and may be helpful in the differentiation of thrombi from tumor or normal anatomy. SEC is more likely to be detected by using a high-frequency ultrasonic transducer (> 5 MHz, as used in TEE) and high gain settings (Fig. 2). There is a very strong association between left atrial spontaneous echo contrast and left atrial thrombi. Spontaneous echo contrast is believed to be a reflection of erythrocyte aggregation in low shear rate conditions. SEC has also been associated with elevated plasma fibrinogen concentration, which reinforces red cell rouleaux formation by eliminating the normal electrostatic forces of red blood cells that result from their negative surface charge [7]. Although most widely studied in the left atrium and LAA, SEC may also occur in the right atrium. Spontaneous echo contrast is seen in patients especially among those with AF or left atrial enlargement. SEC may be seen in patients with sinus rhythm. Spontaneous echo contrast is encountered in almost 80% of the patients with AF and left atrial thrombi. Mitral regurgitation appears to lessen the frequency of spontaneous echo contrast.

The left atrial appendage is the most frequent site of thrombus formation in the LA (Figs. 3A and 3B). Thrombus has a tendency to be formed in the dysfunctional left atrial appendage perhaps because of its shape and the presence of trabeculations. LAA is sometimes seen in the parasternal short axis through the cardiac base and the apical two chamber view. However, LAA is best evaluated by TEE. The widespread use of this high resolution technique has suggested that clinically significant thrombi are commonly sequestered in this structure; these thrombi are rarely seen with transthoracic imaging. The LAA is evaluated at the mid-esophageal level. This technique involves rotation of the TEE transducer between 0° and 150° along the LAA axis [3].

The ability to estimate blood flow velocity in the left or right atrium and left and right atrial appendages offers a more quantifiable measure of stasis. LAA mechanical function can be evaluated with TEE utilizing pulsed wave Doppler measurement of LAA emptying and filling velocities. The velocity of blood flow at the orifice of the

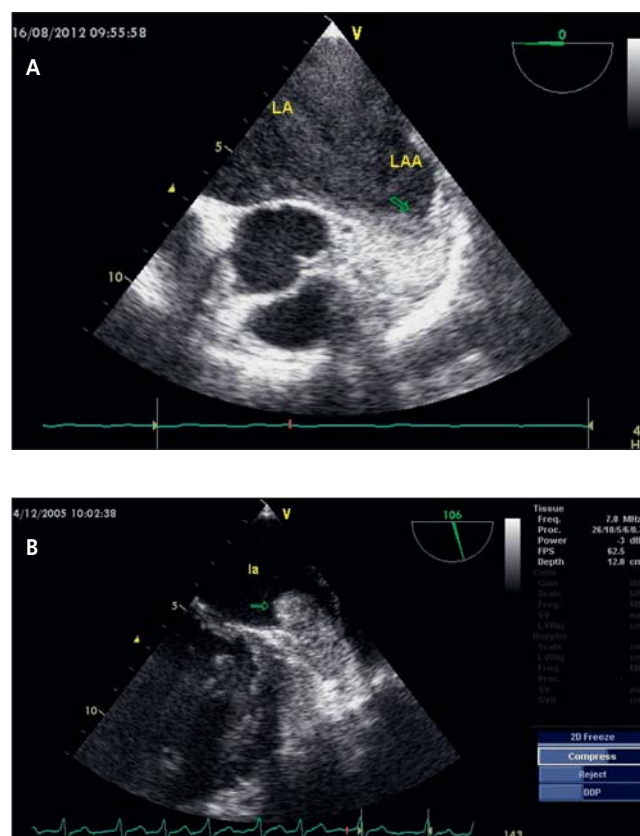


Fig. 3 – (A) and (B) Mid-esophageal views of the left atrium (LA) and left atrial appendage (LAA). Arrows indicate thrombus in the left atrial appendage (LAA). Spontaneous echo contrast (SEC) or "smoke-like" echoes are also depicted in (A).

LAA can be sampled by using pulse-wave Doppler, with a low Nyquist limit and low wall-filter settings. The pulsed wave Doppler sample volume should be placed 1 cm inside LAA at transducer angles between 45° and 120° . It reveals a characteristic pattern that is dependent upon the patient's underlying rhythm and atrial function. In patients with sinus rhythm, there are well-defined filling and emptying waves (peak emptying velocity > 55 cm/s), appropriately timed with atrial contraction. However, among patients with atrial fibrillation, some have well-defined wave forms while others have low velocity, poorly defined wave forms. A low appendage blood flow velocity is associated with the presence of appendage thrombus and denser SEC [8,9]. Thrombogenic risk rises with decreasing LAA velocity. The risk of stroke increases sharply with marked reductions in blood flow velocity (< 15 cm/s), particularly in the left atrial appendage or posterior left atrium [10]. Above a threshold LAA velocity greater than 55 cm/s, thrombus was ruled out because this velocity has a negative predictive value of 100% [3].

Left ventricular thrombus

Left ventricular thrombus is one of the most common complications of myocardial infarction. Such thrombus is clinically significant because it may lead to embolic com-

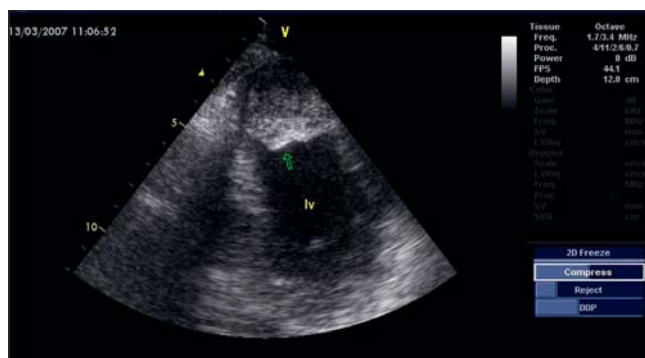


Fig. 4 – LV apical thrombus is depicted by apical 2 chamber view of transthoracic echocardiography.

plications, including stroke. LV thrombus is most often seen among patients with extensive anterior ST elevation myocardial infarction complicated with anteroapical aneurysm formation. Patients with poor LV function are more prone to stasis and thrombus formation. LV thrombus is seen more commonly in patients with dilated ventricles [3]. Conversely, inferior myocardial infarction, successful reperfusion, and preserved global LV systolic function are associated with a lower incidence of LV thrombus [11]. Echocardiographic indices that correlate with LV thrombosis are low ejection fraction (less than 40%), high LV wall motion score indices, and high E/Em ratio [3].

Diagnosis of ventricular thrombus includes some key features. Left ventricular thrombi are usually located in the apical region and lack any infiltration into the ventricular wall (in contrast with the left ventricular masses) (Fig. 4). Morphologically thrombi may be laminar or protruding, with a smooth or irregular shape. They are usually contiguous with the zones of noncontracting myocardium. The TTE appearance of LV thrombus is variable, and depends upon its age. Recent or actively forming thrombus may appear echo-lucent, and is highly mobile and disposed to protrude into the center of the ventricular cavity. Older thrombus generally has smooth cavitory surface and texture resembling the ultrasound appearance of hepatic tissue. Patients with subacute, protruding, echo-lucent, and mobile thrombi are at higher risk of embolic events, compared with those presented with sessile, laminated, and organized thrombi [12]. Thrombus usually has higher echogenicity than the adjacent myocardium and an increase in echogenicity is expected as organization of the thrombus occurs, although this can vary among patients. The sensitivity of TTE for the detection of LV thrombus may be suboptimal due to poor image quality and the difficulty in differentiation of thrombus from normal trabeculations. In patients with suboptimal acoustic windows or prominent LV apical muscle bands and trabeculations which confound the recognition of thrombus, many experts recommend the use of intravenous contrast agents to enhance the visibility of LV apex to improve the sensitivity and specificity of thrombus detection by TTE [13,14]. LV thrombus appears as a filling defect separated from the myocardium by contrast, while SEC or the muscular structures are hidden.

Imaging of the left ventricular apex is difficult by TEE. Because thrombus is often located in the LV apex, it should be suspected when an akinetic cardiac apex is thickened and rounded. A foreshortened image of the LV apex can be minimized by retroflexing the tip of the TEE probe. A deep transgastric view (0–20°) may provide better resolution because it is within the near field of the transducer. To distinguish thrombi from artifacts, it is necessary to acquire optimal images in at least two different views, throughout the cardiac cycle. Some laminated thrombi may be difficult to visualize clearly, and endocardial border delineation may be improved by a higher transducer frequency (> 5 MHz) and contrast echocardiography [3]. Thrombi are more common at the left ventricular apex, in aneurysms, pseudoaneurysms and deep recesses, or between the trabeculations in which intertrabecular flow can be demonstrated with color-flow Doppler and contrast-enhanced echocardiography. An extracardiac mass that compresses the cardiac structures needs to be differentiated from an intracardiac mass. Extracardiac masses which may occasionally be visualized by echocardiography include mediastinal tumors, large hematomas, lung tumors, coronary aneurysms or fistulas, and pseudoaneurysms.

Three-dimensional (3D) echocardiography has been demonstrated to be potentially superior to 2D technique in assessing intracardiac mass as it acquires a pyramidal volume of information that can be visualized from different angles, but 3D echocardiography is unavailable in most centers [15].

Thrombus in the right heart

Thrombus formation is less common in the right atrium compared with the left atrium. Right heart thrombi are most often originated by embolization from a peripheral venous source [16]. They may become entrapped in the tricuspid valve apparatus or right ventricular (RV) trabeculations. In situ thrombosis in the right heart is usually iatrogenic. Foreign bodies such as indwelling vascular catheters, pacemaker leads, and a prosthetic tricuspid valve are predisposing factors [17–19]. Conditions such as RV

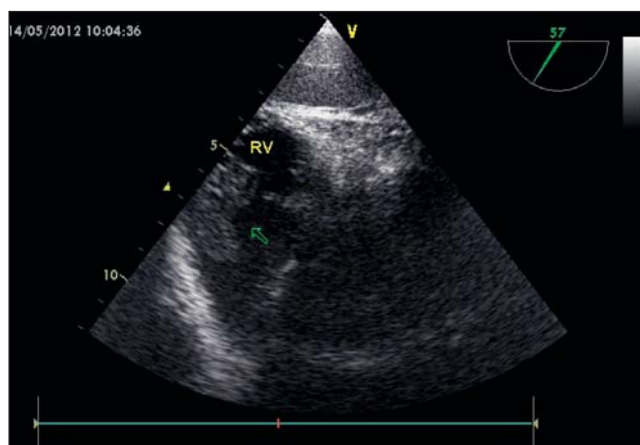


Fig. 5 – Deep transgastric view of the right ventricle (RV). The arrow indicates thrombus in the RV.

infarction or arrhythmogenic RV cardiomyopathy which cause RV dilatation and systolic dysfunction are the rare causes of thrombosis [3]. Particularly, in a patient with right heart thrombus Behçet's disease should be under consideration.

Thrombi also may be formed in the RA and the right atrial appendage among patients with atrial fibrillation or hypercoagulable states. In contrast to the LAA, the right atrial appendage is broad-based and less distinct in appearance. The pectinate muscles extend toward the tricuspid valve and are not confined to the appendage. The shallow anatomy of the right atrial appendage makes it a less likely site for thrombus formation. Thrombus occurs in 3–6% and 15–20% in right atrial appendage and left atrial appendage respectively among patients with AF [8]. The majority of patients with right atrial thrombi also have left atrial thrombi.

Thrombi in the right heart may become infected or cause pulmonary embolism. TTE and TEE may demonstrate RV dysfunction, tricuspid regurgitation, and leftward atrial septal bowing in patients with pulmonary thromboemboli. However, direct visualization of the thrombus located in the pulmonary arteries or entrapped in the right atrium can rarely be possible.

Comparing the sensitivity, specificity, and the accuracy of TTE and TEE for diagnosis of the thrombi located in right atrium or right atrial appendage is hard due to the scarcity of data. However, the right atrial appendage is rarely seen by TTE. In contrast right atrial or right atrial appendage thrombi are easily visualized by TEE. Images of the thrombi in the right atrium (RA) may be obtained from the mid-esophageal four-chamber or bicaval views between 0° and 90° on multiplane TEE. They should be differentiated from an eustachian valve or a Chiari network, which are the remnants of the right sinus venosus adjacent to the inferior vena cava. The former is mostly seen as a thin, mobile, and linear structure, whereas Chiari network is a large and fenestrated framework extending across the RA with additional attachments to its upper wall and the atrial septum [20]. Unlike thrombi, these structures do not cross the tricuspid valve during diastole. In the RV, thrombus may be seen in mid-esophageal four-chamber view and in transgastric RV inflow view between 80° and 110° [3] (Fig. 5).

Tumors of the right atrium are unusual, and tend to become large before the onset of symptoms. The most common primary benign cardiac neoplasm is myxoma [21]. Larger thrombus may be difficult to distinguish from the mass. A far more common cause of tumor within the right atrium is the extension of an intraabdominal tumor, especially hepatoma or renal cell carcinoma, which may directly invade the inferior vena cava and extend into the right heart. Right atrial tumors can be visualized with TTE from subcostal windows. However, TEE, especially with the longitudinal bicaval view, can better elucidate the tumor arising from the inferior vena cava to the right atrium [22,23].

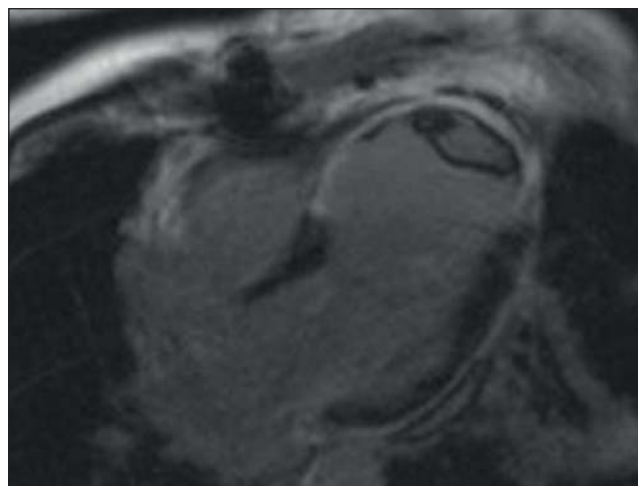


Fig. 6 – MR view of thrombus located in LV apical aneurysm. With permission of Tuncay Hazirolan from Hacettepe University Department of Radiology.

Magnetic resonance imaging

Although echocardiography and CT are often sufficient for the evaluation of cardiac and paracardiac masses, CMR imaging can provide useful information in many cases [24]. Obesity, limited inter-rib spaces, and pulmonary diseases restrict the ability of TTE to obtain satisfactory images of the heart chambers. Echocardiography is an excellent method for evaluation of left-sided structures but is less accurate for the right side of the heart, paracardiac region, lungs, and the mediastinum. CMR imaging demonstrates the localization of cardiac masses and also provides information on the extension of a tumor. Additionally, CMR imaging permits increased specificity for evaluation of the tissue characteristics such as hemorrhage, calcification and cystic necrosis which are commonly present in the stroma of these tumors and help to differentiate tumors from thrombi. Thrombus located in the LV apical aneurysm is demonstrated in Fig. 6. CMR imaging confirms the diagnosis through the addition of contrast material, which helps to distinguish the tumor from the myocardium, thrombus and blood flow artifacts [25]. Preoperative differentiation of intracardiac myxoma and thrombus may be difficult. Clinical symptoms, if present, may be similar, especially with respect to intracardiac obstruction and peripheral embolization. In addition, atrial thrombi frequently mimic echocardiographic characteristics of atrial myxoma and it is difficult to distinguish accurately. Hypointensity on T1-weighted images and hyperintensity on T2-weighted images relative to the myocardium, suggestive of tissue with high extracellular water content, are features commonly observed in myxoma [26]. In addition, myxomas typically have heterogeneous appearance in MRI, both before and after contrast administration, due to areas of necrosis or hemorrhage. Atrial thrombi typically have a brighter appearance than tumor or myocardium in inversion-recovery imaging with short inversion times and a darker appearance with long inversion times. Some thrombi show delayed contrast enhancement, which characterizes them as organized clots. However, care must be

taken to use thin sections for the detection of small thrombi, and the entire region of interest must be included in the imaging volume. Along with cine and T2-weighted images, the standard perfusion and myocardial delayed enhancement sequences may be very helpful for evaluation of the contrast enhancement characteristics of cardiac masses. Because they are avascular, thrombi do not show contrast uptake on perfusion sequences and usually appear as dark foci bordering the endocardium. The delayed enhancement sequence is the most sensitive sequence for depiction of the thrombus. Thrombus usually appears as a dark intracavitary or mural filling defect and is often attached to a center of hyperenhanced, infarcted myocardium [27]. Preliminary data suggest that myocardial delayed-enhancement magnetic resonance imaging is more accurate in detecting LV thrombus than TTE [28]. Although atrial thrombus can be detected by contrast and noncontrast CMR techniques, diagnostic accuracy is limited compared to TEE [29]. In a study of 24 patients, CMR imaging was more sensitive than TEE in detecting intracardiac thrombi [30]. Data suggest that for patients with ischemic heart disease, CMR is superior to both TEE and TTE for diagnosis of intraventricular thrombi. In the study by Srichai and colleagues, the sensitivity and specificity of CMR for the diagnosis of ventricular thrombus was compared with TTE and TEE in 361 patients with ischemic heart disease scheduled for ventricular reconstructive surgery. Of these, 160 patients underwent all three studies within 30 days of surgical/pathologic confirmation. The authors determined that CMR was significantly more sensitive and specific (88% and 99%, respectively) than TTE (23% and 96%, respectively) or TEE (40% and 96%, respectively) [31].

Cardiac computerized tomography

CT has emerged as a potential rival to CMR and echocardiography. Like CMR, CT has the capability to obtain high-resolution thin section images and can be gated to the cardiac cycle to allow cinematic displays of cardiac motion, although with a lower temporal resolution than CMR. It is more sensitive than CMR imaging for the detection of calcification, which represents an often referred advantage relative to CMR. Current multislice CT scanners allow multiplanar reconstructions using isotropic voxels, resulting in high-resolution imaging in virtually any plane. CT requires the use of ionizing radiation, and gated CT examinations may result in a radiation dose that exceeds that of cardiac catheterization. It usually requires the administration of iodinated contrast, with the attendant risks of nephrotoxicity and potential allergic reactions. Its utility in tissue characterization is inferior to MRI [27]. Contrast-enhanced CT is more sensitive for detecting ventricular and atrial thrombi than TTE, but the technique has been demonstrated to be inferior to TEE for displaying atrial thrombi [32].

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