Cardiac Masses and Potential Cardiac “Source of Embolus”

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#### SUGGESTED READING

A cardiac mass is defined as an abnormal structure within or immediately adjacent to the heart. There are three basic types of cardiac masses:

- **Tumor**
- **Thrombus**
- **Vegetation**

Abnormal mass lesions must be distinguished from the unusual appearance of a normal cardiac structure, which may be mistakenly considered as an apparent “mass.” Echocardiography allows dynamic evaluation of intracardiac masses with the advantage, compared with other tomographic techniques, that both the anatomic extent and the physiologic consequences of the mass can be evaluated. In addition, associated abnormalities (e.g., valvular regurgitation associated with a vegetation) and conditions that predispose to development of a mass (e.g., apical aneurysm leading to left ventricular (LV) thrombus or rheumatic mitral stenosis resulting in left atrial (LA) thrombus) can be assessed. Disadvantages of echocardiography include suboptimal image quality in some patients, a relatively narrow field of view compared with computed tomography (CT) or magnetic resonance imaging (MRI), and the possibility of mistaking an ultrasound artifact for an anatomic mass.

The first step in assessing a possible cardiac mass is to ensure that the echocardiographic findings represent an actual mass rather than an ultrasound artifact. As discussed in detail in Chapter 1, artifacts can be caused by electrical interference, characteristics of the ultrasound transducer/system, or various physical factors influencing image formation from the reflected ultrasound signals. These include beam width artifact, near field “ring down,” and multipath artifact. Appropriate transducer selection, scanning technique, and evaluation from multiple examining windows will help to distinguish artifacts from actual anatomic structures.

Besides ultrasound artifacts, several normal structures and normal variants may be mistaken for a cardiac mass (see the Echo Exam section at the end of this chapter). In the ventricles, normal trabeculae, aberrant trabeculae or chordae (ventricular “webs” or false tendons) (Fig. 15.1), muscle bundles (such as the moderator band), or the papillary muscles may be mistaken for abnormal structures.

Valve anatomy includes a wide range of normal variation, and the appearance of a normal (but often unrecognized) structure such as a nodule of Arantius on the aortic valve may be considered incorrectly to
represent a cardiac mass. The belly of a valve leaflet, if cut tangentially, may appear as a “mass” when it actually is a portion of the leaflet itself seen en face. In the atrium, normal ridges adjacent to the venous entry sites (Figs. 15.2 and 15.3), normal trabeculations (Fig. 15.4), postoperative changes (see Fig. 9.29 post transplant), and distortion of the free wall contour by structures adjacent to the atrium (Fig. 15.5) all may be diagnosed erroneously as a cardiac mass.

Definitive diagnosis of an intracardiac mass by echocardiography is based on:

- Excellent image quality, which may require use of a high frequency (5 or 7.5 MHz) short focus transducer to evaluate the LV apex from the transthoracic (TTE) approach, and the use of transesophageal (TEE) imaging to evaluate posterior cardiac structures (e.g., LA, mitral valve).
- Identification of the mass throughout the cardiac cycle, in the same anatomic region of the heart, from more than one acoustic window. This decreases the likelihood of an ultrasound artifact.
- Knowledge of the normal structures, normal variants, and postoperative changes that may simulate a cardiac mass.
- Integration of other echocardiographic findings (e.g., rheumatic mitral stenosis and LA enlargement in a patient with suspected LA thrombus) and clinical data in the final echocardiographic interpretation.

Once it is clear that a cardiac mass is present, the next step is to determine whether that mass most likely is a tumor, vegetation, or thrombus. A definitive diagnosis generally cannot be made from the echocardiographic images alone, because the microscopic and bacteriologic characteristics of the structure cannot be determined. However, a reasonably secure diagnosis often can be made by integrating the clinical data, echocardiographic appearance, and associated echo Doppler findings.

**INFECTIOUS CARDIAC MASSES**

Infectious cardiac masses include valvular vegetations, which are seen in patients with endocarditis (bacterial or fungal). Noninfectious vegetations also occur in patients with nonbacterial thrombotic endocarditis (or marantic endocarditis). Vegetations typically are irregularly shaped, attached to the upstream side of the valve leaflet (e.g., LA side of the mitral valve, LV side of the aortic valve), and exhibit chaotic motion that differs from that of the leaflets themselves (see Figs. 14.1 and 14.2). Valvular regurgitation is a frequent but not invariable
accompaniment of endocarditis. Valvular stenosis due to the vegetation is rare. Paravalvular abscess, which also presents as a cardiac mass, may be difficult to recognize on TTE imaging but can be diagnosed with a high sensitivity and specificity on TEE imaging. Infectious cardiac masses are discussed in detail in Chapter 14.

**CARDIAC TUMORS**

**Nonprimary**

Nonprimary cardiac tumors are approximately 20 times more common than primary cardiac tumors. Tumors can involve the heart by direct invasion from adjacent...
malignancies (lung, breast), by lymphatic spread, or by metastatic spread of distant disease (lymphoma, melanoma). In autopsy series of patients with a malignancy, cardiac involvement is present in approximately 10% of cases, although clinical recognition of cardiac involvement occurs less frequently. Melanoma has the highest rate of pericardial metastases, but since there are relatively few patients with melanoma, a cardiac tumor is more likely to represent a more prevalent malignancy, as shown in Table 15.1.

Almost three fourths of cardiac metastases are due to lung, breast, or hematologic malignancies. Lymphomas associated with acquired immunodeficiency syndrome have frequent and extensive cardiac involvement.

Nonprimary cardiac tumors can affect the heart by invasion of the pericardium, epicardium, myocardium, or endocardium; production of biologically active substances; or toxic effects of treatment on the heart (e.g., radiation therapy or chemotherapy).

Cardiac malignancies most often involve the pericardium and epicardium (approximately 75% of metastatic cardiac disease), presenting as a pericardial effusion, with or without tamponade physiology (Figs. 15.6 and 15.7). Because echocardiographic diagnosis of the cause of a pericardial effusion rarely is possible, the diagnosis of a pericardial effusion (and particularly tamponade) in a patient with a known malignancy should alert the clinician to the possibility of cardiac involvement. Confirmation of the diagnosis requires examination of pericardial fluid and, if necessary, pericardial biopsy. The differential diagnosis of a pericardial effusion in a patient with a known malignancy includes radiation pericarditis and idiopathic pericarditis (which is common in patients with cancer), as well as metastatic disease. Repeat echocardiographic evaluation of patients with a malignant pericardial effusion often is needed after the initial diagnosis for assessment of therapeutic interventions and follow up for recurrent effusion.

Myocardial involvement by metastatic disease is less common than pericardial involvement, but does occur, particularly with lymphoma or melanoma. Intramyocardial masses can project into or compress cardiac chambers, resulting in hemodynamic compromise. Endocardial involvement is rarely seen.

A specific type of cardiac involvement by tumor that should be recognized by the echocardiographer is extension of renal cell carcinoma up the inferior vena cava (Figs. 15.8 and 15.9). A “fingerlike” projection of tumor may protrude into the right atrium (RA) from the inferior vena cava, and the tumor can be followed retrograde (from a subcostal approach) back to the kidney. Correlation with other wide view imaging techniques is needed for full delineation of the tumor extent. Uterine tumors occasionally present in this fashion as well.

Cardiac masses and potential cardiac “source of embolus”

Table 15–1

| Origin of Metastatic Cardiac Tumors in Adults (in Order of Frequency) |
|--------------------|----------------|
| Lung               | Lung           |
| Lymphoma           | Lymphoma       |
| Breast             | Breast         |
| Leukemia           | Leukemia       |
| Stomach            | Stomach        |
| Melanoma           | Melanoma       |
| Liver              | Liver          |
| Colon              | Colon          |

one third of patients with carcinoid tumors have cardiac involvement, half the deaths in carcinoid patients are due to heart failure resulting from severe tricuspid regurgitation.

**Primary**

As for tumors elsewhere in the body, the distinction between benign and malignant primary cardiac tumors is based on pathologic examination of tissue and its tendency to invade adjacent tissue or metastasize to distant sites (Table 15.2). Although 75% of primary cardiac tumors are benign, a pathologically benign cardiac tumor can have “malignant” hemodynamic consequences if it obstructs the normal pattern of blood flow. Thus, the echocardiographic examination includes definition of both the anatomic extent of a cardiac tumor and its physiologic consequences.

**Benign Primary Cardiac Tumors**

Cardiac myxomas account for 27% of primary cardiac tumors. Cardiac myxomas most often are single, arising from the fossa ovalis of the interatrial septum and protruding into the LA (in approximately 75% of cases) (Fig. 15.11). Other sites of origin include the RA (18%), the LV (4%), and the right ventricle (RV; 4%). More than one site can occur in an individual patient (5% of cases).

The clinical presentation of a cardiac myxoma can include constitutional symptoms (fever, malaise), clinically evident embolic events, and symptoms of mitral valve obstruction. A myxoma also may be an unexpected finding on a study requested for other clinical indications.

A LA myxoma may nearly fill the LA chamber (Fig. 15.12), with prolapse of the tumor mass across the mitral annulus into the LV in diastole (accounting for the tumor “plop” on auscultation). The mass often has an irregular shape characterized by protruding “fronds” of tissue or a “grape cluster” appearance. The echogenicity of the mass may be nonhomogeneous, and sometimes areas of calcification are noted.

The degree to which the tumor causes functional obstruction to LV diastolic filling can be evaluated qualitatively by color flow imaging and quantitatively by the pressure half time method. Careful echocardiographic evaluation from multiple views, often including TEE, is needed in planning the surgical approach. Important goals of the echo examination are:

- to identify the site of tumor attachment;
- to ensure that the tumor does not involve the valve leaflets themselves;
- to exclude the possibility of multiple masses.

Postoperatively, complete excision should be documented by echocardiography. Sequential long term...
follow up is indicated because recurrent myxomas have been reported, particularly with a familial form of this disease, with multiple myxomas, or with a less than full thickness excision.

The echocardiographic approach to myxomas arising in other locations is similar to that described for LA myxomas, except that the imaging and Doppler examination are tailored toward evaluating the specific region of tumor involvement in that patient. Again, it should be emphasized that the diagnosis of a myxoma, based on the clinical features, anatomic location, and echocardiographic appearance of the tumor, is only presumptive until confirmed histologically. A “typical” myxoma may turn out to be a metastatic malignancy or a primary cardiac malignancy on pathologic examination. Hence the echocardiographic examination should be as complete as possible to exclude tissue invasion by the tumor, multiple sites of involvement, or atypical features.

Figure 15.8 Renal cell carcinoma extending up the inferior vena cava is seen on a subcostal view (above) and in an apical four chamber view (below) protruding into the RA and across the tricuspid valve into the RV. This tumor was resected en bloc at the time of surgery.

Figure 15.9 TEE imaging in a patient with renal cell carcinoma in a different patient showing the extension into the RA from the inferior vena cava without involvement of the atrial wall, septum, or valves.

Figure 15.10 Carcinoid heart disease with thickening and shortening of the tricuspid leaflets (arrows) seen in an apical four chamber view (left). Mild stenosis and severe regurgitation of the tricuspid valve were present as seen on color flow imaging (right).
A *papillary fibroelastoma* is a benign cardiac tumor that arises on valvular tissue, thus mimicking the appearance of a valvular vegetation. A papillary fibroelastoma appears as a small mass attached to the aortic or mitral valve with motion independent from the normal valve structures (Fig. 15.13). A papillary fibroelastoma also may be seen attached to the tricuspid or pulmonic valve or at nonvalvular sites. Unlike a vegetation, a fibroelastoma is more often found on the downstream side of the valve (LV side of mitral valve, aortic side of aortic valve). The histologic appearance is very similar to the smaller Lambl’s excrescences, which can be seen on normal valves in the elderly. Usually a small papillary fibroelastoma is of no clinical significance; the relationship of larger benign valve tumors to embolic events is controversial. In addition, some cases of superimposed thrombus formation resulting in systemic
Embolic events have been described. Often these tumors are better visualized on TEE imaging.

Other benign cardiac tumors seen in adults include hemangiomas, and mesotheliomas of the atroventricular node.

Lipomatous hypertrophy of the interatrial septum presents as a cardiac mass that may be mistaken for a tumor. Lipomatous hypertrophy typically involves the superior and inferior fatty portions of the atrial septum, sparing the fossa ovalis region (Fig. 15 14). However, symmetric ellipsoid enlargements of the interatrial septum also have been described. If the etiology of atrial septal hypertrophy is unclear on echocardiography, CT scanning may establish the diagnosis of lipomatous hypertrophy by showing the characteristic radiographic density of adipose tissue.

**Malignant Primary Cardiac Tumors**

Malignant primary cardiac tumors are rare. In adults, angiosarcomas, rhabdomyosarcomas (Fig. 15 15), mesotheliomas, and fibrosarcomas are seen (see Table 15 1). The clinical presentation is variable, ranging from an “incidental” finding on echocardiography or nonspecific systemic symptoms (fever, malaise, fatigue) to signs and symptoms of cardiac tamponade. Because metastatic disease is far more likely than a primary cardiac origin, thorough evaluation must include a search for potential primary sites. Ultimately, the diagnosis depends on examination of tissue from the cardiac mass.

The echocardiographic examination focuses on:

- The anatomic location and extent of the tumor involvement,
- The physiologic consequences of the tumor (e.g., valve regurgitation, chamber obliteration, obstruction), and
- Associated findings (pericardial effusion, evidence of tamponade physiology).

Along with other imaging techniques, the echocardiographic examination may help guide therapy by determining whether the tumor is resectable or whether palliative cardiac procedures are likely to be beneficial. Specific attention also is directed toward possible involvement of the valves, coronary arteries, or conducting system.

**Technical Considerations/Alternate Approaches**

Although echocardiography has definite advantages for evaluating cardiac tumors, it has significant disadvantages as well. These include (1) poor acoustic access, resulting in suboptimal image quality, which limits the confidence with which tumor location and extent can be defined or results in a missed diagnosis (TEE imaging may obviate this limitation in some patients); (2) the need for a careful and meticulous examination to detect and fully evaluate the cardiac tumor (as for other applications, echocardiography is operator dependent, and a significant learning curve for obtaining optimal data can be observed); and (3) the limited “field of view” inherent in echocardiography (i.e., structures adjacent to the heart in...
the mediastinum and lung are difficult to evaluate). Other tomographic imaging techniques, specifically CT and MRI, have the advantage of a wide field of view so that the relationship between cardiac and extracardiac tumor involvement can be evaluated. Often judicious use of both echocardiographic techniques (to assess cardiac involvement in detail and to evaluate the physiologic consequences of the tumor mass) and CT or MRI (to assess potential extracardiac involvement) may be needed in an individual patient for optimal clinical decision making. Both CT and MRI may provide data on the tissue characteristics of the abnormal mass, which currently cannot be obtained with echocardiography (Fig. 15-16).

**LEFT VENTRICULAR THROMBUS**

**Predisposing Conditions**

Thrombus formation in the LV tends to occur in regions of blood stasis or low velocity blood flow. The most familiar example of blood flow stasis in the LV is a ventricular aneurysm, in which low velocity swirling blood flow patterns are seen. Stasis also may occur with less severe segmental wall motion abnormalities (e.g., apical akinesia) and with diffuse LV dysfunction (e.g., dilated cardiomyopathy). LV thrombus formation is extremely rare in the absence of an akinetic or dyskinetic apex or diffuse LV dysfunction. Thrombus formation also often accompanies a LV pseudoaneurysm. In this case, the thrombus lines an area of LV rupture that has been contained by the pericardium (see Fig. 8-29).

Even when a definite LV thrombus is not seen on an echocardiographic examination, the likelihood of thrombus formation remains high in patients with LV aneurysm, apical akinesia, or diffuse LV systolic dysfunction with an ejection fraction less than 20%. Doppler analysis of apical flow patterns has been suggested to help identify which of these patients are at highest risk of thrombus formation. Evidence of
apical flow stasis or of continuous swirling of flow around the apex is thought to identify patients at particular risk for apical thrombus.

Identification of Left Ventricular Thrombi

The sensitivity of echocardiography for detecting LV thrombi is extremely operator dependent (Table 15–3). A careful and thorough examination requires not only standard views but also angulated apical views and the use of higher frequency short focus transducers to improve near field resolution. It is advantageous to use a 5 or 7.5 MHz transducer from the standard apical four chamber window and also to move the transducer slightly laterally while angulating it medially to obtain an apical short axis view. Scanning across the apex in several views usually allows distinction of apical thrombi from prominent apical trabeculations or false tendons, which are bright linear structures that attach to mural trabeculae. Thrombus is often (though not always) somewhat more echogenic than the underlying myocardium, and has a contour distinct from the endocardial border.

The diagnosis of LV thrombus is most secure when an echogenic mass is seen with a convex surface that is not a “ring down” artifact, is clearly distinct from the endocardium, and is located in a region of abnormal wall motion (Fig. 15.17). The diagnosis of laminated thrombus is more of a problem unless a clear demarcation between the thrombus and the underlying myocardium is seen, but it can be suspected when the apex appears “rounded” and akinetic with apparent excessively thick apical myocardium.

Clinical Implications

In some cases apical images are suboptimal despite careful examination technique. In this situation definite exclusion of apical thrombus may not be possible. Even so, clinical management (e.g., chronic anticoagulation) may depend more on assessment of overall LV function or the presence of an apical aneurysm than on the presence or absence of an echocardiographically documented thrombus.

The presence of a LV thrombus on echocardiographic examination is a strong predictor of subsequent embolic events, particularly when the thrombus protrudes into the ventricular cavity or shows independent mobility. Sessile, nonprotruding thrombi may have lower embolic potential.

Alternate Approaches

TTE is the clinical procedure of choice for identification of LV thrombi. TEE imaging rarely is helpful and is less sensitive, because the apex may not be depicted in standard image planes and the LV apex

<table>
<thead>
<tr>
<th>TABLE 15–3 Sensitivity and Specificity of Diagnostic Tests for Intracardiac Thrombus Formation</th>
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<tr>
<td>Test</td>
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<tr>
<td>LA Thrombus</td>
</tr>
<tr>
<td>TTE*</td>
</tr>
<tr>
<td>TEE†</td>
</tr>
<tr>
<td>CT with contrast‡</td>
</tr>
<tr>
<td>Contrast angio‡†</td>
</tr>
<tr>
<td>CMR‡**</td>
</tr>
<tr>
<td>LV Thrombus</td>
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<tr>
<td>TTE§</td>
</tr>
<tr>
<td>TEE*</td>
</tr>
<tr>
<td>LV angio‡†</td>
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<td>Contrast-enhanced CMR§</td>
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CMR, cardiac magnetic resonance imaging; CT, computed tomographic imaging; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.
is at a considerable distance from the transducer, thereby limiting resolution of structural detail. LV contrast angiography and radionuclide ventriculography both have a low sensitivity and specificity for diagnosing LV thrombus. In the research setting, indium 111 labeled platelets with gamma camera imaging have shown a high specificity, but this approach is not available for routine clinical use. Contrast enhanced cardiac magnetic resonance imaging has a very high sensitivity and specificity for detection of LV thrombus and may be appropriate in selected patients.

**Predisposing Factors**

LA thrombi tend to form when there is stasis of blood flow in the LA. In general, low velocity flow in the LA is associated with atrial enlargement, mitral valve disease, and atrial fibrillation.

The highest incidence of LA thrombus is in patients with rheumatic mitral stenosis and atrial fibrillation. However, in the presence of mitral stenosis or poor LV function, even patients in sinus rhythm and those with only modest LA enlargement can have LA thrombi. LA thrombi are less common in patients with mitral regurgitation, presumably because the high velocity regurgitant jet mechanically disrupts the area of blood stasis within the LA.

**Identification of Left Atrial Thrombi**

Visualization of LA thrombi using TTE imaging is limited by two factors:

1. The LA is in the far field of the image from both parasternal and apical windows, thus limiting resolution of LA structures and possible thrombi.
2. A large percentage of LA thrombi are found in the left atrial appendage, which is difficult to image from the TTE approach.

TEE imaging has a high sensitivity and a high negative predictive value for the diagnosis of left atrial thrombi. Hence, TEE evaluation is the appropriate procedure when the presence or absence of LA thrombus is important for patient management. From the TEE approach the LA lies close to the transducer, and the appendage can be visualized using 7.5 MHz transducer in at least two orthogonal views. Optimally, the LA appendage is evaluated by centering the appendage in the image plane at the 0° transducer position, using a small field of view and a high frequency transducer. Then the image plane is slowly rotated through 180°, keeping the atrial appendage centered in the image, to evaluate for possible thrombus. In addition, the body of the LA and atrial septal region are evaluated using rotational scanning from 0° to 180° from a high esophageal position (Fig. 15 18).

Stasis of blood flow may be seen on TEE imaging as “spontaneous” echo contrast, that is, echogenic reflections from the low velocity blood flow appearing as white swirls on the echocardiographic image (Fig. 15 19). While the appearance of “spontaneous” contrast depends on technical factors such as...
transducer frequency and instrument gain, as well as the pattern of blood flow, this finding is associated with an increased risk of LA thrombus formation and embolic complications.

Doppler recordings of the pattern of blood flow in the LA appendage may be helpful in identifying patients at highest risk of thrombus formation (Fig. 15 20). With a pulsed Doppler sample volume positioned approximately 1 cm from the entry of the appendage into the body of the LA, a normal contraction velocity is about 0.4 m/s; values less than this are associated with an increased risk of thrombus formation.

In some patients the LA appendage can be imaged using a transthoracic parasternal approach, starting in the short axis view at the aortic valve level and angulating the transducer inferiorly and laterally to demonstrate the triangular appendage just inferior to the pulmonary artery. From the apical two cham- ber view, the LA appendage may be visualized by slight superior angulation of the transducer. If a discrete echogenic mass is seen in the LA of a patient with mitral stenosis and atrial fibrillation, the specificity of this finding for LA thrombi is high (Fig. 15 21). However, the sensitivity of TTE for detection of LA thrombus is very poor. If no LA thrombus is seen in a patient in whom the diagnosis is suspected, a TTE study certainly does not exclude this possibility.

Prognosis/Clinical Implications

The importance of a LA thrombus depends on the clinical setting. In a patient with new atrial fibrillation and an embolic stroke, the most likely cause of the stroke is a LA thrombus whether or not one is actually imaged, and thus the demonstration of a LA thrombus would be unlikely to change clinical management. In contrast, in a patient with rheumatic mitral stenosis the presence of a LA thrombus is a contraindication to mitral balloon commissurotomy. TEE evaluation for LA thrombus is routine prior to elective cardioversion and before interventional and electrophysiology procedures in which catheters or devices will be in the LA, for example, mitral valvuloplasty or atrial fibrillation ablation.
Alternate Approaches

While few direct comparisons of echocardiography versus CT or MRI have been performed, these imaging modalities have been reported to have a high sensitivity for detection of LA thrombus. Intracardiac echocardiography also can be used to evaluate for LA thrombus at the time of an invasive procedure.

RIGHT HEART THROMBI

Formation of thrombi in the right side of the heart is rare, although it has been reported in cases of severe RV dilation and systolic dysfunction. A more likely source of thrombi seen within the right side of the heart is venous thrombi that have embolized and become entrapped in the tricuspid valve apparatus or RV trabeculations during passage from the peripheral veins toward the pulmonary artery (Fig. 15 22). Thrombi also can form on indwelling catheters or pacer wires. While thrombi in the right side of the heart can sometimes be demonstrated by meticulous TTE imaging (Fig. 15 23), TEE echo is better able to resolve the presence, extent, and attachment of right sided heart thrombi.

When mobile echogenic targets are seen within the right heart chambers, it is important to distinguish thrombi from eustachian valve remnants, microbubbles, or reverberation artifacts. Eustachian valve remnants, which are persistent portions of the embryologic valves of the sinus venosus, are typically mobile, thin linear structures attached at the junction of the inferior or superior cavae and the RA cavity. They may be extensive and can cross the atrium, attaching to the fossa ovalis, sometimes referred to as a Chiari network. They do not extend antegrade to cross the tricuspid valve in diastole, however. Microbubbles, which are encapsulated gas bubbles that can be seen in patients with indwelling venous access, appear as discrete echogenic targets that are usually located in different parts of the heart during successive cycles.

CARDIAC SOURCE OF EMBOLUS

Basic Principles

In a patient with a suspected cardiac origin of a systemic embolic event, echocardiographic evaluation is directed toward identification of:

- Abnormal intracardiac masses (e.g., LV thrombus, LA tumor, valvular vegetation),
- Abnormalities that may predispose the patient to development of intracardiac thrombi (e.g., LV aneurysm, mitral stenosis, atrial flow stasis),

![Figure 15 22](image1) RA thrombus (arrows) seen on a subcostal (left) and apical four chamber view (right). This may represent a thrombus in transit from a peripheral venous thrombosis.

![Figure 15 23](image2) Transthoracic view of the main pulmonary artery (MPA) with bifurcation into the right and left pulmonary artery (LPA) demonstrates an echodensity nearly filling the right PA (arrow) in this 63 year old woman with recurrent pulmonary emboli referred for surgical thrombectomy.
In patients with an abnormal intracardiac mass on echocardiography in the aftermath of a recent systemic embolic event, the likelihood is very high that a portion of the mass embolized, thereby causing the clinical event. Cardiac masses known to be associated with clinical systemic embolic events include cardiac abnormalities that may serve as a potential conduit for systemic embolism (patent foramen ovale [PFO], atrial septal defect), or aortic atheroma, with or without protruding thrombus. Note that echocardiographic evaluation after an index embolic event may fail to demonstrate a cardiac thrombus even if it was the etiology of the clinical event, because now the thrombus has embolized and is no longer in the heart. Recurrent intracardiac thrombus formation may not yet have occurred.

Identifiable Cardiac Sources of Emboli

In patients with an abnormal intracardiac mass on echocardiography, a definite cardiac source is documented by TTE in approximately 10% to 15% of sequential cases. To a definite cardiac source is documented by TTE in approximately 10% to 15% of sequential cases. To determine whether the echo findings are a marker of whether this association is a cause-effect relationship associated with systemic embolic events, although anatomic variants and disease processes that may be associated with systemic embolic events, particularly those with atrial dilation or ventricular dysfunction. Patients with a large atrial septal defect are at risk for “paradoxical” systemic embolization of peripheral venous thrombi. Thrombi can pass from the RA to the LA even when the shunt is predominantly left to right, due to streaming of flow or transient shifts in the RA to LA pressure gradient. Patients with Eisenmenger’s complex and a large ventricular septal defect are at risk of systemic embolization from peripheral venous thrombus formation. However, paradoxical embolization is unlikely in adults with a small ventricular septal defect, because the high LV, compared with RV pressure, limits flow from right to left.

Prosthetic valves are another potential source of embolic events; the incidence of clinical events is higher with mechanical compared with tissue valves. Demonstration of small thrombi on prosthetic valves is difficult even with TEE imaging, due to shadowing and reverberations from the prosthetic leaflets and sewing ring. Hence, the diagnosis often is presumptive when there is evidence of suboptimal anticoagulation at the time of the event or when other causes for the clinical event have been excluded, even if the level of anticoagulation appears to have been adequate. In these patients the primary goals of the echo cardiographic examination are to assess prosthetic valve function (because significant thrombus may result in stenosis and/or regurgitation) and to exclude other intracardiac sources of thrombus formation (e.g., associated LV systolic dysfunction).

TEE imaging provides imaging of atrial structures in more detail and has led to the recognition of other anatomic variants and disease processes that may be associated with systemic embolic events, although whether this association is a cause-effect relationship or whether the echo findings are a marker of increased risk is unclear:

- PFO
- Interatrial septal aneurysm
- Swirling pattern of blood flow in the LA in the absence of an exogenous “contrast” agent (thought to represent flow stasis and often called spontaneous contrast)
- Atherosclerosis in the aorta

A PFO is present in 25% to 35% of unselected patients at autopsy. During fetal development, incomplete closure of the interatrial septum shunts oxygenated placental blood from the RA to LA and then to the brain. This potential interatrial communication fuses within the first few days after birth in most individuals. If the flap valve covering the fossa ovalis remains unfused, there usually is no passage of blood across the interatrial septum. The “flap” is
functionally closed, because LA pressure normally exceeds RA pressure. However, if RA pressure transiently exceeds LA pressure (as during a cough or the Valsalva maneuver), or if RA pressure chronically exceeds LA pressure (e.g., after pulmonary embolization or with chronic lung disease), there can be right to left passage of blood (or thrombi) across the interatrial septum.

Echocardiographic demonstration of a PFO is possible with color flow Doppler imaging from a TEE approach in only about 5% to 10% of patients, with a lesser number detected by transthoracic color Doppler imaging. Detection of a patent foramen is enhanced by intravenous injection of echo contrast material (such as agitated saline solution), providing opacification of the right sided heart structures.

Passage of contrast across the interatrial septum is seen as bright echo contrast in the LA within one to three beats of its appearance in the RA (Fig. 15.24). It is important to use a view in which the contrast effect does not obscure identification of microbubbles in the left side of the heart. Often the site of origin of the contrast in the LA can be identified on frame by frame analysis. Using echo contrast, a patent foramen is detectable at rest in approximately 5% of the general population. When maneuvers to transiently increase RA pressure are performed simultaneously with contrast injection, the prevalence of detectable PFO by contrast TEE increases to approximately 25% similar to the incidence at autopsy (Fig. 15.25).

Passage of very small microbubbles through the pulmonary capillaries can occur with a peripheral
injection of agitated saline; microbubbles from transpulmonary passage typically appear in the LA via the pulmonary veins late after the appearance of contrast material in the RA. With an atrial septal defect or PFO, contrast material appears in the LA within three beats of its appearance in the right heart. With transpulmonary passage, contrast material is seen in the left heart after more than three beats.

In young patients (<45 years) with transient ischemic attacks or cerebrovascular events of unknown cause (called cryptogenic stroke), a higher incidence of PFO is found than in the general population, suggesting that passage of thrombi across the atrial septum may be a significant cause of systemic embolic events in these patients. Often a peripheral venous source of thrombi is identified in these patients. Percutaneous device closure of a PFO is increasingly performed in patients with a systemic embolic event, although results of randomized trials have not yet been reported. Intracardiac or TEE imaging is used to monitor percutaneous device closure of a PFO or atrial septal defect (Fig. 15 26).

An interatrial septal aneurysm is defined as a transient bulging of the fossa ovalis region of the interatrial septum (total excursion from the septal plane) greater than 15 mm in the absence of chronically elevated LA or RA pressure (Fig. 15 27). Septal aneurysms are associated with a high likelihood (up to 90%) of associated fenestration. Until recently the diagnosis rarely was made from TTE imaging due to suboptimal image quality, and this finding was thought to be of little clinical significance. The excellent views of the interatrial septum on TEE have resulted in an increasing recognition of this anatomic variant. Several investigators have suggested a possible relationship between the presence of an atrial septal aneurysm and an increased risk of systemic embolic events.

“Spontaneous” contrast is seen in the LA when there is stasis of blood flow. It is seen more often on TEE than TTE imaging due to the higher transducer frequency and the closer proximity of the LA when interrogated from the esophagus but can be seen on TTE imaging in some patients. Spontaneous contrast is associated with LA enlargement and LA thrombus.

Figure 15 26 TEE imaging during placement of a percutaneous atrial septal defect closure device shows: (1) the secundum atrial septal defect (left), (2) the device across the defect with the LA side being pulled into position (arrow) and the RA side being deployed (middle), and (3) closure of the defect with full deployment of both the LA and RA sides of the device (right).

Figure 15 27 Incidental finding of an atrial septal aneurysm (arrow) in an elderly patient seen in a transthoracic apical four chamber view (left). Peripheral venous injection of agitated saline to provide a contrast effect (right) shows opacification of the right heart with a few microbubbles seen in the left heart, consistent with an associated patent foramen ovale or fenestration in the atrial septal aneurysm.
formation, and it may be a marker for a “prethrombotic” state when definite atrial thrombi are not seen. In extreme cases of spontaneous contrast in mitral stenosis patients, the jet of diastolic blood flow across the stenotic mitral orifice can be seen on two dimensional imaging due to the contrast effect.

Spontaneous contrast can be seen in the LV when there is stasis of blood flow, such as in the region of an apical aneurysm. Spontaneous contrast also is observed frequently in patients with mechanical prothetic valves. Here the mechanism of spontaneous contrast formation may be different, relating to the mechanical impact of the valve occluder during closure resulting in microcavitation or liberation of gas from solution. Of course, patients with mitral prothetic valves also may also have stasis of blood flow in the LA if long standing disease has resulted in LA enlargement and atrial fibrillation.

The presence of atheroma in the descending thoracic aorta is associated with an increased risk of stroke and transient ischemic attack. These are recognized as a focal area of increased thickness in the aortic endolum with an irregular border and nonuniform echogenicity. An atheroma is considered “complex” if thickness is greater than 4 mm, there is evidence of ulceration, or areas of independent mobility are present. (See Suggested Readings and Chapter 16).

Indications for Echocardiography in Patients with Systemic Embolic Events

Current understanding of potential cardiac etiologies for systemic embolism is incomplete, and there is considerable controversy as to the indications for TTE and TEE imaging in patients with suspected systemic embolic events. In patients with embolic events the prevalence of PFO is about 30%, as compared with a prevalence of 10% in control subjects. Aortic atheromas (see Chapter 16) are seen in 20% of patients with embolic events, as compared with 4% of control subjects. Other echocardiographic findings in patients with embolic events include LA thrombus in approximately 9%, spontaneous contrast in approximately 17%, and atrial septal aneurysm in 13%. The prevalence of these findings is highest in patients with cryptogenic stroke (e.g., no obvious primary cerebrovascular disease or other etiology). The potential cause and effect relationship between some of these echocardiographic findings and clinical embolic events remains controversial as discussed in the Suggested Reading section.

Current ACC/AHA guidelines recommend echocardiography in patients with neurologic or other vascular occlusive events:

- when there is abrupt occlusion of a major peripheral or visceral artery in patients of any age,
- in younger patients (<45 years) with a cerebrovascular embolic event,
- in older patients with a neurologic event without other evidence of cerebrovascular disease, and
- in patients in whom the clinical therapeutic decision would be altered based on the echocardiographic results.

The use of echocardiography in older patients with cerebrovascular disease of questionable significance or with other evident causes for the cerebrovascular event remains controversial. If TTE studies are unrevealing, TEE imaging should be performed, given its higher sensitivity for diagnosis of a PFO, LA thrombus, interatrial septal aneurysm, valvular vegetation, and small intracardiac tumors.

SUGGESTED READING

**General**


**References**


**Useful pathology atlas with comprehensive coverage of cardiovascular disease, including cardiac tumors.**


**Lipomatous hypertrophy of the interatrial septum is typically considered a benign incidental finding. However, this study suggests that atrial septal thickening is associated with increased severity of coronary artery disease, even after correction for the effects of age, gender, and body mass index.**


In 75 consecutive patients undergoing surgery for cardiac mass removal, masses were most often seen in the LA (46%), followed by the RA (inferior vena cava/superior vena cava (27%), LV (8%), and RV (7%), plus 12% that were attached to a valve. The most common causes of masses requiring excision were myxomas (41%), thrombi (16%), fibroelastoma (13%), and hyperplasmoma (9%). The baseline or post procedure intraoperative TEE altered management in 16% of cases.
Cardiac Tumors


In adults, benign tumors of the heart in order of prevalence are myxoma (45%), lipoma (20%), and papillary fibroelastoma (13%), with fewer cases of angiofibroma, hemangiomia, thalassomyoma, or teratoma. However, in children the most common benign cardiac tumor is thalassomyoma (45%), followed by myxoma, fibroma, and teratoma (15% each).


In this series, the average diameter of a cardiac papillary fibroelastoma was 9 ± 4.6 mm; 83% occurred on valves and 44% were mobile.


A comprehensive literature review was used to gather data on clinical and echocardiographic features of papillary fibroelastoma. The attachment site was described in 611 cases: 36% aortic valve, 29% mitral valve, 11% tricuspid valve, and 7% pulmonic valve. The most common attachment site was described in 611 cases: 36% aortic valve, 29% mitral valve, 11% tricuspid valve, and 7% pulmonic valve. The most common attachment site was described in 16% of these patients with a thrombus (specificity 93%) and was negative in 48 of 56 without a thrombus (specificity 86%). A definitely positive echo study had a positive predictive value of only 29%.


In 78 patients with surgical, autopsy, or indium 111 platelet imaging evidence of LV thrombus, the two dimensional TTE result was positive or equivocal in 21 of the 22 patients with a thrombus (sensitivity 93%) and was negative in 48 of 56 without a thrombus (specificity 86%). A definitely positive echo study had a positive predictive value of only 29%.


Autopsy study (n = 3314) with malignant disease in 24% (n = 806) and cardiac involvement in 12% of these cases (n = 95). Analysis of frequency of primary tumors. Used as the source of data for Table 15–2.


A large autopsy series of patients with a malignancy (n = 1929) with a rate of cardiac involvement of 8.4%. In men, the highest frequency of cardiac involvement was seen with mesothelions, melanoma, and lung cancer. In women, melanoma, lung, and renal neoplasms had the highest rates of cardiac involvement.

Left Ventricular Thrombi


In 78 patients with surgical, autopsy, or indium 111 platelet imaging evidence of LV thrombus, the two dimensional TTE result was positive or equivocal in 21 of the 22 patients with a thrombus (sensitivity 93%) and was negative in 48 of 56 without a thrombus (specificity 86%). A definitely positive echo study had a positive predictive value of only 29%.


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Left Atrial Thrombi


In 231 consecutive patients undergoing intraoperative TEE before elective mitral valve surgery or excision of a LA tumor, the sensitivity (100%) and specificity (99%) of TEE detection of LA thrombus was determined compared to direct visualization by the surgeon.


In 213 consecutive patients with rheumatic heart disease undergoing surgery, atrial thrombi were present in 30 of 147 (20%) with predominant mitral stenosis, with 28 of these 30 patients in atrial fibrillation. The specificity of TEE detection of LA thrombus was 100%, with a sensitivity of 93% (two atrial thrombi were missed by imaging). Positive predictive value was 100%, negative predictive value was 99%, and diagnostic accuracy was 99%.

Management of Atrial Fibrillation


Review of the literature on LA thrombus formation and the risk of embolic events with cardioversion. Summarizes the clinical approach to the use of echocardiography in management of patients with atrial fibrillation of prolonged or unknown duration. 139 references.

fibrillation without prolonged anticoagulation with the use of transesophageal echocardiography to exclude the presence of atrial thrombi.

N Engl J Med 329:739–755, 1993. TEE imaging was performed in 119 patients with atrial fibrillation longer than 2 days in duration, echo was not receiving long term anticoagulant therapy and had no contraindications to the TEE procedure. LA thrombi were identified in 12 (13%) patients. In the 78 patients without detectable atrial thrombus and successful conversion to sinus rhythm, none had an embolic event. Most of these patients received short term heparin therapy before cardioversion and warfarin for 1 month after cardioversion.


18. Hart RG, Halperin JL, Pearce LA, et al., for the Stroke Prevention in Atrial Fibrillation Investigators: Lessons from the Stroke Prevention in Atrial Fibrillation Trials. Ann Intern Med 138:831–838, 2003. Summary of the three Stroke Prevention in Atrial Fibrillation trials with treatment recommendations. The risk of stroke with aspirin therapy depends on clinical risk factors: about 7% per year in high risk patients (previous embolic event, systolic blood pressure >160 mm Hg, heart failure, and women >75 years), 2% to 4% per year in moderate risk patients (hypertension but no high risk features), and in less than 2% per year low risk patients (no hypertension or high risk features).

19. Klein AL, Gruiman RA, Jasper SE, et al; ACUTE Steering and Publications Committee for the ACUTE Investigators. Efficacy of transesophageal echocardiography-guided cardioversion of patients with atrial fibrillation at 6 months: a randomized controlled trial. Am Heart J 151:380–389, 2006. TEE guided cardioversion was compared to a conventional cardioversion strategy in a multicenter randomized trial of 1222 patients with atrial fibrillation longer than 2 days in duration. With the TEE guided approach anticoagulation was started at the time of cardioversion and continued for 4 weeks after cardioversion. With the conventional strategy, patients received 3 weeks of therapeutic anticoagulation before and after cardioversion (with no TEE). At 6 months, follow up there was no difference between groups in overall mortality (5% to 4%) or embolic events (1% to 2%). However, in the TEE guided group there was a lower risk of hemorrhagic complications (4.4% vs. 7.5%) and a higher prevalence of sinus rhythm at 6 months (63% vs. 54%, p = 0.05).

Cardiac Source of Embolus

20. de Bruijn SF, Agerma WR, Lammers GJ, et al: Transesophageal echocardiography is superior to transthoracic echocardiography in management of patients of any age with transient ischemic attack or stroke. Stroke 37:2531–2534, 2006. In 251 consecutive patients with recent cryptogenic stroke or transient ischemic attack, a potential cardiac source of embolus was identified in 55%; 90 of these 127 findings (71%) were seen on TEE but not TTE. The most common major risk factors for embolic events was atrial appendage thrombus in 38/251 (16%), with other major risk factors including dilated cardiomyopathy in 5 patients (2%) and LV thrombus in 2 patients(1%). Major risk factors for embolic events were aortic atherosclerosis in 69 (30%), PFO in 15 (6%), spontaneous echo contrast in 7 (3%), and atrial septal aneurysm in 13 (5%). Cardiac sources were detected in both younger and older patients at equal rates.

21. Faktin D, Kelly RP, Fenelley MP. Relations between left atrial appendage blood flow velocity, spontaneous echocardiography contrast and thromboembolic risk in vivo. J Am Coll Cardiol 23:961–969, 1994. In 140 patients with atrial fibrillation, LA spontaneous contrast was present in 78 (56%) patients and LA thrombus was present in 15 (11%) patients. On multivariate analysis, spontaneous echo contrast was the only significant predictor for the presence of thrombus. LA appendage velocity was negatively associated with the degree of spontaneous contrast, and an appendage velocity less than 35 mm/s was associated with a 30 times higher risk of spontaneous contrast.

22. Honuma S, Sacco RL, Di Tullio MR, et al, for the PFO in Cryptogenic Stroke Study (PICSS) Investigators: Effect of medical treatment in stroke patients with patent foramen ovale: Patent foramen ovale in cryptogenic stroke study. Circulation 103:2625–2631, 2002. In a multicenter randomized trial, 630 stroke patients were randomized to treatment with aspirin or warfarin after evaluation by TEE. A PFO was present in 34%, but there was no difference in clinical events comparing those with and without a PFO, in those with large versus small PFOs, or PFOs associated with an atrial septal aneurysm. In patients with PFO there was no difference in clinical outcomes in those treated with aspirin versus warfarin.

23. Natanzen ME, Goldman ME. Patent foramen ovale: Anatomy versus pathophysiology which determines stroke risk? J Am Soc Echocardiogr 16:71–76, 2003. In a retrospective study of 78 patients with a PFO detected on TEE, patients with a clinical embolic event (compared with those without) had greater contrast shunting from right to left and had less overlap between the septum primum and septum secundum (7.5 ± 3.6 mm vs. 9.9 ± 6.0 mm, p = 0.26). There was no difference in the size of the separation between the septum primum and secundum or in the presence of atrial septal aneurysm. Evidence for elevation of LA pressure was more common in those without an embolic event, raising the possibility that hemodynamics, not anatomy, determines stroke risk in patients with a PFO.

24. Slottow TL, Steinberg DH, Waksman R: Overview of the 2007 Food and Drug Administration Circulatory System Devices Panel meeting on patent foramen ovale closure devices. Circulation 116:677–682, 2007. Prospective randomized trials of PFO closure to prevent recurrent cryptogenic stroke are in progress, but enrollment has been slow, no study have been completed and no device is approved for this indication. The U.S. Food and Drug Administration convened a panel to discuss the obstacles to completion of a
randomized trial. This article also provides a concise summary of the literature and a comprehensive list of references. The final recommendation of the panel was to support the AHS/ASA guideline that all eligible patients be encouraged to enroll in a randomized trial.


In the Northern Manhattan Study (NOMAS), PFO was present on TTE saline contrast echocardiography in 164/1100 (14.9%) adults over age 39 years, and an atrial septal aneurysm was present in 27 (2.5%) subjects (19 in association with PFO). The presence of PFO was not associated with an increased risk of ischemic stroke, which occurred in 68 subjects (6.2%) at a mean follow up of 79.7±28.0 months.


In 503 consecutive patients with stroke, the prevalence of PFO was higher in the 227 with cryptogenic stroke as compared with the 276 with stroke of known cause, both in the patient group younger and older than 55 years of age. On multivariate analysis the presence of a PFO was independently associated with stroke risk with an odds ratio of 3.7 (95% confidence interval [CI] 1.42–9.65) in younger and 3.00 (95% CI 1.73–5.23) in older adults.


Valve excrescences (thin, elongated, mobile structures attached near the leaflet closure line) are seen in approximately 40% of normal individuals on TEE and do not appear to be associated with an increased risk of thromboembolism.


The only TEE finding predictive of long term mortality (19% after about 3 years) after an ischemic stroke in 245 consecutive patients was the severity of aortic atherosclerosis. Other TEE findings were common, with a PFO in 19%, thrombus in 2.4%, spontaneous echo contrast in 3.7%, atrial septal aneurysm in 3.3%, valve masses in 7.8%, but none of these predicted long term outcome. Complex aortic atheroma, present in 14.7%, was associated with a hazard ratio of 2.7 (95% CI 1.4–5.3) for long term mortality. The definition of complex aortic atheroma was protrusion ≥4 mm into the aortic lumen, or plaque with evidence of ulceration or mobility.


This review article summarizes the literature on the association between aortic atheroma and stroke. Aortic atheroma also is associated with atherosclerosis in other vascular beds (carotid, coronary, renal, abdominal aorta), aortic stenosis, mitral annular calcification, and atrial fibrillation. The role of imaging with different modalities is summarized including TTE and TEE, epiaortic scanning, MRI, and CT.
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