Comparison of Two-Dimensional Echocardiography and Ultrafast Cardiac Computed Tomography for Evaluating Intracardiac Thrombi in Cerebral Ischemia

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Two-dimensional echocardiography has a high specificity for the detection of intracardiac thrombi, but technically difficult studies are often encountered. Ultrafast cardiac computed tomography may be useful in such cases. Using transthoracic two-dimensional echocardiography and ultrafast cardiac computed tomography, we studied 36 patients with cerebral ischemia; one patient had the studies performed on two occasions, making a total of 37 sets of studies. Technical difficulties occurred in 12 echocardiographic (32%) and two ultrafast cardiac computed tomographic (5%) studies. The two techniques agreed in 29 sets of studies (78%). Among the eight discrepant sets of studies, two-dimensional echocardiography was positive for a left ventricular thrombus while ultrafast cardiac computed tomography was negative in three and equivocal in one and echocardiography was equivocal while ultrafast cardiac computed tomography was negative in two and positive in one. In the latter case, a left ventricular thrombus was confirmed at autopsy. In the other discrepant set of studies echocardiography was negative while ultrafast cardiac computed tomography revealed a left atrial and appendage thrombus. Because of its ease of performance and safety, two-dimensional echocardiography is the appropriate initial screening test for left ventricular thrombus. Ultrafast cardiac computed tomography can provide additional information in patients with technically difficult or equivocal two-dimensional echocardiographic studies or patients with cardiac disorders predisposing to atrial thrombi formation. (Stroke 1990;21:1033-1038)

Cerebral embolism of cardiac origin accounts for approximately 15–20% of all cerebral infarctions. Left ventricular or atrial thrombi are treatable causes of cerebral embolization and, therefore, their identification is important. Two-dimensional echocardiography (2DE) has been available since the mid-1970s to evaluate cardiac abnormalities, including intracardiac thrombi. However, the usefulness of 2DE is limited by technically difficult studies and by equivocal or false-positive results. In addition, transthoracic 2DE provides limited visualization of thrombi in the left atrium and left atrial appendage. Initial studies of contrast-enhanced computed tomography (CT) of the heart have suggested a role for this technique when 2DE is technically limited or the results are equivocal. However, several limitations of conventional CT have been identified. Ultrafast (cine) cardiac computed tomography (UFCCT) is a more recently developed technique that uses a focused electron beam to rapidly acquire multilevel cardiac tomograms. Rapid acquisition minimizes image obscuration due to motion of the surrounding tissues. Definition of structures, including intracardiac masses, is enhanced due to characterization of different tissue densities. Since therapy in patients with presumed cardioembolic cerebral ischemia is often guided by determining if a thrombus is present, it is important to have a reliable cardiac imaging technique to identify such abnormalities. We compared 2DE and UFCCT in patients with suspected cardioembolic cerebral ischemia to determine if there was good
correlation between these two tests and to identify circumstances in which one technique was superior to the other for the detection of intracardiac thrombi.

Subjects and Methods

Patients suspected of having cardioembolic cerebral ischemia were evaluated between December 1986 and April 1989 in the Division of Cerebrovascular Diseases. Characteristics that led us to suspect a cardiac source of emboli were the sudden onset of a focal neurologic deficit, abnormal results of a cardiac examination, known cardiac disease, previous cardioembolic cerebral infarction, or no other identifiable cause of focal cerebral ischemia in a young adult (aged 15–45 years).

The patients underwent transthoracic 2DE using the Advanced Technology Laboratories Ultramark 8 (Bothell, Wash.) with a 2.5- or 3.5-MHz transducer. Standard two-dimensional views were obtained from the parasternal, apical, and subcostal positions. The 2DE studies were blindly read by a panel of trained echocardiogram interpreters. Criteria for the diagnosis of intracardiac thrombi were a mass protruding into the atrial or ventricular cavity, distinct from the underlying myocardium, and visible on at least two different views.

An UFCCT scan of the heart was performed using the Imatron C-100 scanner (San Francisco, Calif.) following the injection of 30–60 ml Iohexol contrast medium (Sterling Drug Incorporated, Barceloneta, Puerto Rico) into an antecubital vein. Multi-level short- and long-axis views were obtained using 8-mm sequential cuts. The UFCCT studies were blindly interpreted by a qualified radiologist. Left ventricular thrombus or left atrial thrombus was diagnosed by the identification of a filling defect within the contrast-filled cavity attached to the chamber wall and visualized on one or two levels in one or more projections.

The number of days between the 2DE and UFCCT studies and the interval from the onset of cerebral ischemia to diagnostic evaluation were noted. The official reports of the results of 2DE and UFCCT were reviewed.

Results

Our initial population of patients with suspected cardioembolic stroke included 54 patients that underwent both 2DE and UFCCT. However, patients that did not have the studies within 1 week of each other were excluded from the analysis. This left 36 patients (20 men and 16 women, mean age 60 years) who underwent 37 2DE and UFCCT studies within 1 week of each other; one patient had the studies done twice.

Thirty patients had cerebral infarction and the other six had transient ischemic attacks. The interval from the onset of cerebral ischemia to diagnostic evaluation with 2DE and UFCCT ranged from 0 to 13 days in 33 patients; four sets of studies were obtained 1–5 months after the event. The number of days between the 2DE and UFCCT studies ranged from 0 to 7 (mean 3.5) days. No patient suffered additional episodes of cerebral ischemia between the studies.

Twelve (32%) 2DE studies and two (5%) UFCCT studies were technically difficult. An equivocal interpretation, defined as a report that could not definitely identify or exclude an intracardiac thrombus, was noted in three 2DE studies and one UFCCT study. The degree of corroboration between the techniques is illustrated in Figure 1. The two techniques agreed in 29 sets of studies (78%); both studies were negative in 25 patients, while intracardiac thrombi were diagnosed in four patients. Eight patients had discrepant results (Table 1). The equivocally positive 2DE study that was not technically difficult visualized a possible 1.5×1.5 cm aortic valve calcification or vegetation, while UFCCT did not visualize any lesion. One 2DE study was equivocally positive for a left atrial thrombus while UFCCT was negative. Two of the 2DE studies equivocally positive for intracardiac masses were also technically difficult (Table 1). Among the eight discrepant sets of studies, no UFCCT study was technically difficult. The equivocally negative UFCCT study corresponded with a 2DE study that was positive for a left ventricular thrombus. Three patients with left ventricular thrombi by 2DE had no evidence of thrombi by UFCCT. One patient with a negative 2DE study had a large left atrial and appendage thrombus by UFCCT (Figure 2).

Pathologic data were available in two patients. One patient with an equivocal 2DE study that could not exclude a left ventricular thrombus due to technical difficulty with a poor acoustic window had a UFCCT study positive for left ventricular thrombus (Figure 3); left ventricular thrombus was proven by autopsy, which revealed a 6×3×2.1 cm white mural thrombus filling the left ventricular apex (Figure 4). Pathologic data confirmed the absence of intracardiac thrombi in another patient with negative 2DE and UFCCT studies.

Table 1. Comparison of transthoracic two-dimensional echocardiography (2DE) and ultrafast cardiac computed tomography (UFCT) results

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<th>2DE: Neg</th>
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Figure 1. Bar graph comparing results of transthoracic two-dimensional echocardiography (2DE) and ultrafast cardiac computed tomography (UFCT) in 37 studies. Neg: negative; pos: positive; equiv: equivocal.
### TABLE 1. Patients With Discrepant Results of 2DE and UFCCT

<table>
<thead>
<tr>
<th>Age/sex</th>
<th>Clinical data</th>
<th>2DE Findings</th>
<th>UFCCT Findings</th>
<th>Days between studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>81/M</td>
<td>CAD, L MCA infarct</td>
<td>Equivocally positive; could not exclude LV thrombus*</td>
<td>LV thrombus*</td>
<td>No 6</td>
</tr>
<tr>
<td>40/F</td>
<td>MI, prior L MCA infarct with new L MCA infarct</td>
<td>LV thrombus</td>
<td>LV hypokinesis</td>
<td>No 0</td>
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<tr>
<td>74/M</td>
<td>A Fib, cardiomyopathy, L MCA infarct</td>
<td>LV thrombus</td>
<td>Negative</td>
<td>No 3</td>
</tr>
<tr>
<td>26/M</td>
<td>R MCA infarct</td>
<td>Equivocally positive for LA thrombus</td>
<td>Negative</td>
<td>No 6</td>
</tr>
<tr>
<td>78/F</td>
<td>CAD, L carotid TIA</td>
<td>Equivocally positive 1.5x1.5 cm aortic valve calcification or vegetation</td>
<td>No Negative</td>
<td>No 2</td>
</tr>
<tr>
<td>75/F</td>
<td>I, MCA infarct</td>
<td>LV thrombus</td>
<td>Equivocally negative; LV trabeculation, could not absolutely exclude LV thrombus</td>
<td>No 5</td>
</tr>
<tr>
<td>73/M</td>
<td>CAD, R cerebellar infarct</td>
<td>LV thrombus</td>
<td>Negative</td>
<td>No 1</td>
</tr>
<tr>
<td>77/F</td>
<td>A Fib, brain stem and cerebellar infarct</td>
<td>Negative</td>
<td>Large LA and LA appendage thrombi</td>
<td>No 7</td>
</tr>
</tbody>
</table>

2DE, transthoracic two-dimensional echocardiography; UFCCT, ultrafast cardiac computed tomography; TDS, technically difficult study; M, male; F, female; CAD, coronary artery disease; L, left; R, right; MCA, middle cerebral artery; MI, myocardial infarction; A Fib, atrial fibrillation; TIA, transient ischemic attack; LV, left ventricular; LA, left atrial.

*Left ventricular thrombus proven on autopsy.

**FIGURE 2.** Ultrafast cardiac computed tomogram of left atrial and left appendage thrombi in 77-year-old woman with atrial fibrillation and brain stem and cerebellar infarcts who had negative transthoracic two-dimensional echocardiogram.
Discussion

Our study demonstrates good correlation between 2DE and UFCCT, with agreement in 78% of studies. Several reasons could account for the lack of concordance in the remainder of the studies. Technical difficulties may play a role. Technically difficult 2DE studies occurred in 32% of all patients and in 25% of the discrepant cases. It has been reported that approximately 11–25% of 2DE studies are technically inadequate. Commonly encountered technical difficulties among our patients were poor acoustic windows due to obesity or chronic obstructive pulmonary disease. Other situations that can produce poor acoustic windows are pectus excavatum, recent chest surgery, or interposed ribs. Less commonly, an uncooperative patient creates movement artifacts that obscure images. The presence of these limitations may lead to inadequate visualization of the cardiac apex or atria, which are the most common locations for intracardiac thrombi. When these areas are not visualized, an intracardiac thrombus cannot reliably be excluded.

Compared with 2DE, UFCCT has fewer technical difficulties. Only 5% of all UFCCT studies were technically difficult. In one, the upper one third of the left atrium was not well visualized due to patient movement. In the other, morbid obesity produced technical limitations. In general, definition of struc-
tures, including intracardiac masses, is facilitated with UF CCT due to tissue plane delineation and rapid acquisition time. The ability of UF CCT to successfully image the cardiac apex and the atria in nearly all circumstances makes it a useful technique when these areas are not visualized by 2DE. However, the risks associated with contrast administration need to be considered.

Another limitation of transthoracic 2DE is suboptimal visualization of left atrial masses, particularly in the appendage. One of our patients had a large left atrial and appendage thrombus seen by UF CCT that was not detected by 2DE. One reason for the lack of visualization of a thrombus in this location is inadequate delineation of tissue planes. Acoustic impedance of thrombi or other masses may not differ enough from that of the surrounding blood or endocardium to enable adequate ultrasonic reflection. The left atrial appendage is often inaccessible by 2DE due to its location. In a series of 293 patients with rheumatic heart disease undergoing mitral valve surgery with intraoperative inspection of the left atrium, 2DE performed ≤1 week before surgery failed to detect left atrial thrombi in 21 patients; in 11 of these patients the thrombus was in the left atrial appendage. In another study of 92 patients with mitral valve disease who underwent cardiac surgery, 2DE failed to identify eight of 13 left atrial thrombi, of which seven were in the left atrial appendage. While isolated success in detecting left atrial appendage thrombi has been reported, 2DE is less than optimal for detecting thrombi in that location. In our one instance of presumed left atrial thrombus, there was a suggestion that UF CCT is superior to 2DE. One study evaluating left atrial thrombi showed a slightly higher sensitivity with conventional CT (91%) than with 2DE (86%) and suggested better delineation of left atrial thrombi with CT. Transesophageal echocardiography, which yields excellent visualization of the left atrial appendage and left ventricle, should substantially improve 2DE visualization, especially of left atrial appendage thrombi. Transesophageal echocardiography was not available at our institution at the time of this study. Further studies comparing these techniques, ideally correlated with pathologic data, will be helpful to determine their sensitivity and specificity for detecting left atrial and appendage thrombi.

Whenever technically difficult or equivocal 2DE or UF CCT studies occur, there should be some caution in interpreting the results. Some authors have recommended that equivocal 2DE studies or those with disagreement between observers should be interpreted as negative. Reasons that have been identified as producing equivocal interpretations or false-positive 2DE studies are echo artifacts and normal or abnormal cardiac structures (such as papillary muscle, trabeculae, chordae, or aneurysms) that can simulate intracavitary echoes and may resemble thrombi. Although pathologic data is lacking, we tentatively postulate that our technically difficult and equivocally positive 2DE study was in error due to problems in visualizing the left atrium. In three patients, 2DE identified a left ventricular thrombus that was not visualized on UF CCT. Since pathologic data were not available, we cannot definitively determine which technique was accurate.

Using 2DE and UF CCT, Helgason et al evaluated patients with suspected cardioembolic stroke and found a slightly higher incidence of technically difficult 2DE studies (43%) than we did (32%). Either 2DE or UF CCT detected intracardiac thrombi in 13 of the 40 patients in that series. Left atrial thrombi were visualized in nine patients (seven by UF CCT alone and two by 2DE alone). Left ventricular thrombi were visualized in five patients by UF CCT. Interestingly, intracardiac thrombi were not diagnosed in any patient by both techniques. In contrast, four of our patients had intracardiac thrombi identified by both 2DE and UF CCT. Disregarding technically limited studies and considering only those patients that had both 2DE and UF CCT, Helgason et al found discordance in the diagnosis of intracardiac thrombi in 10 of 35 patients (29%). These authors interpreted their data to indicate that UF CCT was more sensitive than 2DE for detecting intracardiac thrombi. However, the sensitivity of a technique can really be determined only if the results are compared with surgical or pathologic data.

Currently, 2DE should be the initial screening technique for intracardiac thrombi. UF CCT could be used when 2DE is negative in patients with a high clinical suspicion of an intracardiac thrombus, particularly in the left atrium or left atrial appendage. In addition, UF CCT may be helpful when 2DE is technically difficult or when the results are equivocal. Transesophageal 2DE may be helpful in patients with suspected left atrial thrombus or when transthoracic 2DE is technically difficult. Further studies on more patients with pathologic correlation are needed to determine the sensitivity and specificity of UF CCT in the detection of intracardiac thrombi.

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**KEY WORDS** • echocardiography • tomography, x-ray computed • cerebral ischemia • coronary disease
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