A New Noninvasive Technique for Imaging Atherosclerotic Plaque in the Aortic Arch of Stroke Patients by Transcutaneous Real-Time B-Mode Ultrasonography
An Initial Report

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Background and Purpose—Aortic arch atherosclerotic plaque is a probable source of atheroembolic stroke. Transesophageal echocardiography (TEE) has been used to image the aorta of patients with stroke to identify atherosclerotic plaque. TEE is moderately invasive and does not always visualize plaques present in the distal ascending aorta and proximal aortic arch.

Methods—In the current study, transcutaneous B-mode ultrasonography was performed to image the aortic arch through a lateral supraclavicular window, and the results were compared with those of TEE in 20 patients. The aorta was subdivided into the proximal ascending (PAsc), distal ascending (DAsc), proximal aortic arch (PAA), and distal aortic arch (DAA) to be certain the plaques identified by each technique were the same. Plaques were characterized as simple (<4 mm thick) or complex (>4 mm thick).

Results—In the PAsc, 8 simple plaques were identified with TEE but not with B-mode. In the DAsc, 1 complex plaque was identified with both techniques, and B-mode identified 1 additional complex and 1 simple plaque. In the PAA, 6 simple and 5 complex plaques were identified by both techniques, and TEE identified 1 additional complex plaque. In the DAA, TEE identified 2 simple and 2 complex plaques; B-mode identified 3 complex plaques.

Conclusions—B-mode imaging compared favorably with TEE in identification of plaques in the aortic arch and distal ascending aorta, although it could not identify simple plaques in the proximal ascending. B-mode could visualize plaques not seen by TEE in the distal ascending aorta. B-mode ultrasonography is complementary to TEE in performance of a comprehensive assessment of plaque in the aortic arch and provides a noninvasive method for sequential studies of plaques that can be visualized. (Stroke. 1998;29:673-676.)

Key Words: aortic arch n atherosclerosis n echocardiography, transesophageal n ultrasonography
Figure 1. Schematic diagram of the technique of performing real-time B-mode ultrasonography of the aortic arch. The patient is examined in a sitting or lying position, but the sitting position provides better visualization. The probe is placed in the supraclavicular fossa, imaging from the right to the left. The position of the aortic arch in the sonographic beam is shown as it traverses from right to left and posteriorly over the heart. The B-mode image is seen in reverse, with the ascending on the left and the descending on the right, because it is taken in a lateral view as the arch courses posteriorly over the heart.

Studies were compared at the end of the collection of 20 sequential cases. The location of the plaque and the morphology of the plaque were determined in each study before comparison of the results. The B-mode studies were performed by one of the investigators (J.W.), who was aware of the clinical findings of the patient. The TEE studies were performed without knowledge of the clinical findings in the patient.

**B-Mode Ultrasonography**

B-mode ultrasonography of the aortic arch was performed with an Acuson XP 128 color-flow duplex Doppler instrument, with use of an L7 phased-array linear probe at 7.5 MHz. Doppler examination was performed at 5.0 MHz. A lateral supraclavicular approach was used to visualize the ascending aorta, aortic arch, and proximal descending aorta. The angle of insonation required to visualize the arch produces an image that is inverse to the true direction of the arch, with the ascending aorta to the right and the arch curving to the left toward the descending aorta. A schematic diagram of the technique for imaging the aortic arch is shown in Fig 1.

For purposes of comparing TEE and B-mode ultrasonography, the arch was subdivided into segments: the proximal ascending aorta, distal ascending aorta, proximal aortic arch, and distal aortic arch. This ensured that the same plaque was being imaged by each technique. The origin of the innominate artery was taken as the border between the proximal and distal arch, as seen in the schematic diagram of the arch (Fig 2).

TEE was performed with the patient in the lateral decubitus position. A multiplane probe (ATL HDI 300 or Hewlett Packard HP-2500), with frequencies ranging from 5 to 7 MHz, was used. Topical anesthesia was accomplished with Cetacaine (Cetylite Industries) and lidocaine, and intravenous sedation when needed was titrated with Demerol (Sanofi Winthrop) and Versed (Roche Laboratories). Twenty sections of the arch were visualized and aortic plaque was identified. The aorta was subdivided into the same segments as the B-mode scans for comparison. Calculations of sensitivity and specificity comparing B-mode and TEE were not made, because it is known that TEE does not visualize all aortic plaques that can be seen with open aortography, particularly in the distal ascending aorta. 

Plaques were characterized as simple if they were <4 mm thick and complex if they were >4 mm thick.7 They were also described as sessile, crescentic, pedunculated, or flat.

**Results**

TEE identified 8 simple plaques on the wall of the proximal segment of the ascending aorta. This segment could not be visualized well with B-mode ultrasonography, although the wall of the proximal ascending aorta could be seen in 12 of the 20 cases with B-mode. In the distal ascending aorta, B-mode identified 2 complex and 1 simple plaque, whereas TEE identified only 1 complex plaque (Fig 2). In the proximal aortic arch, TEE identified 6 simple and 4 complex plaques, and B-mode identified 6 simple and 3 complex plaques. In the distal aortic arch, TEE identified 2 simple and 2 complex plaques; B-mode identified 3 complex plaques. The additional complex plaque seen in the distal aortic arch on B-mode was the same as the additional plaque seen as being in the proximal aortic arch on TEE, but it was localized to different segments by the two techniques. The results are summarized in the Table and in a schematic diagram (Fig 2).

All complex plaques visualized with TEE were also identified with B-mode sonography. The morphological conformation of the plaques were also similar, indicating that the same plaques were being seen. Both techniques showed the plaques as pedunculated (Fig 3) and proliferative (Fig 4). Mobility of plaque could be seen as well with both techniques. TEE was able to detect simple plaques not seen with B-mode imaging, particularly in the proximal ascending aorta.

### Table and in a schematic diagram (Fig 2).

| Localization of Simple and Complex Plaques in the Proximal Ascending Aorta, Distal Ascending Aorta, Proximal Aortic Arch, and Distal Aortic Arch Visualized With B-Mode Ultrasonography and TEE |
|---|---|---|---|---|
| | Simple | Complex | Simple | Complex | Simple | Complex |
| B-mode | 0 | 0 | 1 | 2 | 6 | 5 |
| TEE | 8 | 0 | 0 | 1 | 6 | 6 |

Figure 2. Schematic diagram of the results of B-mode and TEE examination of the aortic arch is shown. The location of plaques in the aortic arch was divided into subdivisions: proximal ascending aorta, distal ascending aorta, proximal aortic arch, and distal aortic arch. The locations of complex and simple plaques seen with B-mode imaging and TEE in the subdivisions of the aortic arch are identified. Complex plaques are denoted as large, irregular shapes and simple plaques as small, regular shapes.
Discussion
An association has been established between aortic plaque identified by TEE and atheroembolic cerebrovascular disease. Tunick et al first described the identification of protruding masses with mobile components with TEE in patients who had systemic embolic events during cardiac catheterization. These observations were further extended to patients with embolic stroke, and it was confirmed through pathological examination that these masses were atherosclerotic. Amarenco et al performed pathological examinations of 500 consecutive patients with cerebrovascular and other neurological diseases and found a prevalence of aortic plaque of 57.8% in patients with no known cause of cerebral infarction and 22% in patients with other possible etiologies of cerebral infarction.

Toyoda et al reported a 42% prevalence of aortic atheroma identified by TEE in 62 patients with clinical criteria of embolic stroke. Amarenco et al found complex aortic plaques in 50% of 12 patients with embolic stroke for which no other etiology had been determined. Horowitz et al reported mobile aortic plaques in 4% of 183 patients with cerebral infarction.

Amarenco et al demonstrated that the prevalence of complex aortic plaques >4 mm thick on TEE was significantly higher in stroke patients compared with control patients, a finding confirmed by Jones et al. The French Study of Aortic Plaques in Stroke Study Group documented an incidence of recurrent brain infarction of 11.9 per 100 person-years in stroke patients with aortic wall thickness of >4 mm and 3.5 per 100 person-years in stroke patients with aortic wall thickness of <4 mm, indicating that complex atherosclerotic plaque in the aortic arch is a significant predictor of recurrent brain infarction. The increased frequency of recurrent brain infarction in patients with complex aortic plaques was confirmed by Mitusch et al. In these studies the population was small, and treatment modalities and concomitant risk factors were not accounted for. Repeat TEE to document changes in aortic plaque morphology consistent with an embolic event was not performed, so it is uncertain whether embolization of aortic plaque was the etiology or whether aortic arch atherosclerosis was a marker for more severe cerebrovascular disease.

Correlation of the plaque morphology of ultrasound images of aortic plaque on TEE and pathological specimens has been limited because most aortic plaques are not removed surgically. Tunick et al reported morphological correlation of one complex symptomatic plaque removed surgically with the presence of thrombus. Amarenco et al identified ulceration on pathological specimens of aortic plaque described at autopsy but did not correlate these findings with ultrasound images.

The correlation of ultrasonographic carotid plaque morphology and histology has been described in several studies. Heterogeneous lucencies have been associated with intraplaque and intraluminal thrombus and acute hemorrhage into plaque. These findings are significantly more frequent in symptomatic plaques and have predictive value for future symptoms. Plaque configuration also appears to play a role, with crescentic plaques with scalloped borders having a greater frequency of ipsilateral ischemic events. Recurrent symptoms are associated with plaque growth in a crescentic configuration. Imaging aortic plaque with the same linear real-time B-mode ultrasonographic technique used to image carotid plaque may allow for extrapolation of plaque characteristics from the carotid to the aortic arch.

Noninvasive B-mode imaging can visualize atherosclerotic plaque in the distal ascending aorta and aortic arch. Plaques in the proximal ascending aorta that are seen with TEE cannot be visualized, but almost all of these are simple plaques. Complex plaques visualized with epicardography during cardiac surgery are located primarily in the curvature of the arch from the distal ascending aorta to the proximal descending aorta, which can all be seen with B-mode ultrasonography in most patients. B-mode may be more sensitive than TEE in identifying plaques at the junction of the ascending aorta and the arch, which can be obscured by the bronchi.

Real-time B-mode ultrasonography of the aortic arch is a noninvasive method that can be incorporated into the neurovascular evaluation of patients with stroke and transient ischemic attack at the time duplex examination of the carotid bifurcation is performed. Patients who would not normally undergo TEE can be screened for aortic plaque, and if plaque is identified a TEE can be performed to corroborate the findings. In patients for whom visualization of the aortic arch is not definitive with B-mode, TEE can be performed if there is a clinical indication that the stroke was embolic. TEE is often performed in patients suspected of having a cardioembolic stroke. In these patients, B-mode can supplement the TEE to visualize the portions of the arch that may be difficult to visualize with TEE. A combination of transthoracic echocardiography and B-mode ultrasonography of the aortic arch may

Figure 3. A pedunculated plaque in the proximal aortic arch visualized with B-mode ultrasonography (A) and TEE (B). The shape of the plaque is the same, though linear scanning with B-mode appears to delineate layers of density and lucency not visualized by sector scanning with TEE.

Figure 4. A large proliferative plaque is seen with B-mode (A) and TEE (B) at the curvature of the distal arch into the descending aorta. The plaque is of intermediate echodensity, but no underlying lucencies are seen.

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be sufficient in some patients to rule out an embolic source. B-mode imaging of the aortic arch should also be useful for sequential studies of plaques identified with TEE that can be visualized with B-mode without subjecting the patient to the discomfort of repetitive TEE examinations. This may be of value in therapeutic trials of agents to prevent stroke from aortic arch plaque, so that morphologic changes in plaque may be correlated with method of treatment and cerebrovascular events.

The current study was performed to establish the technique of percutaneous B-mode imaging of the aortic arch and determine whether the plaques identified were similar to those seen with TEE. The number of patients was small, and correlation with methods of treatment and risk factors was not obtained. Further studies will be required to establish the interobserver and intraobserver reliability of the technique, and the sensitivity and specificity must be documented in large numbers of patients before the technique can achieve general applicability.

The technique has the potential for becoming a standard method of visualizing atherosclerotic plaque in the arch of the aorta.

References

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