Imaging of Distal Internal Carotid Artery by 
Ultrasonography With a 3.5-MHz Convex Probe

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Background and Purpose—Conventionally, carotid ultrasonography has been performed with a 7.5-MHz linear probe to evaluate the extracranial internal carotid artery (ICA). However, usually only the carotid bulb or proximal portion of the ICA can be evaluated. We attempted to evaluate the distal extracranial ICA with a 3.5-MHz convex probe.

Methods—The subjects were 17 consecutive patients with ICAs free of occlusive disease and 3 other patients with distal extracranial ICA stenosis. Using a 7.5-MHz linear probe and a 3.5-MHz convex probe, we performed long-axis B-mode imaging of the ICAs to evaluate the distance between the distal limit of visualized ICA and the bifurcation of the common carotid artery.

Results—The distal limit of the ICA, visualized with a 7.5- or a 3.5-MHz probe, was 31±11 or 57±8 mm distal to the common carotid artery bifurcation, respectively. In the 3 patients with distal extracranial ICA stenosis, the lesion could be successfully diagnosed with only the 3.5-MHz probe.

Conclusions—This form of carotid imaging is feasible and may be potentially useful in the evaluation of carotid disease.

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Key Words: carotid arteries □ stenosis □ ultrasonography

Conventional duplex carotid ultrasonography with a 7.5- to 10-MHz linear-array probe has enabled us to characterize atherosclerotic lesions and to measure blood flow velocities of the common carotid artery.1 However, with these probes, ultrasonographic assessment of the distal ICA is technically difficult, especially in patients with high carotid bifurcations, very short necks, or extremely deep vessels.2 This limitation of the conventional method is attributable to the depth of the internal carotid artery (ICA) relative to the probe surface and to the interruption of ultrasound signals by the mandibular bone. Scanning with a lower-ultrasonic-frequency apparatus is suitable for precise observation sites relatively far from the probe surface.2 To visualize the distal extracranial ICA and to measure flow velocity overcoming the depth of the ICA, we selected a lower-frequency probe, ie, a 3.5-MHz convex-array probe, developed for abdominal insonation. In the present study, we found carotid ultrasonography with a 3.5-MHz convex-array probe to be useful for visualizing the distal extracranial ICA and for precisely measuring flow velocity.

Subjects and Methods
The subjects were 17 consecutive patients (63±9 years of age) with ICAs free of occlusive disease and another 3 patients with distal extracranial ICA stenosis. Among these 20 patients, 19 had undergone intra-arterial digital subtraction cerebral angiography, and the 1 remaining patient had undergone MR angiography. Informed consent was obtained from all patients. The angiographic findings of the 3 patients that revealed relatively distal ICA stenosis are shown in Figure 1. All 38 carotid bifurcations were angiographically depicted at the level between the second and fourth cervical spines.

Ultrasonographic examinations were performed with an Aloka SSD 5500 apparatus. We used a 7.5-MHz linear-array probe and a 3.5-MHz convex-array probe. Two sonographers performed the test and were blinded to results of the angiogram. The patients were studied prospectively with the same scanning protocol. One sonographer performed long-axis B-mode imaging of the ICA combined with color flow imaging with a 7.5-MHz probe in longitudinal and oblique positions. In 17 patients with normal angiograms, we measured the length of the visualized ICA. Then, the other sonographer used the 3.5-MHz probe the same way and was blinded to the results of the angiogram. Statistical significance was set at P<0.05.

Continuous data are expressed as mean±SD, and continuous variables were analyzed by use of the paired t test. Statistical significance was set at P<0.05.

Results
In 34 ICAs of these 17 patients, the detectable ICA ranges were 31±11 and 57±8 mm from the common carotid artery.
bifurcation with the 7.5- and 3.5-MHz probes, respectively (Figure 2). The visualized distal end of the ICA was located farther away with the 3.5-MHz probe than with the 7.5-MHz probe, and the difference was significant ($P < 0.001$).

In the 3 patients with distal ICA stenosis, these lesions could not be visualized with a 7.5-MHz probe. With a 3.5-MHz probe, we were able to visualize these stenotic lesions and confirm their distal ends on color flow imaging. The peak systolic velocities at the stenosis were $>200$ cm/s in all 3 patients with the 3.5-MHz probe (the Table), suggesting the existence of significantly stenotic lesions. These results were consistent with the angiographic findings of stenotic ICA.

**Discussion**

Duplex ultrasonography with a 3.5-MHz probe combined with color flow imaging allowed clear visualization of the distal ICAs. We were also able to visualize distal ICA stenosis with a 3.5-MHz probe. However, B-mode imaging without color flow imaging could not visualize the distal ICA because of coarse imaging resulting from the use of a lower-ultrasonic-frequency apparatus.

Yasaka et al\(^3\) reported a newly established technique of transoral carotid ultrasonography that avoids interruption by the mandibular bone. Although this transoral technique enables us to evaluate the distal portion of the ICA, some patients cannot endure the associated pharyngeal stimulation. On the other hand, our method can be applied to any patient without discomfort. We demonstrated in this study that duplex scanning with a 3.5-MHz convex probe originally designed for abdominal insonation is also potentially useful and greatly facilitates the detection of occlusive lesions in the distal extracranial ICA.

In all patients with distal ICA stenosis, a narrowed vessel lumen was visualized and the distal end of the lesion was easily detected on color flow imaging with a 3.5-MHz probe. In these patients, peak systolic velocities $>200$ cm/s were consistent with angiographic findings of moderate to severe ICA stenosis.\(^4\)

Furthermore, in all 17 patients without ICA occlusive lesions, we were better able to measure ICA flow velocities at straight points rather distal to the bifurcation with a 3.5-MHz probe than with a 7.5-MHz probe. Anatomically, the origin of the ICA dilates to form the carotid bulb, and the ICA does not always have a straight course following the bulb, whereas the distal extracranial ICA runs linearly.\(^5\) This anatomy suggests that flow velocity measurement at the distal ICA is likely to be more reproducible and to reflect the intracranial occlusive lesion better than measurement at the proximal ICA.

If a 3.5-MHz convex probe is used, current and generally accepted velocity criteria may not be applicable because they were validated for different frequencies and transducer configurations. A prospective validation of these criteria is necessary before any recommendation for the use of 3.5-MHz probes can be made. Although in this pilot study a definitive conclusion could not be drawn about the accuracy and better utility of a 3.5-MHz convex transducer because of the small number of patients, we believe this method will yield more accurate information on distal ICA assessment, especially with additional study.

**Ultrasonographic Findings of the 3 Patients With ICA Stenosis**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Detectable Range of ICA With 7.5-MHz Probe, mm</th>
<th>Distance From Bifurcation to Point of Stenosis With 3.5-MHz Probe, mm</th>
<th>PSV at Stenosis With 3.5-MHz Probe, cm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>22–30</td>
<td>206</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>25</td>
<td>575</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>35</td>
<td>257</td>
</tr>
</tbody>
</table>

PSV indicates peak systolic flow velocity. In all patients, ICA stenosis could not be visualized with a 7.5-MHz probe.
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References


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