Transoral Carotid Ultrasonography

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Background and Purpose—We attempted ultrasonographic evaluation of the distal extracranial internal carotid artery (ICA) using the transoral method (transoral carotid ultrasonography [TOCU]).

Methods—The subjects consisted of five healthy volunteers and seven stroke patients. Examinations were performed with a color Doppler flow imaging system equipped with convex array transducers (7 or 9.5 MHz), originally designed for transrectal use. After local anesthesia of the pharynx, we inserted a probe covered with thin gum transorally, touching the tip to the pharyngeal posterolateral wall. We then attempted to detect the ICA and measure flow velocity of the distal extracranial ICA using principal images obtained by TOCU.

Results—TOCU was successfully performed in all subjects without any difficulty. In the healthy volunteers, the ICA was identified at a depth of 2.2±0.6 cm and visualized as a vertical linear vessel 2.9±0.3 cm in length and bent slightly backward. The diameter and mean flow velocity of the distal extracranial ICA were 4.7±0.2 mm and 50±7 cm/s, respectively. In the stroke patients, some remarkable findings were obtained, including a narrow ICA with low flow velocity in a patient with possible ICA dissection, a lucent echo without flow signal in a patient with acute cardioembolic ICA occlusion, and decreased ICA flow velocity in a patient with ipsilateral MCA stenosis.

Conclusions—These preliminary data demonstrate the potential applicability of TOCU to the evaluation of flow in the far distal extracranial ICA. TOCU definitely warrants further investigation in patients with carotid artery disease. (Stroke. 1998;29:1383-1388.)

Key Words: carotid artery diseases ■ cerebrovascular disorders ■ ultrasonography, Doppler

Carotid ultrasonography with CDFI has enabled the evaluation of plaques or occlusive diseases at the extracranial carotid arteries by B-mode imaging, color flow imaging, and measurement of flow velocity.1–4 It has also contributed to the assessment of occlusive diseases of distal arteries, such as occlusions at the top of the ICA or the main trunk of the MCA, by comparing bilateral flow velocities obtained from the CCAs.5,6

However, in patients with higher bifurcation of the CCA,7 the mandibular bone prevents visualization of the origin of the ICA.8 The course of the ICA from the bifurcation to the skull base is not always straight but occasionally curves strongly at its origin and on rare occasions is coiled or kinked. The origin of the ICA is usually somewhat dilated, and this widening extends up to 2 cm from the origin before the ICA assumes a uniform diameter.8 Furthermore, reverse flow at the ICA origin has been observed.1 Consequently, obtaining an appropriate size and location of sample volume at the ICA origin can be difficult. In addition, measuring the incident angle between blood flow and pulsed Doppler beam, allowing determination of correct blood flow velocity, is occasionally troublesome.

Conventional carotid ultrasonographic assessment of the distal extracranial ICA is limited by the mandibular bone, even in patients with a lower bifurcation, while far distal segments before the petrous portion are often affected by pathological processes, such as dissection, fibromuscular dysplasia, stationary arterial waves, and hypoplasia of the ICA.5,9

In contrast, the ICA ascends vertically under the pharyngeal posterolateral wall after branching from the CCA, and its pulse can be easily felt by placing a finger on this wall. We used transoral carotid ultrasonography (TOCU) to place a special probe on the pharyngeal posterolateral wall and attempted to identify the distal extracranial ICA and measure ICA flow velocity. We then assessed whether TOCU is useful for evaluation of the distal extracranial ICA.

Subjects and Methods
The subjects consisted of five healthy volunteers (aged 33±5 years) and seven stroke patients (aged 61±14 years). The demographic profiles of the stroke patients are summarized in Table 1.

Examinations were performed with the use of a Toshiba SSA 260 A CDFI system (Toshiba Inc) equipped with a 7-MHz convex array transducer (PVL-625RT) and an ATL Ultramark 9 CDFI system (ATL Inc) equipped with a 9- to 5-MHz convex array transducer (C9-5 ICT) (Figure 1). These transducers were originally designed for transrectal use. We covered the probes with disposable sterile thin gum after covering the tip of the probe with echo jelly.

Informed consent was obtained from all subjects. After local anesthesia of the pharynx was induced with the use of lidocaine, the...
probe was inserted transorally, and the tip was touched to the pharyngeal posterolateral wall (Figures 1 and 2).

Using the CDFI system, we attempted to distinguish the ICA from other vessels, such as the external carotid artery and its branches and the jugular vein (Figure 3). We identified an ICA by delineation of a vessel running linearly from the lower to the higher pharynx and by confirming that flow was proceeding upward to the skull base, that the flow velocity pattern was identical to that of the ICA, and that branching was absent. We determined the characteristics of TOCU color flow images of the distal extracranial ICA and measured the length, depth (from the surface of the posterior wall to the anterior wall of the ICA), diameter, and flow velocity of the distal extracranial ICA.

Conventional Duplex carotid ultrasonography with linear array probes (7.5 or 10 to 5 MHz) was also performed in all subjects on the same day of TOCU examination. The flow velocities of the CCA and proximal ICA were measured by an external approach and compared with those of the distal extracranial ICA, which were obtained by a transoral approach.

The correlation between the mean flow velocity of the CCA measured with the use of both linear (10 to 5 MHz) and convex array (9 to 5 MHz) transducers was examined in the 10 CCAs of five separate healthy volunteers (men aged 32 ± 4 years) with the use of the ATL Ultramark 9 CDFI system (ATL Inc) to elucidate whether differences in the frequency and geometry of the ultrasound beams cause discrepancies in the measured values of flow velocity. Continuous data are expressed as mean ± SD, and continuous variables were analyzed with the use of the paired t test. Statistical significance was established at the P < 0.05 level.

**Results**

TOCU was performed in all subjects without difficulty. However, most subjects needed to spit two or three times during and after the examination.

In the healthy volunteers, the distal extracranial ICA was identified at a depth of 2.2 ± 0.6 cm and was visualized as a 2.9 ± 0.3-cm-long vertical linear vessel bent slightly backward (Table 2). The diameter of the distal extracranial ICA (4.7 ± 0.2 mm) was significantly smaller than that of the proximal ICA (5.6 ± 0.9 mm; P < 0.001). The bifurcation of the CCA could not be visualized with the use of TOCU. Correction of the incident angle between the ICA and Doppler beam was easily performed because the incident angle was 60° or less in all cases. The mean flow velocity (50 ± 7 cm/s) of the distal extracranial ICA obtained by the transoral approach was significantly higher (P < 0.01) than that of the proximal ICA (37 ± 8 cm/s) by the external approach and as high as that (54 ± 8 cm/s) of the CCA.

**TABLE 1. Demographics of Stroke Patients**

<table>
<thead>
<tr>
<th>Pt No.</th>
<th>Age/Sex</th>
<th>Risk Factors</th>
<th>Stroke Type</th>
<th>Site of Ischemic Lesion</th>
<th>Angiographic Findings Using the External Approach</th>
<th>Duplex Carotid Ultrasoundographic Findings Using the External Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64/M</td>
<td>DM, HC</td>
<td>Lacunar infarction</td>
<td>R ICA territory</td>
<td>R ICA stenosis (10/9/96)</td>
<td>R ICA stenosis (7/22/97)</td>
</tr>
<tr>
<td>2</td>
<td>47/M</td>
<td>DM, HC, OMI</td>
<td>Cardioembolic stroke</td>
<td>R ICA territory</td>
<td>R ICA occlusion (7/21/97)</td>
<td>R ICA occlusion (7/23/97)</td>
</tr>
<tr>
<td>3</td>
<td>37/M</td>
<td>None</td>
<td>Brain infarction of undetermined cause</td>
<td>R ICA territory</td>
<td>R M1 stenosis (5/1/97)</td>
<td>Low flow velocity of R CCA and ICA (7/23/97)</td>
</tr>
<tr>
<td>4</td>
<td>74/M</td>
<td>HT</td>
<td>TIA</td>
<td>L ICA territory</td>
<td>.</td>
<td>R ICA plaque (7/25/97)</td>
</tr>
<tr>
<td>5</td>
<td>74/M</td>
<td>HT</td>
<td>Atherothrombotic infarction</td>
<td>R ICA territory, medial medulla of Lt side</td>
<td>R ICA occlusion, stenosis of Lt distal VA and BA</td>
<td>R ICA occlusion (7/30/97)</td>
</tr>
<tr>
<td>6</td>
<td>59/M</td>
<td>HC, DM</td>
<td>Atherothrombotic infarction, post–STA–MCA anastomosis, bilateral</td>
<td>R MCA territory</td>
<td>R M1 stenosis, L M1 occlusion (5/25/87)</td>
<td>High flow velocity of bilateral ECA (7/30/97)</td>
</tr>
<tr>
<td>7</td>
<td>69/M</td>
<td>AF</td>
<td>Asymptomatic</td>
<td>.</td>
<td>Dissection of L ICA origin* (12/13/94)</td>
<td>Dissection of L ICA origin (9/8/97)</td>
</tr>
</tbody>
</table>

Pt indicates patient; DM, diabetes mellitus; HC, hypercholesterolemia; OMI, old myocardial infarction; HT, hypertension; AF, atrial fibrillation; TIA, transient ischemic attack; STA, superficial temporal artery; VA, vertebral artery; BA, basilar artery; M1, horizontal portion of the MCA; and ECA, external carotid artery. Pt 1 had a lacunar infarction in 1992 and developed R ICA stenosis in 1996. Pt 2 had an angiographic examination 6 hours after the onset of stroke. Pt 4 had three TIs between 4/2/87 and 6/26/97 but did not have an angiographic examination. Pt 5 had a past history of brain infarction in the R MCA territory due to R ICA occlusion 9 months previously and developed a medial medullary infarction.

*Helical CT angiographic findings.
The side-to-side ratio of the mean flow velocity of the distal extracranial ICA was calculated by dividing the mean flow velocity of the faster side by that of the slower side and was 1.17 ± 0.03. The pulsatility index (0.7 ± 0.1) of the distal extracranial ICA recorded by the transoral approach was lower than those of the CCA (1.7 ± 0.3) and proximal ICA (1.0 ± 0.4) as determined by the external approach (P < 0.01 and P = 0.051, respectively).

In a stroke patient (patient 7), we compared enhanced CT findings with those of TOCU (Figure 2) and found that the locations of the ICA, external carotid artery, and jugular vein corresponded well between the two methods.

Although the results of the stroke patients were almost identical to those of the healthy volunteers (Tables 2 and 3), there were some remarkable findings associated with various pathologies. In one patient (patient 1) who was suspected of having a right ICA dissection, the right ICA was evident as a narrow signal with low flow velocity (Figure 4), which was consistent with cerebral angiographic findings. In a patient (patient 2) with acute cardioembolic ICA occlusion 3 days after stroke onset, confirmed by right CCA angiography (Figure 5), the right ICA was visible on a TOCU-obtained B-mode image but did not show any flow signal, while the left ICA flow was normal. In contrast, we were unable to demonstrate the occluded right ICA either on a B-mode image or on CDFI in a patient (patient 5) with atherothrombotic right ICA occlusion confirmed by angiography. In a patient with stenosis of the right MCA (patient 3), the ICA flow velocity of the affected side (57 cm/s) was lower than that (82 cm/s) of the nonaffected side. The side-to-side ratio (82/57 = 1.44) was higher than 1.23 (mean ± 2SD of the side-to-side ratio in the control subjects).

Among all subjects, correlation between the mean flow velocities of the CCA and ICA, when the ICA was determined by the transoral approach, was high (r = 0.82), whereas correlation was not high (r = 0.68) (Figure 6) when the ICA was assessed by the external approach.

No significant difference in the mean flow velocities of the CCA measured with the linear and convex array transducers was observed (49.1 ± 8.6 cm/s and 48.6 ± 9.1 cm/s, respectively; P = 0.62).

**Discussion**

The ICA runs so linearly and superficially under the pharyngeal posterolateral wall that sufficient length of the distal extracranial ICA can be evaluated to allow accurate flow...
velocity measurement. This may explain the high correlation observed between the mean flow velocities of the CCA and ICA determined by the transoral approach.

TOCU enables assessment of the arterial diameter and flow velocity of the distal extracranial ICA, the site used for angiographic measurement of diameter reduction in the North American Symptomatic Carotid Endarterectomy Trial and the Asymptomatic Carotid Atherosclerosis Study. The present findings suggest that TOCU may be useful in obtaining accurate measurements of the diameter of the distal extracranial ICA, particularly in patients with a high carotid bifurcation or kinking of the proximal extracranial ICA.

In the present study, mean flow velocity measured by conventional carotid ultrasonography with the use of the linear array transducer in the proximal ICA was significantly lower than that measured by TOCU with the use of the convex array transducer in the distal ICA, while no difference in the mean flow velocities of the CCA measured by the linear and convex array transducers was observed. Therefore, the difference in the mean flow velocity at the proximal and

<table>
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<th>TABLE 2. Dimensions of ICAs as Determined by TOCU</th>
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<tr>
<td>Depth, cm</td>
</tr>
<tr>
<td>Healthy volunteers (5 patients, 10 vessels)</td>
</tr>
<tr>
<td>(1.3–2.8)</td>
</tr>
<tr>
<td>Stroke patients (7 patients, 13 vessels*)</td>
</tr>
<tr>
<td>(0.6–2.5)</td>
</tr>
<tr>
<td>All subjects (12 patients, 23 vessels*)</td>
</tr>
<tr>
<td>(0.6–2.8)</td>
</tr>
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</table>

Values in parentheses are ranges.

*One vessel was excluded from analysis because no identification of an occluded ICA could be made.

<table>
<thead>
<tr>
<th>TABLE 3. Mean Velocity and Pulsatility Index of the CCA and ICA</th>
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<tbody>
<tr>
<td>CCA</td>
</tr>
<tr>
<td>Mean velocity, cm/s</td>
</tr>
<tr>
<td>Pulsatility index</td>
</tr>
<tr>
<td>Stroke patients (7 patients, 14 vessels)</td>
</tr>
<tr>
<td>Mean velocity, cm/s</td>
</tr>
<tr>
<td>Pulsatility index</td>
</tr>
</tbody>
</table>

*P<0.01 vs CCA and ICA (transoral approach) (paired t test).
†P<0.01 vs ICA (transoral approach) (paired t test).
‡P<0.01 vs ICA (external approach) (paired t test).
§P<0.05 vs ICA (external approach) (paired t test).

Figure 3. CDFI and Doppler waveforms of a healthy volunteer. Left, Short-axis views obtained at the right pharyngeal upper (top) and lower (bottom) posterior wall. Middle, Long-axis views at the lines of a (top), b (middle), and c (bottom) indicated on the short-axis views. Right, Doppler waveforms of the ICA (top), jugular vein (middle), and external carotid artery (bottom). E indicates external carotid artery; I, internal carotid artery; and V, jugular vein.
distal ICA is not due to difference in the frequency and geometry of the ultrasound beams but is probably due to the diameter of the proximal ICA being larger than that of the distal ICA while blood flow volume is the same. When measuring flow velocity with high reproducibility at the proximal ICA using conventional carotid ultrasonography, we should put a sample volume at the point distal to the CCA bifurcation at which the arterial walls become parallel. However, in practice this is difficult because of limited visualization of the proximal ICA by the mandibular bone, and thus in the present study we were obliged to take measurements at the somewhat dilated part of the proximal ICA.

The ICA origin is prone to atherosclerotic lesions, and carotid ultrasonography with the use of the external approach

Figure 4. Angiographic images of early (A) and late (B) arterial phases after the same right CCA injection in the patient with a clinical diagnosis of right ICA dissection (patient 1), and CDFI and Doppler waveforms of the right ICA (C and D) and the left ICA (E and F). Arrow indicates the right ICA; arrowhead, the right external carotid artery.

Figure 5. Left, Right CCA angiography of the patient with cardioembolic right ICA occlusion (patient 2, arrow); middle, B-mode image of the right ICA (*) of the same patient; right, CDFI of the left ICA (arrow) of the same patient.
is useful to evaluate the quality and distribution of the lesion. However, the distal end of the lesion is sometimes difficult to confirm when an external approach is used, which may make it difficult to determine indication of carotid endarterectomy. At the very least, TOCU enables easy evaluation of the distal extracranial ICA, although this procedure cannot adequately demonstrate the carotid bifurcation.

We were able to identify the ICA in the patient with acute occlusion of the right ICA but not in the patient with an old ICA occlusion. The echogenicity of the thrombus may become as high as that of the tissue surrounding the occluded artery, and thus the age of the thrombus may be determined by the echogenicity of the ICA as demonstrated by TOCU. In that case, identification of the ICA without flow signal may indicate a recent occlusion, and failure to make such an identification because of increased echogenicity may indicate an old occlusion.

Recently, Kimura et al reported mobile echogenic intravascular structures at the ICA origin in patients with acute cardioembolic stroke, which were considered to be thrombi extended from the distal end of the ICA, where emboli are prone to lodge. Although such mobile echogenic intravascular structures were not detected by TOCU in our patient with cardioembolic stroke (patient 2), in the future, retrograde extension of the thrombi from the top of the ICA may be demonstrated with the use of serial TOCU examinations in the acute phase of cardioembolic ICA occlusion.

We examined two patients with suspected old ICA dissection. The lesion in one patient was limited to the ICA origin, but that in the other was located along the entire ICA. In the latter case, TOCU demonstrated a narrow ICA at the cervical portion, which was consistent with angiographic findings probably due to the dissection. Carotid Doppler sonography has been able to provide early recognition of ICA dissection and monitoring of ICA. Therefore, TOCU may contribute to evaluating the distribution of an ICA dissection in its acute phase.

The transoral approach was introduced by Keller et al in 1976. They used a bidirectional continuous-wave Doppler ultrasound system to detect flow in the vertebral arteries. However, to our knowledge, ours is the first report to describe evaluation of the ICA by the transoral approach with continuous-wave Doppler, B-mode, or CDFI.

In conclusion, these preliminary data illustrate the potential applicability of TOCU to evaluate flow in the far distal extracranial ICA. This method definitely warrants further examination in patients with carotid artery disease.

Acknowledgments

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