The Importance of Doppler Angle of Insonation on Differentiation Between 50–69% and 70–99% Carotid Artery Stenosis

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Aim: to investigate the importance of Doppler angle differentiating between 50–69% and ≥70% internal carotid artery (ICA) stenosis.

Material and methods: fifty-one patients with a previous diagnosis of 50–69% ICA stenosis (n = 53) were re-evaluated by duplex scanning. Spectral Doppler velocity waveforms were obtained from common carotid (CCA), ICA and external (ECA) carotid arteries with the same Doppler angle of insonation as used at the initial duplex scanning, followed by repeated measurements with a fixed 60° angle of insonation.

Results: the peak systolic velocity (PSV) in the ICA was 181 ± 55 cm/s (mean ± SD) at the second duplex scanning when the same angle of insonation (mean 46° ± 9) was used as during the initial investigation. When the examination was done with a 60° angle of insonation, PSV ICA was 261 ± 96 cm/s (mean ± SD). In fifteen arteries the estimated degree of ICA stenosis changed from 50–69% to 70–99% due to the application of a fixed Doppler angle of insonation at 60°.

Conclusion: the Doppler angle of insonation has a significant effect on spectral Doppler velocity measurements. It is crucial that duplex criteria are standardised with a fixed angle of insonation and that this angle is consistently used during velocity estimations.

Key Words: Doppler; Angle of insonation; Carotid artery.

Introduction

Duplex scanning is the principle non-invasive investigation for carotid artery stenosis and in recent years many authors have suggested using it as the only imaging modality prior to endarterectomy in the majority of cases.1–3 However, it is well known that the findings obtained from duplex scanning are strongly dependent on the experience of the operator and the equipment used.4–6 Variations in diagnostic performance of duplex scanning have a significant impact on the management and outcome of patients with extracranial carotid artery atherosclerosis. Doppler angle of insonation has been pointed out as being an essential factor for interpreting the results. The aim of the present study was to investigate the importance of Doppler angle in differentiating 50–69% from ≥70% internal carotid artery (ICA) stenosis.

Materials and Methods

Among 3353 carotid artery duplex scans performed between January 1993 and February 1999 with available hard copies of spectral Doppler registrations, 143 lesions were interpreted as having 50–69% ICA stenosis. ICA peak systolic velocity (PSV) 140–230 cm/s with PSV ICA/common carotid artery (CCA) ratio <3.2 and ICA end diastolic velocity (EDV) <100 cm/s have been used to define 50–69% ICA stenosis.7 Our vascular laboratory routinely performed carotid artery duplex scanning with a Doppler angle of insonation ≤60°. Patients from the Uppsala area (n = 90), examined with an angle of insonation <60°, were invited for re-examination. Six patients were deceased and 33 did not attend for various reasons, leaving 51 patients with 53 lesions which were re-evaluated by duplex scanning according to the protocol below. The median (range) interval between the initial and the re-examination was 32 (15–63) months.

Duplex scanning was performed using an Acuson Sequoia (Acuson, Montainview, CA, U.S.A.) fitted with a 4–6 MHz linear array probe. Spectral Doppler velocity waveforms were obtained from CCA, ICA and external (ECA) carotid arteries with the same Doppler angle of insonation as used at the initial duplex scanning, followed by repeated measurements with a fixed 60° angle of insonation. Similar spectral Doppler cursor alignment and beam steering were used in order to obtain the same angle of insonation that were used at the initial duplex scanning. The primary cursor was
Table 1. Doppler parameters at re-examination with the same angle of insonation as at the initial examination and with an angle of insonation at 60°. The values are given as mean ± SD (range).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>&lt;60° angle of insonation (25–57°)</th>
<th>60° angle of insonation</th>
</tr>
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<tbody>
<tr>
<td>PSV ICA cm/s</td>
<td>181 ± 55 (65–360)</td>
<td>261 ± 96 (90–480)</td>
</tr>
<tr>
<td>PSV CCA cm/s</td>
<td>63 ± 17 (30–115)</td>
<td>72 ± 21 (32–115)</td>
</tr>
<tr>
<td>PSV ICA/CCA ratio</td>
<td>3.1 ± 1.4 (1.3–8)</td>
<td>4.1 ± 2.5 (0.8–14.4)</td>
</tr>
</tbody>
</table>

Table 2. Number of arteries with various degrees of ICA stenosis with respect to the Doppler angle of insonation.

<table>
<thead>
<tr>
<th>Degree of stenosis with &lt;60° of insonation</th>
<th>Degree of stenosis with 60° of insonation</th>
</tr>
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<tbody>
<tr>
<td>30–49%</td>
<td>30–49%</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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parallel to the flow when the measurements were repeated with a fixed 60° angle of insonation. PSV >230 cm/s and/or PSV ICA/CCA ratio ≥3.2 and/or EDV ≥100 cm/s was used for diagnosis of a 70–99% stenosis.7

Results

The PSV in the ICA was 181 ± 55 cm/s (mean ± SD) at the second duplex scanning performed with the same angle of insonation (mean ± SD = 46° ± 9, range 25–57°) as used during the initial investigation. When the examination was done with a 60° angle of insonation the PSV ICA (mean ± SD) was 261 ± 96 cm/s (Table 1).

The degree of ICA stenosis with respect to the Doppler angle of insonation at the re-examination is shown in Table 2. In 15 arteries the estimated degree of ICA stenosis changed from 50–69% to 70–99% due to the application of a fixed Doppler angle of insonation at 60°. Of the 27 patent arteries with an angle of insonation less than 45°, 11 were allocated to a 70–99% ICA stenosis with a Doppler angle of 60°. On the other hand, only four of the 23 arteries with an angle of insonation >45° moved to a higher degree of ICA stenosis when the measurements were performed with a Doppler angle of 60°.

Discussion

Duplex scanning is an accurate non-invasive diagnostic method for imaging extracranial carotid arteries.8 It is apparent from several studies that angiography would not have altered the management in over 90% of patients scheduled for surgery.9,10 The experience gained from previous publications shows that carotid endarterectomy can be safely performed in selected patients based on findings obtained solely from duplex scanning.11–13 Duplex scanning has the ability to provide haemodynamic information as well as evaluating plaque morphology. However, duplex performance depends on the correct application of the method and the experience of the operator.11,12

Various spectral Doppler criteria have been used for definition of the degree of ICA stenosis.11–17 The widely used criteria from the University of Washington vascular laboratory were validated against angiography using a consistent Doppler angle of insonation of 60°.18 However, an angle of insonation of less than or equal to 60° has been commonly used in other studies.17 Byrd et al.19 evaluated the importance of standardisation in laboratories participating in the Asymptomatic Carotid Surgery Trial (ACST) and highlighted the importance of consistent Doppler angle in grading ICA stenosis. Questionnaires were sent to all vascular laboratories participating in the ACST which demonstrated that 61% of laboratories used a variable angle of insonation between 30–60°. Only 29% utilised a consistent Doppler angle of 60° at all times during scanning.

It is well known that using a Doppler angle greater than 60° increases the risk of error in determining the velocity. A 5° of error in estimating the Doppler angle at 30° will cause only a 5.4% error in velocity determination. However, at 60° this error becomes 12% and at 70° it becomes a 19% error.20 Therefore an angle of insonation of 60° or less has been recommended for velocity measurements. This is usually interpreted as meaning that a Doppler angle less than 60° has no significant impact on the velocity measurements. The results of this study demonstrated that higher peak systolic velocities were obtained using 60° angle of insonation compared to the measurements with lesser degrees. This difference altered the estimated degree of ICA stenosis from 50–69% to ≤70% in 15 out of 53 arteries. This has important implications on the selection of patients for surgical treatment.

It is important to mention that the true Doppler angle is the angle between the direction of flow and the Doppler beam, not between the axis of the artery and the Doppler beam. Colour flow imaging is a useful modality in determining the true angle. This is especially important when there is an off-axis jet, often seen at the site of stenosis. For most of the superficially located vessels running parallel to the transducer face, a beam flow angle less than 60° can be obtained by using beam-steering that is available in most of the
linear array probes. However, it is not always possible to align a fixed angle of insonation of 60° during carotid artery duplex scanning. The axis of the common or internal carotid artery may not lie within the scan plane. The arteries may be tortuous and sometimes the flow is not aligned with the axis of the artery. If a 60° of insonation cannot be achieved, the angle used should be noted for comparison of future examinations. In symptomatic patients with borderline velocity values, alternative diagnostic modalities such as MR or conventional angiography should be considered for reliable grading of ICA stenosis.

In conclusion, the results of this study highlight one of the most important but often neglected factors in determining the degree of ICA stenosis, the Doppler angle of insonation. Consistency of the Doppler angle is one of the crucial factors in order to obtain reproducible and reliable results.

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**References**


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