Diagnostic Performance of Duplex Ultrasonography in the Detection of High Grade Internal Carotid Artery Stenosis

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Objectives: to establish on a national basis whether the diagnostic accuracy of carotid duplex justifies carotid surgery without preoperative angiography.

Design: prospective national multicentre study with 10 participating university and county hospitals.

Material and Methods: one hundred and thirty-four patients, aged 69 ± 9 years, were subjected to routine carotid duplex ultrasonography and angiography. The influence of relevant factors on the relation between ultrasonographic and angiographic variables was evaluated using multiple regression analysis. The capacity of carotid ultrasonography to detect internal carotid artery (ICA) stenosis ≥80% was assessed by receiver operating characteristic analysis.

Results: the correlation between peak systolic velocity in ICA (PSV_{ICA}) and the angiographic degree of stenosis was strong and significantly influenced only by the applied Doppler angle. Accordingly, the optimal PSV_{ICA} cutpoint values for the diagnosis of ICA stenosis ≥80% (ECST method) differed substantially (2.1 and 3.2 m/s) between the two considered angle ranges (0±49° and 50±62°), the ability to identify high grade ICA stenosis being significantly better at small Doppler angles (0±49°).

Conclusion: ultrasonographic duplex technique identifies high grade ICA stenosis with a high degree of accuracy, which can be further improved by the application of small Doppler angles and the use of angle range specific PSV_{ICA} cut-off points.

Key Words: Carotid duplex ultrasonography; Angiography; Internal carotid artery stenosis.

Introduction

Many vascular centres now often rely entirely on duplex sonography1 to select the patients for carotid surgery,2–4 thereby avoiding the risk for complications to preoperative angiography.5

In recent years, several studies of the relationship between sonographically measured flow velocities and the angiographically determined degree of the carotid stenosis have been carried out.6–13 However, in most cases, this relationship was studied retrospectively and not all parameters that might influence the accuracy of the duplex measurements were evaluated in sufficient detail. The aim of this study, which was initiated by the Swedish Quality Board for Carotid Surgery, was to compare prospectively the results of ultrasound and angiography. The main intention was to establish on a national basis whether the diagnostic accuracy of different duplex variables is sufficient enough to justify carotid surgery without preoperative angiography.

Methods

Patients and procedure

All Swedish hospitals reporting to the national quality registry for carotid surgery were invited to participate and 10 hospitals accepted (Table 1). Four of these were university hospitals, the other six being county hospitals. The patients were recruited from January 1998 to February 1999. The results of duplex examinations were documented according to a specially designed protocol. The protocol was used in all patients with high grade symptomatic internal carotid stenoses, who were identified as possible candidates for subsequent carotid angiography. In the protocol, the examiner was to report not only on the peak systolic and end-diastolic velocities in the internal (ICA) and common carotid (CCA) arteries on both symptomatic and asymptomatic side, but also on the angle between the ultrasound beam and the flow direction during the flow velocity measurements. The examiner was also expected to report whether there was any indication of tight stenosis by the colour or power Doppler despite

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a normal or even low flow velocity in the internal carotid artery.

All patients who, for clinical reasons, were examined with the duplex technique and later with angiography were eligible. In total, 161 patients were recruited. Hard copies and protocols from the carotid duplex examinations and the angiographic images were sent to the two coordinating centres (The Department of Clinical Physiology, Huddinge University Hospital for duplex examinations and the Department of Neuroradiology, Karolinska Hospital for the angiograms) for further processing. Twenty-seven out of the 161 recruited patients were excluded from the study because of time delay between the duplex examination and angiography (>2 months; 13 patients), angiography prior to the duplex examination (4 patients), incomplete duplex protocol or discrepancies between protocol and hard copies (7 patients), and CCA stenosis or very distal ICA stenosis (3 patients). The study was performed in accordance with the ethical rules of the Ethics Committee of Karolinska Institutet and all patients gave their informed consent to the collection and use of the data from the two examinations.

### Carotid duplex ultrasonography

The duplex examinations were performed according to the routines adopted in the respective vascular laboratories. The following equipments were used: Acuson XP and Sequoia (Acuson), Ultramark 9 – HDI (Advanced Technology Laboratories), Apogee 400 (Interspec) and Sonos 5500 (Hewlett Packard). The majority of patients were examined employing an equipment provided by one manufacturer (see Table 1). Linear transducers within frequency range 5–10 MHz and, in a few cases, curvilinear transducers (4 MHz) were used. The protocols and hard copies from each examination were sent to the Department of Clinical Physiology at Huddinge University Hospital for approval, compilation and evaluation. Only flow velocities and angles of insonation given in the protocols and verified with hard copies were accepted for further processing. If the Doppler angle exceeded 62°, as was the case in three ICAs, the flow measurements were considered to lack sufficient precision and the data were abandoned. The following ultrasonographic parameters were evaluated: (i) peak systolic (PSVICA) and (ii) end-diastolic (EDVICA) flow velocity in the internal carotid artery, (iii) a ratio PSVICA/PSVCCA, and (iv) a ratio PSVICA/EDVCCA.

### Angiography

All participating centres were asked to perform the angiographic examinations according to their current routine, which in all cases involved intraarterial digital subtraction angiography performed by transfemoral catheterisation. In most centres, the examination started with the aortic arch angiography. In cases, in which a sufficient amount of information could not be secured solely on the basis of the aortic arch injection angiography, the procedure was supplemented by selective catheterisation of one or both of CCAs. Selective angiographies were obtained in 59 cases on the right and 65 cases on the left side. In one of the participating university hospitals only bilateral selective examination of CCAs was performed whereas in three of the county hospitals only aortic arch angiography was carried out. All centres were asked to submit films with a view of each ICA (both symptomatic and asymptomatic side) showing the maximal stenosis and at least one additional view of each ICA.

### Table 1. Number of patients included and the type of the ultrasonographic equipment used in the participating hospitals.

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Number of included patients</th>
<th>Used ultrasonographic equipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blekingosjukhuset</td>
<td>4</td>
<td>Acuson XP</td>
</tr>
<tr>
<td>Danderyds Sjukhus</td>
<td>11</td>
<td>Acuson XP and Sequoia</td>
</tr>
<tr>
<td>Falu Lasarett</td>
<td>8</td>
<td>Acuson XP</td>
</tr>
<tr>
<td>Huddinge Universitetssjukhus</td>
<td>30</td>
<td>Acuson Sequoia, and ATL Ultramark 9 HDI</td>
</tr>
<tr>
<td>Karolinska Sjukhus</td>
<td>27</td>
<td>Acuson XP</td>
</tr>
<tr>
<td>Malmo Allsanna Sjukhus</td>
<td>4</td>
<td>Acuson XP</td>
</tr>
<tr>
<td>Malarsjukhuset</td>
<td>8</td>
<td>Acuson XP, and HP Sonos 5500</td>
</tr>
<tr>
<td>Norrlands Universitetssjukhus</td>
<td>29</td>
<td>Acuson Sequoia, and Interspec Apogee 400</td>
</tr>
<tr>
<td>Regionsjukhuset i Orebro</td>
<td>9</td>
<td>Acuson XP</td>
</tr>
<tr>
<td>Sodersjukhuset</td>
<td>4</td>
<td>Acuson XP and Sequoia</td>
</tr>
<tr>
<td>Total</td>
<td>134</td>
<td></td>
</tr>
</tbody>
</table>

* Denotes a university hospital.
Measurements of the degree of ICA stenosis were performed at the angiographic coordinating centre by one experienced neuroradiologist blinded to the results of the carotid ultrasonography, which were evaluated at a different coordinating centre. When both aortic arch angiography and selective angiography were available, the measurements were made only in the radiograms from the selective study. For each ICA, the degree of stenosis was measured according to the European Carotid Surgery Trial (ECST) method and the common carotid artery method (Fig. 1). Measurements according to the North American Symptomatic Carotid Endarterectomy Trial (NASCET) were not performed in this study. All measurements were carried out according to the technique described by Rothwell et al. using an eyepiece with a scale of 0.2 mm. In some cases, in which the aortic arch angiogram was of insufficient quality, a selective angiography was performed on the symptomatic side alone. In some of these cases, the measurements of the degree of stenosis were possible only on the symptomatic side. The contralateral vessels in these cases (8 right and 4 left carotid arteries) were excluded from the study. In all other cases stenosis measurements were carried out on both sides.

Statistical analyses

Univariate relations between ultrasonographic duplex and angiographic variables were tested with regression analysis. Multiple linear regression model was fitted to the data explaining the variance in $\log_{10} PSV_{ICA}$. The analyses were carried out using GBSTAT 6.5 (Dynamic Micro Systems Inc., U.K.).

For each considered sonographic parameter, the relation between true-positive and false-positive rates, with the angiographically verified ICA stenosis of $\geq 80\%$ as a reference (ECST method), was evaluated at several discriminating thresholds by constructing receiver operating characteristic (ROC) curves based on boundary conditions restricting their theoretical shape.

To determine whether an ultrasound parameter provided a significant amount of diagnostic information regarding the occurrence of ICA stenosis of $\geq 80\%$, the $z$ statistic based on the slope $(m) \pm \text{SD}$ of the respective ROC curve was compared with $m = 1.0$, indicative of an uninformative test, with use of standard tables for normal distribution. The difference between two parameters’ discriminating abilities was assessed by calculating the area $(A)$ under the respective ROC curve as a percentage of the entire probabilistic area; the area under the identity line between true positive and false positive rate equal to $50\%$ of the entire probabilistic area being indicative of totally uninformative test. The $z$ statistic for a difference between the areas under the respective hyperbolic ROC curves was then calculated.

The Student’s $t$-test for paired samples was performed as appropriate. All values are given as means $\pm \text{SD}$. The significance level was set at $p = 0.05$.

Results

Measurement of the degree of ICA stenosis

Carotid duplex sonography and angiography data were acquired from 134 patients (88 men and 46 women) aged $69 \pm 9$ years. The number of included patients in each hospital is given in Table 1. The time interval between the duplex and angiography procedures was $\leq 1$ week in $50\%$, $\leq 1$ month in $87\%$, and $\leq 2$ months in all of the patients. No statistically significant differences were found between the angiographic estimations of ICA stenoses obtained with the two calculation methods employed. Thus, the mean degree of stenosis determined with ECST method was $64 \pm 29\%$ ($n = 124$) on the right and $71 \pm 24\%$ ($n = 129$) on the left side. The corresponding values achieved with common carotid method were $64 \pm 29\%$ and $70 \pm 25\%$. The distribution of the angiographic degree of carotid stenosis (determined with ECST method) between the patients and between the right- and left-sided ICA is given in Figure 2. Since only patients who qualified for angiography were
included in the present study, the high grade stenoses predominated. Thirteen ICAs were occluded as indicated by angiography, the occlusion being confirmed by the results of duplex sonography in 8 of these arteries. In the remaining 5 arteries, the ultrasound method failed to detect any occlusion. In 4 of these cases, only the aortic arch angiography was performed. One ICA was indicated to be occluded by duplex sonography, but the finding was not confirmed by angiography.

In 11 cases, a severe ICA stenosis was strongly suggested by colour or power Doppler images despite a concomitant low or normal peak systolic velocity. In 9 of these cases, angiography verified the presence of a high grade stenosis, whereas in 2 other cases, only a 50% and 43% reduction of lumen diameter, respectively, was calculated from the angiographic images, thus implying that the conclusions based on colour Doppler recordings resulted in an overestimation of the respective lesions in these cases. The ICAs which were classified as being afflicted with high grade stenoses solely on the basis of colour or power Doppler sonography and, in addition, those identified as occluded, were excluded from the following statistical analysis.

Univariate regression analysis

The correlation between ultrasound duplex parameters and angiographic degree of stenosis was best described by an exponential regression model (Table 2). As can be seen from the table, this relationship was similar for all the sonographic parameters considered and none of the parameters proved to be superior to the commonly measured peak systolic velocity. Figure 3 gives the details of the relationship between the angiographic degree of carotid stenosis and the right- and left-sided PSVICA, respectively.

Multiple regression analysis

Despite general recommendations for adopting a Doppler angle around 60° when measuring flow velocities in the carotid arteries, in this study the angles of insonation varied between 0° and 62°. The distribution of the employed Doppler angles is presented in Figure 4.

In order to estimate the influence of the adopted Doppler angle on the measured PSVICA, as well as the influence of other relevant parameters such as angiographic degree of stenosis, age, sex, the type of equipment and investigating vascular laboratory, a multiple regression analysis was performed. The angiographic degree of stenosis and the adopted Doppler angle were the only factors that were significantly associated with PSV both in right- and left-sided internal carotid artery (see Table 3). Together, these two factors explained 79% and 73% of the PSV variability on the right and left side, respectively. The respective regression equations for the right- and left-sided internal carotid artery are presented in Table 4. The table also gives the values of PSVICA calculated from these equations for the Doppler angles 20°, 40° and 60°, given an angiographic stenosis of 80% in the internal carotid arteries. As can be seen from the table
there is a substantial amount of variation in PSVICA measured at different insonation angles.

ROC analysis

Since there appeared no statistically significant differences between the right- and left-sided ICA as far as the relationship between PSV and angiographic degree of stenosis concerns, the ROC-analysis was performed on pooled data from both sides. Table 5 gives the mean values for the ROC indices (m and A) for all the sonographic parameters tested. As can be seen from the table, the slope (m) of the respective ROC curves differs significantly from the slope of a totally uninformative test (m = 1.0), thus implying that all the parameters possess the ability to identify >80% angiographic stenosis. It can also be seen, that there exist no statistically significant differences in this respect between the evaluated ultrasonic parameters with the ECST3 method as a radiographic reference.

Figure 5A shows the ROC curve for PSVICA. The curve indicates the PSVICA value of 2.6 m/s as the optimal cutoff point for the diagnosis of >80% ICA stenosis. This cutpoint offers the best combination of sensitivity (88 ± 3%) and specificity (86 ± 3%) values. When two separate ROC curves were constructed, one for PSVICA measured with Doppler angles within the range of 0±49° (Fig. 5B), and the other for PSVICA measured with Doppler angles between 50° and 62° (Fig. 5C), the diagnostic capacity of PSVICA differed between these two groups. Hence, the optimal cutpoint value for PSVICA obtained with Doppler angles between 0° and 49° was 2.1 m/s whereas the corresponding value of 3.2 m/s was found for PSVICA measured within the angle range of 50–62°, a finding consistent with the results of the multiple regression analysis (see Table 4). Furthermore, the ability to detect ICA stenosis of >80% was significantly better with PSVICA measured at an insonation angle within the 0–49° range (p < 0.01), offering at the optimal cutpoint a sensitivity of 95 ± 4% and specificity of 93 ± 4%, as compared to the corresponding values of 89 ± 4% and 89 ± 3% for PSVICA obtained within the angle range 50–62°.
The analyses were performed separately for the right- and left-sided ICA. Regression coefficient estimates and their corresponding 95% confidence intervals for some presupposed Doppler angles, given an angiographic stenosis of 80%. The calculations are based on the regression equations for the relation between PSVICA, Doppler angle, and the angiographic degree of stenosis on right and left side.

Table 4. Calculated values for PSVICA with corresponding 95% confidence intervals for some presupposed Doppler angles, given an angiographic stenosis of 80%. The calculations are based on the regression equations for the relation between PSVICA, Doppler angle, and the angiographic degree of stenosis on right and left side.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>β-coefficient</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiographic degree of stenosis</td>
<td>0.0097</td>
<td>20.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Doppler angle</td>
<td>0.0056</td>
<td>4.18</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 3. Final multiple linear regression model explaining the variation in log10 PSVICA, tested for the independent variables age, sex, angiographic degree of stenosis, adopted Doppler angle, vascular laboratory involved, and the type of equipment employed. The analyses were performed separately for the right- and left-sided ICA. Regression coefficient estimates and their corresponding t- and p-values are presented.

<table>
<thead>
<tr>
<th>Independent variable</th>
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</tr>
</tbody>
</table>

Discussion

The European Carotid Surgery Trial (ECST)\(^4\) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET)\(^2\) showed that internal carotid artery surgery, combined with medical treatment, was superior to conservative regimen alone in patients with TIA, minor stroke or amaurosis fugax, and ICA stenosis ≥70% (NASCET)\(^2\) or ≥80% (ECST)\(^4\), thus highlighting the importance of a proper identification of this patient category. Since these multicenter studies are based on radiographic estimation of the degree of stenosis, there has been a need for validation of the ultrasound technique, now generally used for diagnosis of high grade internal carotid artery stenosis. Furthermore, in recent years, duplex ultrasonography has been recommended as the sole diagnostic procedure prior to carotid surgery.\(^17\) A prerequisite for elimination of preoperative angiography is the availability of a reliable, high quality duplex ultrasonography, and the results of the present study indeed show that the ultrasound technique provides a high diagnostic accuracy when performed at the participating Swedish hospitals. Thus, using a cutoff value of 2.6 m/s for the PSVICA, a sensitivity of 88% and specificity of 86% was reached for the diagnosis of ≥80% ICA stenosis (ECST\(^2\) method).

No incremental accuracy was achieved with other quantitated flow parameters when compared to PSVICA. The levels of accuracy for the sonographic parameters presented currently are comparable to or somewhat lower than the corresponding levels reported from some previous studies.\(^6\)–\(^9\),\(^11\)–\(^12\) Two facts may explain the somewhat higher accuracy described in some of the previous reports. Firstly, the majority (5 out of 6) of these studies were retrospective, with the risk of selection bias. Secondly, all of these studies referred to patients recruited from only one institution.

Previous reports based on ultrasonographic examinations performed at several centres participating in the NASCET and ACAS trials\(^18\),\(^19\) showed a poorer relationship between the sonographic parameters and the radiographic degree of stenosis, suggesting that factors such as different examination technique and equipment might exert a significant influence in this respect. Indeed, it has been demonstrated recently, that the diagnostic capacity of duplex scanning for the detection of ICA stenosis varied significantly in terms of receiver operating parameters between two examining hospitals, despite the fact that the two hospitals used the same type of equipment and relied on the same physician interpreters.\(^20\) In order to evaluate the influence of the above-mentioned and other factors on the relationship between duplex parameters and angiographic degree of ICA stenosis, we performed a multiple regression analysis which showed that only the angiographic degree of stenosis and the Doppler angle were significantly related to the measured PSV in the internal carotid artery and explained about 75% of the PSV variability.

The influence of Doppler angle is most probably caused by a geometrical spectral broadening of the linear transducers, a phenomenon which leads to an overestimation of the true maximal velocity. As has been shown \textit{in vitro},\(^21\),\(^22\) this overestimation depends on the angle between the ultrasound beam and the direction of the moving ultrasound reflecting object, with an increasing overestimation occurring along
with an increasing Doppler angle. The results of these two in vitro studies are in accord with our clinical results. Hence, the currently observed varying relationship between PSVICA and radiographic degree of stenosis at different Doppler angles reflects an increasing overestimation of the maximal flow velocity at increasing Doppler angle (Table 4). The effect of Doppler angle is substantial and of clear clinical significance, being probably one of the reasons for the inconsistencies in previously suggested diagnostic PSV criteria for high grade ICA stenosis ranging from 2.1 to 3.25 m/s.6±8,11

The effect of Doppler angle on the relationship between PSVICA and radiographic degree of stenosis becomes also evident from the comparison of the ROC curves for PSVICA measured with Doppler angles within the range of 0–49° and 50–62°, respectively. Thus, the optimal cutpoint values for the diagnosis of radiographically verified (ECST3 method) ≥80% ICA stenosis differed (2.1 and 3.2 m/s, respectively) for the two angle ranges considered. Furthermore, the overall ability to identify high grade ICA stenosis was significantly better when PSVICA was measured with the Doppler angle at the lower range of 0–49°. The latter finding is important since it implies that the commonly recommended Doppler angle around 60° for velocity measurements in the internal carotid artery provides, in fact, less accurate discrimination between high and moderate degree of ICA stenosis.

Despite the generally accepted recommendation to use a Doppler angle of 60°, approximately 40% of the present examinations were performed with Doppler angles ≤50°. This is not entirely surprising. According to a report from an on-going multicenter study, 61% of the participating vascular laboratories applied varying angle of ICA insonation, shifting between 30° and 60° depending on particular local demands due to the vessel/stenosis anatomy.23 In view of our present data showing that differences between the flow velocity results obtained at different insonation angles can be substantial, it could be argued that a strict compliance to the previously recommended 60° Doppler angle is of special importance in securing correct flow velocity measurements. However, our data also show that such strict compliance to 60° angle recommendation would significantly reduce the diagnostic ability of the method and give less accurate estimation of ICA stenosis. This is not surprising since the error due to the cosine term in the Doppler equation increases along with the increasing Doppler angle. Therefore, the use of a small as possible insonation angle should be advocated. In addition, this should be combined with Doppler angle range specific PSVICA cutpoint values.

Fig. 5. ROC curves based on the data from PSVICA measurements in both right- and left-sided ICA for identification of ≥80% ICA stenosis. (A) – ROC curve for PSVICA measured with the Doppler angle 0–62°; (B) – ROC curve for PSVICA measured with the Doppler angle 0–49°; and (C) – ROC curve for PSVICA measured with the Doppler angle 50–62°. The fitted curves defining true-positive rate (TPR) at increasing false-positive rate are described by a slope, m.16 The individual data points represent the actual true-positive (TPR observed) and corresponding false-positive rates ±SD at the tested PSVICA cutoff values for the diagnosis of ≥80% ICA stenosis (ECST3 method). The cutoff values marking the boundaries of the tested cut point range and the optimal cut point values (bold style) for the respective ROC curves are indicated.
Factors such as age and sex, the investigating vascular laboratory and the ultrasound equipment did not seem to influence the relation between the PSVICA and the angiographic degree of ICA stenosis. The lack of the effect of age and sex was also previously reported7 and our present results are not controversial in this respect. On the other side, the occurrence of interequipment variability has been observed in an earlier study24 in which two different ultrasound equipment types that were employed in the present study as well produced significantly different PSV values from the same ICA segment. The fact that in our study the ultrasound equipment was dominated by only one manufacturer provides the most plausible explanation of the currently observed lack of interequipment variability.

As far as the calculation of the radiographic degree of ICA stenosis concerns, the present results did not reveal any statistically significant differences between the ECST3 and common carotid method.14,15 This finding is in keeping with a previous report of Rothwell et al.,15 being further confirmed by the outcome of the current ROC analysis which gave almost identical PSVICA cutpoint values for the diagnosis of ≥80% ICA stenosis with each of the radiographic reference methods employed (2.6 m/s with ECST3 and 2.7 m/s with common carotid method,14,15 respectively). One of the main purposes of this study was to compare the results of ultrasonography and angiography in cases with a tight ICA stenosis. Since a reduction of the normal ICA diameter distal to a stenosis will affect the results of measurements with NASCET2 method because of a partial ‘collapse’ of the distal ICA which may occur already in 70% stenosis (as measured according to ESCT3),15 we refrained from using this method of calculation.

Five out of 13 internal carotid arteries indicated as occluded by angiography, were not occluded according to the duplex examination. Based on colour or power Doppler images and low PSVICA, in 3 of these cases, the ICA stenosis was classified as very tight (preocclusion), whereas in 2 other cases the diagnosis of tight ICA stenosis was justified by high PSVICA values (3.4 and 4.3 m/s, respectively). The observed discrepancies may have arisen from the insufficiency of the aortic arch angiography to detect minimal blood flows. A possible occlusion of these tight or very tight stenoses during the time period between the ultrasonography and angiography may be another cause for the observed inconsistencies.

In conclusion, the present prospective national multicentre study demonstrates that the ultrasonographic duplex technique identifies high grade ICA stenosis with a high degree of accuracy. The diagnostic capacity of the method can be further improved by the application of small Doppler angles and the use of angle range specific PSVICA cutpoints.

Acknowledgements

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Appendix

Collaborators at participating hospitals:

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Falun Lasarett: Dr Johan Nordmark
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Karolinska Sjukhuset: Dr Nils Gunnar Wahlgren
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Mälarsjukhuset: Dr Ingvar Jansson, Dr Margit Svaahn and Dr Werner Fischer-Colbrie
Norrlands Universitetssjukhus: Dr Jan Malm and Dr Christer Backman

Table 5. Receiver operating characteristic indices based on pooled data from the right- and left-sided ICA (all slopes significantly different from slope = 1, p < 0.001)

<table>
<thead>
<tr>
<th>Ultrasonography (diagnostic criterion)</th>
<th>Radiographic reference method</th>
<th>ROC slope (m) (mean ± sd)</th>
<th>ROC area (A) (mean% ± sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSVICA</td>
<td>ECST3 method</td>
<td>0.029 ± 0.014</td>
<td>92.5 ± 2.2</td>
</tr>
<tr>
<td>PSVICA</td>
<td>Common carotid method14,15</td>
<td>0.022 ± 0.011</td>
<td>93.7 ± 2.0*</td>
</tr>
<tr>
<td>EDVICA</td>
<td>ECST method3</td>
<td>0.029 ± 0.021</td>
<td>92.1 ± 3.7</td>
</tr>
<tr>
<td>PSVICA/PSVCCA</td>
<td>ECST method3</td>
<td>0.031 ± 0.015</td>
<td>92.4 ± 2.3</td>
</tr>
<tr>
<td>PSVICA/EDVCCA</td>
<td>ECST method3</td>
<td>0.036 ± 0.016</td>
<td>91.1 ± 2.5</td>
</tr>
</tbody>
</table>

*p < 0.01 vs. PSVICA/EDVCCA.
Regionsjukhuset i Örebro: Dr Margareta Samuelsson, Dr Dan Lindell and Dr Niklas Rudbäck
Södersjukhuset: Dr Christian Carlström, Dr Håkan Bylund and Dr Stefan Rosfors

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