The inaccuracy of simple visual interpretation for measurement of carotid stenosis by arteriography

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Purpose: To determine intraobserver and interobserver variability of carotid arteriography interpretation as well as the reliability of simple visual interpretation (SVI) or “eyeballing” of arteriography in the measurement of internal carotid artery stenoses.

Methods: Intraobserver and interobserver measurements of 200 carotid arteriograms were performed in a blinded fashion by two vascular surgeons (VS1 and VS2) using a digital caliber computer program similar to software available in catheterization laboratories. The distal normal internal carotid artery was used as a frame of reference. These computer-derived measurements were compared with previous SVI measurements, found by retrospective chart review, that were performed at the initial time of arteriography.

Results: Intraobserver agreement (VS1a vs VS1b and VS2a vs VS2b) within ±5% using the computer program was 94% and 92%. Interobserver agreement within ±5% using the computer program for the four possible combinations ranged from 43% to 48%. Interobserver agreement using the computer program increased to 83% to 88% for correct stenosis interpretation within ±20%. In the 16% to 49% category (by computer measurement), SVI would have placed the stenosis in a higher category 40% to 56% of the time. Likewise, in the 50% to 79% category, comparing SVI with the four different computer caliber measurements, SVI overestimated the stenosis to the 80% to 99% category by 30% to 44%. In the 80% to 99% category, SVI overestimated lesions in 27% to 51% of the cases. All occlusions seen on SVI correlated with computer program measurements. The computer readings in many cases downgraded the degree of carotid stenosis into a lower category and in some cases, may have led to a different treatment paradigm. SVI never underestimated carotid stenosis compared with all matched computer program measurements.

Conclusions: Compared with a method of objective measurement similar to that used in a catheterization laboratory, SVI overestimated most carotid artery stenoses. Given the coming era of carotid stenting and a renewed need for arteriography before carotid intervention, knowledge of variability and correct interpretation of carotid stenosis using available technology remains paramount to warranted treatment. (J Vasc Surg 2005;42:62-6.)

With the approaching era of carotid artery stenting (CAS) comes a renewed obligate need for carotid and cerebral arteriography. Although duplex ultrasound scanning will continue to be the first-line test for screening and initial diagnosis, patients with a significant lesion by ultrasound scan and who are candidates for stenting will require arteriography. As devices are approved, technology advances, physicians become trained, and patient eligibility expands, CAS may soon supplant carotid endarterectomy in the large majority of patients.

Although surgeons from different specialties routinely perform carotid endarterectomy for the indications applicable to the operation and disease, the landscape of catheter-based procedures dramatically expands the potential physician base that will perform CAS. This reality, combined with the prevalence of the cerebrovascular disease and the less invasive nature of CAS, creates a new need for clinical equipoise in the correct interpretation of internal carotid artery stenosis before treatment.

Multiple studies have examined how to optimally measure internal carotid artery stenosis, but no study has previously addressed the critical question of how simple visual interpretation (SVI) compares with the best attempts to use the current technology to objectively determine internal carotid artery stenosis. Furthermore, the amount of variability of objective measurements between observers remains a very important question. Herein, we seek to answer these important questions in the coming era of CAS.

METHODS

A prospective database registry (PATS, Axis Clinical Software, Portland, Ore) maintained by the Division of Vascular Surgery at Southern Illinois University School of Medicine was queried for patients undergoing carotid arteriography during a 5-year period (August 1998 to 2003). All carotid arteriograms were performed by vascular surgeons using a fixed fluoroscopic imaging suite located at Memorial Medical Center in Springfield, Ill. Patients having carotid arteriography in preparation for carotid stenting and those having unilateral carotid arteriography were excluded. Indications for arteriography were variable and changed over the time period but included both symptomatic and asymptomatic patients.
Bilateral digital subtraction carotid arteriography included imaging of the aortic arch using a power injector and selective catheterization of each common carotid artery followed by manifold hand injection of contrast and multiplanar imaging. Intracerebral arteriographic imaging was also routinely obtained.

The degree of stenosis was determined by the attending vascular surgeon at the time of arteriography. The method of stenosis determination was by simple visual interpretation or “eyeballing” and was documented in the catheterization report. These reports were retrospectively reviewed, and the degree of internal carotid artery stenosis was obtained from them.

All arteriographic images of each carotid arteriogram were reviewed, and the optimal image showing the carotid bifurcation was chosen as the index image. All index images were photographed by using a digital camera (Canon EOS D30) and downloaded to a computer database.

Two vascular surgeons (VS1 and VS2) used a digital caliper computer program (Image J, PixelSmart, Lewis-town, NY) to objectively analyze the index images. VS1 and VS2 each measured the index images at two different periods with a 6-week lag time. Measurements between the vascular surgeons were blinded. Four objective measurement databases were created (VS1a, VS1b, VS2a, VS2b).

The method of determining the amount of internal carotid artery stenosis was identical to the North American Symptomatic Carotid Endarterectomy Trial Collaborators study, using the formula: degree of stenosis = internal carotid artery diameter – diameter of stenosis/internal carotid artery diameter × 100.

The Image J caliper program was used to create a perpendicular line that connected the perceived normal-appearing parallel portion of the internal carotid artery distal to the stenosis. Similarly, another perpendicular line was drawn at the area perceived as having the highest amount of stenosis. The placement of these perpendicular lines denoting distance from one arterial wall to the other was observer dependent. Measurement of internal carotid artery stenosis by SVI was obtained from the original catheterization report. Similarly, patients’ records were reviewed for demographic data including age, gender, symptoms, and atherosclerotic risk factors.

Intraobserver objective measurement variability was performed by comparing image datasets VS1a with VS1b and VS2a with VS2b. Percent agreement was computed to assess the consistency of the intraobserver measurements within ±5%. Interobserver objective measurement variability was performed by comparing image datasets VS1a with VS2a and VS1b with VS2b. Percent agreement was computed to assess the consistency of the interobserver measurements within ±5% and ±20%. Correlations between each of the four objective image datasets (VS1a, VS1b, VS2a, VS2b) with the visual interpretation were performed by placing the measurements into one of five categories: 0% to 15%, 16% to 49%, 50% to 79%, 80% to 99%, and occlusion. This generated four measurements (a range) of agreement when each of the objective computer based measurements was compared with the visual interpretation.

**RESULTS**

During the 5-year period, 200 carotid arteriograms were performed in 97 patients. Demographic data are shown in Table I. When the Image J computer program was used, 94% of intraobserver measurements for VS1 (VS1a compared with VS1b) and 92% for VS2 (VS2a compared with VS2b) were within ±5%. Interobserver measurement within ±5% agreement for VS1a compared with VS2a was 43%; VS1b compared with VS2b was 48%. If the threshold for agreement was increased to within ±20%, VS1a compared with VS2a was 83%, and VS1b compared with VS2b was 88%. Fig 1 illustrates an example of how interobserver variability occurred in certain patients.

SVI, when compared with the four objective Image J measurement data sets (VS1a, VS1b, VS2a, VS2b), often overestimated internal carotid artery stenoses, especially in

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**Table I. Demographic data from the 97 patients undergoing carotid arteriography**

<table>
<thead>
<tr>
<th>Category</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age</td>
<td>73.1 yrs</td>
</tr>
<tr>
<td>Female</td>
<td>59 (60%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>87 (90%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>24 (25%)</td>
</tr>
<tr>
<td>Tobacco use</td>
<td>71 (73%)</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>45 (46%)</td>
</tr>
<tr>
<td>Symptomatic</td>
<td>33 (33%)*</td>
</tr>
<tr>
<td>Lesions treated</td>
<td>42</td>
</tr>
</tbody>
</table>

*Used all 100 arteriograms.
the higher categories. Not only did SVI overestimate degree of stenosis but in many cases, placed the stenosis in a higher category compared with the computer-derived measurements. In the 16% to 49% category (by computer measurement), SVI would have placed the stenosis in a higher category 40% to 56% of the time. Likewise, in the 50% to 79% category, comparing SVI with the four different computer caliber measurements, SVI overestimated by 30% to 44% the stenosis to the 80% to 99% category. Table II summarizes this data. In the 0% to 15% category the accuracy of SVI was higher, yielding placement into a higher category 9% to 12% of the time.

All arteries that SVI considered to be occluded were confirmed by the computer program. Overestimation by SVI was observed in the 80% to 99% category as well. The four computer-generated measurements would have placed the stenosis of 80% to 99% determined by SVI in a lower category 27% to 51% of the time. Table II summarizes this data. In the 0% to 15% category the accuracy of SVI was higher, yielding placement into a lower category 9% to 12% of the time.

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### DISCUSSION

In 1954, Eastcott and Rob5 performed the first carotid endarterectomy to prevent stroke. Since that pivotal intervention, no single noncoronary vascular disease has received as much clinical study as extracranial cerebrovascular disease. Fueled by differing beliefs for treatment throughout the past 40 years, many clinical studies have clearly provided level 1 data to prove the efficacy of carotid endarterectomy in the prevention of stroke.5-8

Yet despite the effectiveness and durability of carotid endarterectomy, carotid artery stenting is now on the verge of becoming the preferred method of intervention for stroke prevention. The technologic explosion in guidewires, catheters, stents, and embolic protection devices has given rise to a return in the need for mandatory arteriography before treatment.9 Simply stated, stroke risk correlates to the degree of stenosis and thereby dictates treatment.

Our study is the first to document how much variability occurs when a computer program similar to the technology available is used to measure stenosis in the catheterization or interventional suite. We further have defined how these objective measurements compare with the commonly used method of SVI.

Although there was a significantly large amount of variability for interobserver objective computer measurements in our study, intraobserver measurements varied little. The amount of interobserver variability between objective measurements was not that surprising given the dependence on the vascular surgeon to subjectively choose the position to place the shortest line within the stenosis and within the “normal” parallel distal internal carotid artery. Fig 1 demonstrates the lines drawn to calculate stenosis on the same patient by VS1 and VS2. Interobserver variability probably stemmed most from defining the area of “normal” parallel distal internal carotid artery.

### Table II. The breakdown of categories by digital computer program (four different readings) and the degree of overestimation made by simple visual interpretation

<table>
<thead>
<tr>
<th>Category</th>
<th>N (%) DCP VS1a*</th>
<th>N (%) DCP VS1b†</th>
<th>N (%) DCP VS2a‡</th>
<th>N (%) DCP VS2b§</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%-15%</td>
<td>49/200 (25)</td>
<td>52/200 (26)</td>
<td>48/200 (24)</td>
<td>46/200 (23)</td>
</tr>
<tr>
<td></td>
<td>7/49 (12), 6/52 (11), 4/48 (8), 4/46 (9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16%-49%</td>
<td>51/200 (26)</td>
<td>49/200 (25)</td>
<td>41/200 (21)</td>
<td>45/200 (23)</td>
</tr>
<tr>
<td></td>
<td>28/51 (56), 27/49 (55), 19/41 (46), 18/45 (40)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%-79%</td>
<td>42/200 (21)</td>
<td>41/200 (21)</td>
<td>58/200 (29)</td>
<td>55/200 (28)</td>
</tr>
<tr>
<td></td>
<td>17/42 (41), 18/41 (44), 19/58 (35), 16/55 (30)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%-99%</td>
<td>45/200 (23)</td>
<td>45/200 (23)</td>
<td>40/200 (20)</td>
<td>41/200 (21)</td>
</tr>
<tr>
<td></td>
<td>NA**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusion</td>
<td>13/200 (7)</td>
<td>13/200 (7)</td>
<td>13/200 (7)</td>
<td>13/200 (7)</td>
</tr>
</tbody>
</table>

DCP, Digital computer program; VS, vascular surgeon; SVI, simple visual interpretation.

*First interpretation by digital computer program by vascular surgeon 1.
†Second interpretation by digital computer program by vascular surgeon 2.
‡First interpretation by digital computer program by vascular surgeon 2.
§Second interpretation by digital computer program by vascular surgeon 2.

**Carotid stenoses determined to be 80% to 99% by computer program were never overestimated to occlusion.

### Table III. Degree of overestimation by simple visual interpretation compared with the four digital computer program determinations in the category of 80% to 99% stenosis

<table>
<thead>
<tr>
<th>Category</th>
<th>Number by SVI</th>
<th>Placed in lower category by VS1a</th>
<th>Placed in lower category by VS1b</th>
<th>Placed in lower category by VS2a</th>
<th>Placed in lower category by VS2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%-99%</td>
<td>45</td>
<td>23 (51%)</td>
<td>21 (47%)</td>
<td>14 (31%)</td>
<td>12 (27%)</td>
</tr>
</tbody>
</table>

SVI, Simple visual interpretation; VS, vascular surgeon.
Our data analysis did not include examination of variability of each line drawn, but rather the actual stenosis calculated. Perhaps more work needs to be done in an attempt to standardize how to precisely determine the optimal normal area of internal carotid artery distal to the stenosis. There are infinite areas of potential line placement in the “normal” internal carotid artery distal to the stenosis. Three-dimensional re-creations of a stenosis aided by computer software to consistently calculate the degree of narrowing during a carotid arteriogram may represent another potential avenue of improvement to standardize measurement. This suggestion must be taken with the caveat that treatment recommendations for carotid stenosis have traditionally been determined from two-dimensional arteriograms. Lastly, in this venue, it should be stated that at some point, determining the precise location of the normal distal internal carotid artery becomes moot because the lesion is extremely stenotic.

The accuracy of visual interpretation of internal carotid artery stenosis compared with the criterion standard of arteriography has not been previously reported to our knowledge. When traditional categories of stenosis ranges for carotid stenosis (0% to 15%, 16% to 49%, 50% to 79%, 80% to 99%, and occluded) were used for ease of comparison, visual interpretation underestimated internal carotid artery stenoses at an alarming rate in all categories. More worrisome were the amount of stenoses noted to be <80% in the four objectively measured data sets (VS1a, VS1b, VS2a, VS2b). Depending on the data set, this ranged from 27% to 51% of the time. Several reasons for this high rate may be responsible:

First, comparisons were made retrospectively to a dictated report done at the time of the original procedure and not for purposes of this study. Perhaps a more accurate visual interpretation would occur on a prospective basis.

Second, the overall visual interpretation may take into account the larger common carotid artery. Although this is difficult to prove objectively, the interpreter probably looks at the arterial tree as a whole in relation to the stenosis instead of imagining straight lines in the stenosis and normal distal internal carotid artery.

Finally, our visual interpretation was made without the use of calipers, which some surgeons commonly use to compare stenoses. More work is needed to determine if this method provides acceptable accuracy.

Not surprisingly, visual interpretation of coronary arteriograms has been shown to be inaccurate. Fleming et al demonstrated in 241 coronary studies that 38% were significantly overestimated by visual interpretation. Another study by Schwieger et al compared four interpreters’ measurements of coronary stenosis using both a digital caliper computer program and visual estimation. Among the findings were that visual interpretation commonly overestimated stenoses and had the highest amount of variability. Most important, the authors translated these results into some patients having unnecessary procedures.

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**Fig 2.** Patient underwent carotid arteriography for symptomatic cerebrovascular disease with history of a right-sided transient ischemic attack. The original degree of stenosis by visual interpretation was determined to be 80% to 85%. A digital caliper program and the North American Symptomatic Carotid Endarterectomy Trial Collaborators formula were used to calculate a corrected stenosis of 50%. Measurement numbers represent pixel lengths from the digital caliper program.

**Fig 3.** Patient underwent carotid arteriography for asymptomatic stenosis found by Duplex ultrasound scanning. The original visual interpretation of this lesion was given as a 75%. A digital caliper program and the North American Symptomatic Carotid Endarterectomy Trial Collaborators formula were used to calculate a corrected stenosis of 42%. Measurement numbers represent pixel lengths from the digital caliper program.
Although there may be only one true internal carotid stenosis at any one moment in time, determining this may be next to impossible secondary to the limitations in the current imaging modalities combined with interpreter variability. Nevertheless, correct decisions to intervene on high-grade stenoses based on arteriogram can be made, which improves outcomes. In many cases, SVI overestimated the degree of stenosis by enough that the patient would have been placed in a lower stenosis category if computer measurements had been done initially. This was observed in patients with moderate stenoses (50% to 79% range) and high-grade stenoses (80% to 99%). These findings may portend that some patients had carotid endarterectomy for stenoses incorrectly determined by SVI. Surgeons who use SVI in other vascular surgical procedures may take notice that this is a flawed method of interpretation.

Now that multiple specialties are performing carotid stenting and treatments are based on the finding of arteriography, correct interpretation remains paramount to continuing to improve outcomes. Our study demonstrates that for moderately stenotic internal carotid stenoses, significant blinded variability exists between interpreters. Given this fact, consensus among interpreters may be prudent before treatment.

Finally, SVI represents an inferior method of determining internal carotid artery stenosis in the coming era of carotid stenting. Again, the prevalence of moderate internal carotid stenosis combined with the less invasiveness of the procedure and multiple specialties vying for the same patient, leads to the potential for overestimation of stenosis and unnecessary treatments.

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REFERENCES


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