Clinical trials of carotid endarterectomy (CEA) published over the last decade in both symptomatic and asymptomatic patients have emphasized the importance of accurate vascular imaging prior to operation. Different methods of evaluating carotid stenosis using digital subtraction angiography (DSA) and between ultrasound and angiographic measurements explain many of the discrepancies between clinical outcomes of the different surgical trials. DSA is usually considered the “gold standard” but has a 1% to 2% stroke and death rate, which significantly impacts combined mortality and morbidity of carotid endarterectomy as low as 1.5%. However, no consensus has yet been arrived at for noninvasive imaging alternatives (ultrasound alone, magnetic resonance angiography [MRA] alone, or both combined) to replace DSA. In a recent “Controversies” section of this journal, strongly contrasting viewpoints on the value of ultrasound and MRA were followed by comments by the section editors, who even disagreed with each other.

Different surgical specialties also differ from each other in presurgical imaging assessment. In a recent survey in Canada of surgeons specializing in carotid endarterectomy, 50% still used DSA as their method of choice, but whereas 46% of vascular surgeons used ultrasound alone, this was used as the sole method of neurovascular imaging in only 11% of neurosurgeons (a significant difference, \( P = 0.002 \)). Published data comparing ultrasound to DSA (assuming this is the gold standard) all indicate a high degree of specificity and sensitivity, but not 100%, so leaving room for errors in surgical judgment. Also ultrasound remains inaccurate in evaluating carotid occlusion, despite technical advances. But is DSA really the gold standard? When the lumens of excised plaques were compared with those evaluated by DSA, universally accepted standard methods of measuring the degree of carotid stenosis were found to consistently underestimate the severity of stenosis, sometimes alarmingly due to the discrepancy between linear measurements by DSA versus cross-sectional measurements by ultrasound. However, in vivo measurements of plaques in general correlate significantly better with ultrasound (\( r = 0.80 \)) than with MRA (\( r = 0.76 \)). Muddying the water even more for the gold standard is the variation in interrater reliability when “blinded” external observers differ from the interpretation of the official catheter angiography reports, which most clinicians rely on for surgical decision making. In one study, kappa values for comparisons between officially reported DSA and those of the blinded reviewers were only just acceptable at 0.81 to 0.82.

MRA in general fares better than ultrasound, especially with the introduction of contrast enhancement of MRA in recent years, which has added extra accuracy. There are many studies comparing ultrasound, MRA, and catheter angiography from a variety of sources, including neurological, surgical, and radiological groups. Unfortunately, many of these suffer from serious methodological flaws, such as “nonblinding,” unacceptable delays (often months) between ultrasound and angiography, lack of gold standard comparison, and “cherry picking” best results instead of enrolling consecutive patients, making evidence-based comparisons difficult. Nevertheless, the most recent meta analysis incorporating 63 patient series (all performed after 1994, and comparing the 3 methods) yielded very promising results, with a pooled sensitivity of MRA of 95% and specificity of 90%, with corresponding indices for ultrasound of 86% and 87%. For occluded vessels the results were even better. MRA scored a sensitivity of 98% and specificity of 100%, and ultrasound 96% and 100%, respectively. MRA was superior to ultrasound in discriminatory power, at least with stenoses 70% to 90%. In a study of 50 consecutive patients comparing DSA with contrast-enhanced MRA, sensitivity was 92% but specificity was only 62%, and 24% of carotid arteries would have been misclassified for carotid surgery. In those in whom the ultrasound results were concordant with the MRA findings, misclassification fell to 17%, making a strong case for not relying on either method alone. However, even this low level of error could prove serious, if some patients who need carotid endarterectomy are denied it, while others could have all the risks of surgery but none of the benefits.

Despite all these limitations, we know that present surgical practice of CEA in many (if not most) centers relies heavily on ultrasound alone, or at best, ultrasound associated with MRA at some stage. Since this is the common approach to the most frequently practiced vascular surgical procedure in the world, it is worth further scrutiny. In practice, most surgeons “mix and match” the way they apply evidence-based data from each of the neurovascular imaging techniques. For instance, there are other more subtle factors not evident in trial or study surveys, such as regional discrepancies between the accuracy of different procedures. Probably the major drawback of carotid ultrasound imaging is its high dependency on technological reliability, in both performance and interpretation. Below 50% it is highly unreliable for...
determining the degree of stenosis, and although improving, it still has difficulty differentiating occlusion from 99% stenosis, a critical point for surgical decision making. The failure to accurately detect intracranial stenosis has been overemphasized, since at least in the developed world, this is a distinctly unusual and usually irrelevant finding. Similarly, the miniscule risk of missing an intracranial aneurysm should be factored into the overall safety of the ultrasound procedure.

In an ultrasound laboratory where accuracy and reliability are established and annually reviewed (as in accredited laboratories in the United States), this technique can be reliably used for determining carotid stenoses 50% to 99%, if the results of the technical recordings are clear and indisputable. However, this should then be confirmed, either by a separate examination by another blinded technician, or by comparison to the previous ultrasound examination from the referring physician. The delay between the 2 recordings must have a minimum time gap, probably no more than 2 to 3 weeks. When there is any doubt, an MRA, preferably contrast enhanced, should be performed. Special care should be exercised when evaluating severe bilateral stenoses, due to the artifact produced by mutual flow changes that may exaggerate the stenosis of the artery of interest. Using the internal-common carotid velocities ratio usually overcomes this problem. In patients with carotid stenoses high in the neck, with unusually long lesions, arterial kinking, or other unusual anatomy, MRA examination should also be added.

Using these guidelines, is there still a place for catheter arteriography in pre-endarterectomy neurovascular imaging? The need is becoming vanishingly small, but the procedure is still occasionally necessary as an arbiter when the results of ultrasound and MRA are not concordant. The role of computed tomographic angiography looks promising but has yet to be evaluated. Finally, we would agree with the opinion of previous commentators in this journal that the present shift in clinical practice to these noninvasive vascular procedures is irreversible and can only be to the advantage of patients worldwide.

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Is Ultrasound Sufficient for Vascular Imaging Prior to Carotid Endarterectomy?
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