Imaging for Carotid Artery Stenosis

- Patients with severe carotid artery atherosclerosis are at high risk for stroke and may benefit from revascularization.
- Duplex ultrasonography (DUS) of the carotid artery is recommended for asymptomatic patients:
  - With carotid bruits,
  - Who have experienced transient ischemic attacks (TIAs) in the recent past,
  - Who have experienced a stroke,
  - During pre-operative evaluation for coronary artery bypass graft surgery (CABG) or aortic valve replacement (AVR) (selected patients), and
  - For follow-up imaging after carotid revascularization.
- CTA is recommended as an initial exam for emergency patients with a high likelihood of neurovascular disease requiring immediate therapy.
- MRI/MRA is recommended as initial exam for patients presenting with a TIA in the emergency setting.

Emboli arising from occluded carotid arteries account for an estimated 20-30% of ischemic strokes. Revascularization through carotid endarterectomy or stent placement reduces the risk of stroke and resultant disabilities and imaging plays a pivotal role in identifying patients who may benefit from treatment. Carotid artery duplex ultrasonography (DUS) is the most appropriate choice for screening and initial evaluation because it is low cost, non-invasive, and does not involve radiation exposure. CT angiography (CTA) and MR angiography (MRA) are useful for further elucidation and for patients who present with stroke or have experienced a TIA.

Indications for Imaging

Imaging of the carotid arteries is recommended for screening for carotid artery disease in patients with carotid bruits, patients who have experienced transient ischemic attacks (TIAs), and patients who have experienced a stroke. Carotid bruit is neither specific nor sensitive for carotid artery disease, although a carotid bruit is an independent predictor of cardiovascular and all-cause mortality. Although approximately one third of patients with carotid bruits have been shown to have clinically relevant carotid stenosis, many patients with severe stenosis do not have a bruit.

Patients who have experienced a TIA, defined as a focal neurological deficit lasting less than one hour, have been shown to have an 11% risk of a stroke within 90 days. Therefore, such patients should be evaluated for carotid stenosis as soon as possible.

Figure 1. Diagnostic algorithm for asymptomatic carotid stenosis. *A stroke workup should proceed directly to CTA whereas TIA is initially evaluated with MRA, with CTA to confirm/clarify findings if needed.
possibility after a TIA. Patients experiencing an acute stroke should also undergo carotid imaging to look for evidence of carotid artery occlusion as a potential source of emboli and to serve as a baseline for future imaging studies. In the emergency setting, CTA is the examination of choice for patients with a high likelihood of neurovascular disease requiring immediate therapy. For those with a lower probability of neurovascular disease requiring immediate therapy, carotid DUS followed by MRA and brain parenchymal MR imaging is recommended.

Imaging is also recommended for selected patients who are candidates for coronary artery bypass surgery (CABG) or aortic valve replacement (AVR) surgery. Criteria for pre-operative evaluation include age >60 years and/or a minimum of two cardiovascular risk factors, such as hypertension or elevated cholesterol. Patients who have undergone revascularization (carotid endarterectomy or stent placement) should receive routine follow-up imaging to identify intimal hyperplasia or stent patency/fracture.

**Duplex Ultrasonography (DUS)**

DUS is the method of choice for screening as it is a relatively inexpensive screening method and does not involve radiation exposure. It is reliable for detecting stenosis when performed by a skilled vascular technologist. A bilateral examination of the common carotid artery (CCA), internal carotid artery (ICA), external carotid artery (ECA) and vertebral artery (VA) is routinely performed. Grey-scale images identify plaque location and composition (homogeneous, heterogeneous, and/or calcified). Doppler imaging is used to determine the peak systolic velocity (PSV) and the end-diastolic velocity (EDV) at standardized sites, including the origin, proximal and distal CCA; proximal, mid, and distal ICA; proximal ECA; and proximal/mid VA.

Scanning in multiple planes may be necessary to minimize acoustic shadowing caused by calcified plaque, which, if severe, can limit the accuracy of Doppler interrogation. Anatomical limitations prevent DUS imaging of the distal ICA, although changes in the proximal ICA waveforms can suggest the presence of stenosis in more distal regions. Routine DUS can be insensitive to very low velocities and, therefore, may miss critical stenoses of >99%. Compensatory hemodynamic changes can also lead to misleading DUS data. Therefore, if a stenosis of ≥50% is detected or the findings are inconclusive, further non-invasive imaging with CTA or MRA may be indicated.

**CT Angiography (CTA)**

CTA is a widely available imaging method and it has the advantage of high resolution and rapid acquisition times. Because it is a fast scan, image degradation due to patient motion is less common than with MRA. CTA relies on intraluminal contrast rather than signal changes due to blood flow, as in Doppler ultrasonography or non-contrast MRA. Image resolution is sufficient to discriminate between occlusion from a hairline residual lumen. CTA also shows surrounding anatomy, such as bony structures, which may be useful for surgical planning. Post-processing can be
used, for example, to display 3D surface-shaded images that show surrounding anatomy or to show the course of the vessels in maximum intensity projection images (MIP). Because CTA involves radiation exposure, it is not considered an ideal technique for repeat imaging for young patients.

At the MGH, a 64-detector scanner is used to image the region from the foramen magnum to the aortic arch after administration of iodinated contrast material. CTA has excellent sensitivity and specificity. In a meta-analysis that compared CTA to the gold-standard, catheter-based digital subtraction angiography, CTA diagnosed the degree of carotid occlusion with an overall sensitivity of 97% and a specificity of 99%. For severe stenoses (70-99%), the sensitivity and specificity of CTA was 85% and 93%, respectively. The sensitivity and specificity of detecting an occlusion in the ICA has been shown to be 97% and 99%, respectively.

Limitations of CTA include heavy, circumferential calcification, which can cause beam-hardening artifacts that can result in over-estimation of stenosis. Metal stents can also result in artifacts, although new post-processing techniques can minimize such problems. In addition, because CTA requires the administration of iodinated contrast, use in patients with chronic kidney disease is discouraged.

**MR Angiography (MRA)**

MRA does not expose the patient to radiation and can be performed with or without a contrast agent. Contrast-enhanced MRA appears to be the most accurate non-invasive imaging modality and is regarded by some as the gold standard for visualizing stenosis in the ICA. MRA also offers the advantage of being able to add concurrent brain imaging to the examination. However, MRA is relatively time consuming and is more costly than either DUS or CTA.

Non-contrast MRA depends of the movement of magnetized blood and the images can be degraded by conditions such as turbulence and slow flow. As a result non-contrast MRA has a tendency to overestimate the degree of stenosis and cannot distinguish between a hairline lumen and an occlusion. However, non-contrast MRA appears to be as accurate as contrast-enhanced MRA for detecting ≥70% stenosis and it has the advantage of avoiding the administration of contrast agents, which are best avoided in patients with poor kidney function.

As in all MR imaging, image quality can also be degraded by patient motion, including swallowing and vessel pulsation. Stents also cause signal drop out due to metallic artifacts and, therefore MRA is not recommended for assessing the patency of stents.

**Scheduling**

Appointments can be scheduled by calling **617-724-9729, 617-726-2034**, or through the Radiology Order Entry system, [http://mghroe/](http://mghroe/).

DUS imaging is available at the main campus, the MGH Chelsea Healthcare Center, the Mass General / North Shore Center for Outpatient Care, Danvers, Mass General Imaging Waltham and at the Mass General Vascular Center in Waltham, and Mass General Imaging Worcester.

CTA is available at the main campus, Mass General / North Shore Center for Outpatient Care, Danvers, Mass General Imaging Chelsea, Mass General Imaging Waltham, and Mass General Imaging Worcester.

MRA is available at the same locations as CTA with the exception of Mass General Imaging Worcester.

**Further Information**

For more information about carotid imaging, please contact, **Javier Romero, MD**, Director of Ultrasound Imaging Services and Associate Director of the Neurovascular Laboratory, 617-724-7095 or **Michael R. Jaff, DO, RPVI**, Chair, MGH Institute for Heart, Vascular and Stroke Care, Mass General Hospital, at 617-726-3784.

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References


Figure 1. Diagnostic algorithm for asymptomatic carotid stenosis.

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