Radiology Rounds

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CT and MR Imaging for Evaluation of Acute Stroke

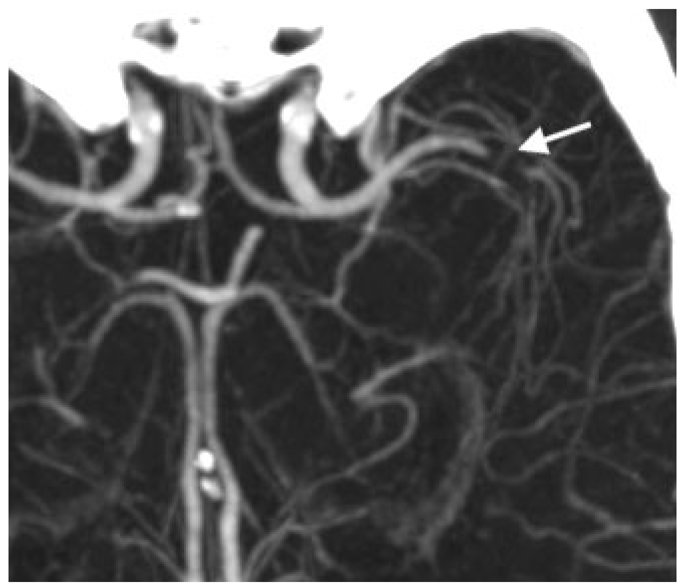
- **Non-contrast CT detects hemorrhage or other possible causes of symptoms, if present.**
- **CTA (CT angiography) detects site of circle-of-Willis occlusion, carotid stenosis, or other vascular abnormalities.**
- **Regions of profound ischemia, likely to be irreversibly infarcted, are detected by CTA parenchymal "source" images and, with greater sensitivity, by DWI (diffusion weighted MR imaging).**
- **"Potentially salvageable" ischemic regions that may be targets for thrombolysis are detected by CTP (CT perfusion) and, with greater coverage, by PWI (perfusion weighted MR imaging).**
- **The data from these advanced CT and MR techniques is often complimentary, and helps triage patients to appropriate therapy and management.**

When a patient arrives with symptoms of stroke, prompt imaging is a vital part of the work-up. For patients with ischemic stroke, thrombolytic therapy with intravenous tissue plasminogen activator (t-PA) must be given within the first 3 hours and intra-arterial thrombolytic therapy must be administered within 6 hours after the onset of symptoms to be effective. Late therapy limits the efficacy of treatment and increases the likelihood of brain edema and hemorrhage, which may be life threatening. Therefore, the potential benefits of recanalization must be weighed against the risks of increased morbidity and mortality. CT and MR imaging now play a significant role not only for diagnosis but also for assessing the volume of ischemic damage and amount of residual perfusion. This data, although still under investigation, plays a role in decision making on whether it is appropriate to give the patient thrombolytic treatment.

CT Scans and CTA for Acute Stroke

The first diagnostic scan in an emergency setting is typically a non-contrast CT to determine whether the symptoms are due to intracranial hemorrhage or there are other lesions, such as a tumor that are causing the symptoms. CT is very rapid and, unlike MRI, is not contraindicated by implants such as pacemakers, clips, or other metal objects, whose presence may not be established before emergent imaging.

If the non-contrast CT image appears normal, the next step at MGH is to administer a non-ionic iodinated contrast agent and perform a CTA scan of the entire



3-D CTA image of intracranial circulation showing occlusion of middle carotid artery (arrow).

neurovascular system, from the top of the head to the aortic arch. High resolution (pixel size, 0.4 mm) CTA images can be rapidly post-processed at the CT scanner console into 3-D images, which are used to determine whether the symptoms are due to partial or complete occlusion, dissection, trauma damage, arteriovenous malformation, or aneurysm. CTA images can also show calcification and some arterial wall thickening due to atherosclerotic plaque. However, dense circumferential calcification may obscure a stenosis, and CTA does not have sufficient resolution to detect vascular occlusions at distal sites.

Information about tissue level, parenchymal brain perfusion may be obtained by rapid injection of a small additional dose of contrast for dynamic first-pass bolus imaging. Although, currently, coverage is limited by the width of the CT detectors to a 2 cm thick “slab” of brain per contrast bolus, future generations of CT scanners, available soon, will have at least double that coverage.

From the sequential images acquired as contrast passes through the tissue capillary bed, it is possible to calculate quantitative cerebral blood flow (CBF), blood volume (CBV), and the mean transit time (MTT), on a pixel-by-pixel basis. Blood volume weighted lesions – like MR-DWI lesions – tend to be present in regions of severe ischemia, likely to be irreversibly infarcted. CTA source images have the advantage of providing blood volume weighted imaging of the entire brain, although they have the disadvantage of being weighted by their unenhanced CT components as well.

	Advantages	**Limitations**
CT	Fast Widely available High resolution CTA sensitivity for large vessel occlusion, 98% CTA images show thickening and calcification of arterial wall CTA source images show region with low blood volume (ischemic core)	Non-contrast CT has an approximately 50% accuracy for acute stroke detection CTA may miss distal occlusions Exposure to radiation Iodinated contrast administration with potential allergy or toxicity*
MRI	DWI abnormalities visible within minutes of stroke onset with sensitivity, 94%; specificity, 96% DWI more accurate for detecting brain stem and lacunar infarction DWI abnormalities highly likely to progress to infarction (ischemic core)	Contraindicated for patients with pacemakers, clips, or other metal objects Subject to movement artifacts MRA images have lower resolution and sensitivity than CTA Difficult to perform during intensive patient monitoring, such as that required for the administration of IV-tPA

* Radiology Rounds, October 2003, http://www.massgeneralimaging.org/newsletter/october_2003/

MRI and MRA for Acute Ischemic Stroke

Diffusion weighted MR imaging detects alterations in the normal pattern of movement of cellular water due to stroke. Diffusion is restricted, within minutes of stroke onset, due to cell swelling, caused by severe restrictions of blood flow. DWI is highly sensitive and specific for detecting severely ischemic lesions in the brain, regions with a high probability of irreversible infarction. Multiple DWI lesions in different vascular territories, if present, provide evidence that the stroke is caused by emboli, which are often associated with cardiac arrhythmia. Abnormalities on T_2 weighted images do not typically appear until at least 6 hours after symptom onset and, therefore, a DWI abnormality with no T_2 abnormality gives some indication of the timing of the stroke when this is unknown (as in “wake up” strokes).

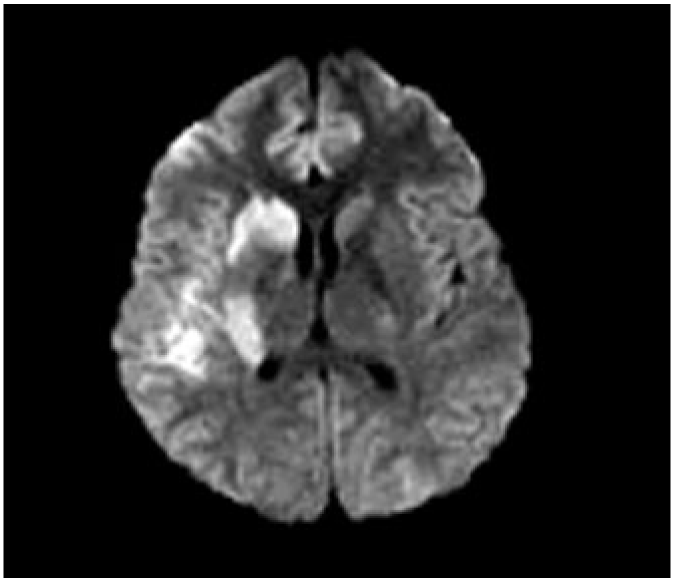
Gadolinium contrast injection can also be used to generate MR angiography (MRA) images of the neck and great vessel origins, although this is not typically part of the acute stroke imaging protocol. However, although MRA images are inferior to CTA with respect to resolution and artifacts, they may be useful if there is a significant degree of atherosclerotic calcification.

Perfusion Imaging

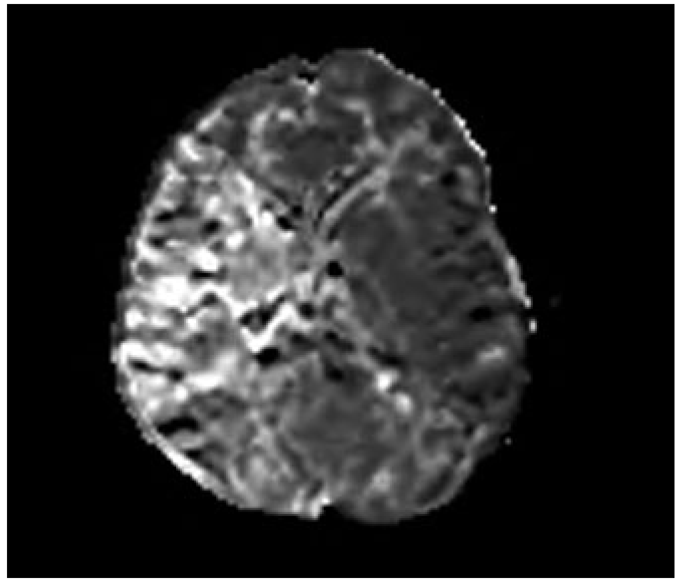
Information about tissue level, parenchymal brain perfusion may be obtained with CT by rapid injection of a small additional dose of contrast for dynamic first-pass bolus imaging. Although, currently, coverage is limited by the width of the CT detectors to a 2 cm thick “slab” of brain per contrast bolus, future generations of CT scanners, available soon, will have at least double that coverage. From the sequential images acquired as contrast passes through the tissue capillary bed, it is possible to calculate quantitative cerebral blood flow (CBF), blood volume (CBV), and the mean transit time (MTT), on a pixel-by-pixel basis.

MR perfusion weighted images (PWI) are acquired by serial imaging of the whole brain as a bolus of gadolinium contrast agent passes through the vasculature. As in perfusion CT, computer processing provides data about CBF, CBV, and MTT.

If there are perfusion deficits that extend beyond the DWI or CT-CBV deficit, then that patient may be a candidate for treatment with intravenous t-PA if symptom onset was within 3 hours or by intra-arterial t-PA if symptom onset was within 6 hours. However, if no MR DWI-PWI or CT CBV-CBF mismatch is present to define “tissue at risk”, thrombolytic treatment may not be appropriate.



A. DWI showing bright region of abnormalities due to severe ischemia.



B. MTT image of same patient, showing bright region of perfusion deficit that is larger than DWI lesion and indicating that this patient may benefit from thrombolytic treatment if stroke onset was within past 3-6 hours.

Further Information

Neuroradiologists are available at all times, both day and night, to conduct and interpret CT and MR studies. For further questions on stroke imaging, please contact Michael Lev, M.D., Director of Emergency Neuroradiology, or Pamela Schaefer, M.D., Director of Clinical MRI and the Associate Director of the Neuroradiology Division, both at 617-726-8320.

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