CT Perfusion Imaging in Acute Stroke

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KEYWORDS

• Acute stroke • CT perfusion • Cerebral blood volume
• Cerebral blood flow • Ischemic core • Ischemic penumbra
• CBV/CBF mismatch

The imaging management of acute ischemic stroke remains challenging both diagnostically and therapeutically. Intravenous tissue plasminogen activator (tPA) (to be used within 4.5 hours of stroke onset based on the 2008 European Cooperative Acute Stroke Study [ECASS III][1–3]) and the MERCI clot retrieval device (to be used within 9 hours of stroke onset) are the only treatments currently approved by the Food and Drug Administration (FDA) for acute stroke.[3–10] The only imaging modality currently required before intravenous tPA administration is unenhanced head computed tomography (CT), used to exclude intracranial hemorrhage (an absolute contraindication) and infarct size greater than one-third of the middle cerebral artery (MCA) territory (a relative contraindication, and predictor of increased hemorrhagic risk following tPA administration).[11,12] The limited time window for intravenous (IV) tPA administration (which remains 3 hours on the package insert), delays in transportation and triage, and multiple contraindications to thrombolysis, however, all limit the use of intravenous tPA to typically less than 5% of patients admitted with ischemic stroke.[13]

CT perfusion (CTP) expands the role of CT in the evaluation of acute stroke by providing physiologic insights into cerebral hemodynamics, and in so doing complements the strengths of CT angiography (CTA) by determining the consequences of vessel occlusions and stenoses (**Fig. 1**).[14–17] Acute ischemic stroke is a disorder of blood flow to the brain, and its characterization and management typically require an answer to the following 4 critical questions[18–20]:

- Is there hemorrhage that explains the symptoms or excludes lytic therapies?
- Is there intravascular thrombus that can be targeted for thrombolysis?
- Is there a "core" of critically ischemic infarcted tissue, and if so, how large?
- Is there a "penumbra" of severely ischemic but potentially viable tissue?

CTP can help to address the latter 2 of these questions, whereas unenhanced CT and CTA can address the first and second, respectively.

CTP is fast,[14] increasingly available,[21] safe when performed correctly,[22] and affordable.[23] It typically adds no more than 5 minutes to the time required to perform a standard unenhanced head CT, and does not hinder IV thrombolysis, which can be administered (with appropriate monitoring) directly at the CT scanner table immediately following completion of the unenhanced scan.[24–26] Like diffusion-weighted imaging (DWI) and MR perfusion-weighted imaging (PWI), CTP has the potential to serve as a surrogate marker of stroke severity, likely exceeding the National Institutes of Health Stroke Scale (NIHSS) score or Alberta Stroke Program Early CT Score (ASPECTS) as a predictor of outcome.[27–35] Because of these advantages, advanced CT imaging could have important implications for the management of stroke patients worldwide.[36–39]

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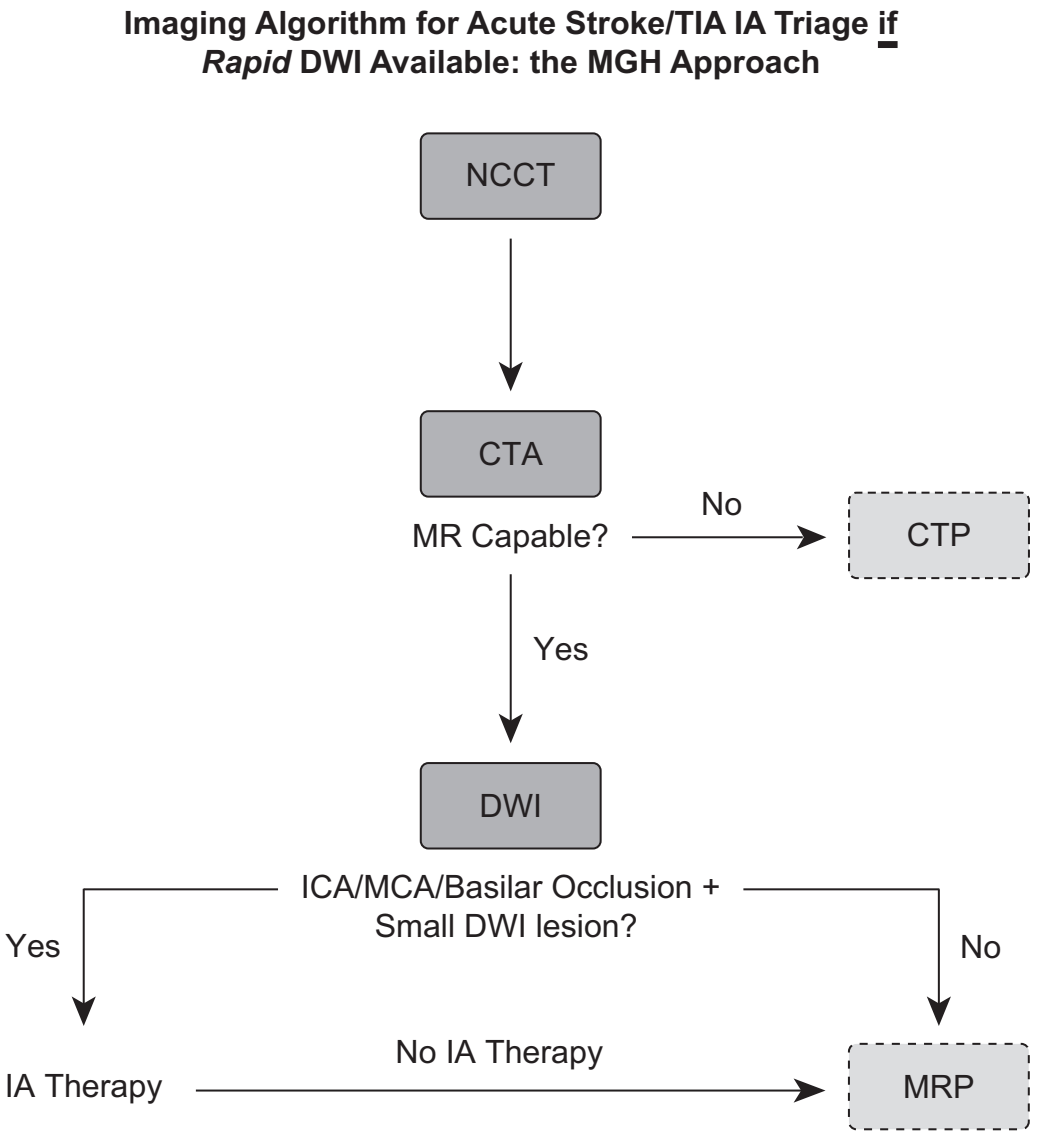

Fig. 1. Sample imaging algorithms used for acute stroke triage to endovascular therapy at Massachusetts General Hospital (MGH) and at University of Virginia. The choice and order of imaging modalities for stroke varies from patient to patient based on the acuity/severity of the clinical presentation, and from center to center based on the local practice patterns and acute scanner/treatment availability (including intraventricular thrombolysis and endovascular therapies such as urokinase and clot retrieval). At the University of Virginia, for example, the imaging algorithm is to perform CTA/CTP for all suspected stroke on a diagnostic basis—to establish the differential diagnosis, stroke subtype, and extent of ischemia—and to proceed to MR imaging in selected cases where additional workup is clinically justified. CTA, computed tomographic angiography; CTP, computed tomographic perfusion; DWI, diffusion-weighted imaging; IA, intra-arterial; ICA, internal carotid artery; INR, international normalized ratio; MCA, middle cerebral artery; N[C]CT, noncontrast computed tomography; MRI, magnetic resonance imaging; MRP, magnetic resonance perfusion; TIA, transient ischemic attack.

TECHNICAL CONSIDERATIONS OF CTP

Acute Stroke CT Imaging Protocol

At a recent meeting of stroke radiologists, emergency physicians, neurologists, and National Institutes of Health (NIH) administrators in Washington, DC, sponsored by the NIH and the American Society of Neuroradiology, both the technical and clinical issues regarding advanced acute stroke imaging were discussed. A position paper of the expert consensus achieved was published simultaneously in the *American Journal of Neuroradiology* and *Stroke*.[40,41] In these articles, expert recommendations for minimum required standards of