Imaging Patterns and Management Algorithms in Acute Stroke

An Update for the Emergency Radiologist

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KEYWORDS

• Stroke • Infarct • MR imaging • MRA • Perfusion • Diffusion • CT angiography • CT perfusion

KEY POINTS

- The clinical diagnosis of acute stroke is inaccurate in approximately 10%–30% of cases; other conditions may demonstrate clinical and imaging appearances that mimic acute infarction.
- The emergency radiologist is critical in the evaluation and triage of patients with symptoms of acute ischemic stroke.
- Noncontrast CT (NCCT) and gradient-recalled echo MR imaging show similar accuracy in the diagnosis of acute intracerebral hemorrhage; NCCT is usually the first imaging modality used to assess acute stroke.
- Diffusion-weighted MR imaging is the gold standard for infarct core. CT and MR perfusion are used to detect ischemic penumbra.
- CT angiography is diagnostically superior to MR angiography for evaluation of vasculature; time-of-flight MRA allows for adequate evaluation of vasculature in those who cannot receive contrast.

INTRODUCTION

Stroke is the fourth leading cause of death in the United States and a leading cause of serious, long-term adult disability.[1] Arterial ischemia accounts for 87% of strokes; the remaining strokes are mostly hemorrhagic.[2] Major advances in treatment of acute ischemic stroke over the past decade have markedly improved the outcomes in stroke patients with the potential for remarkable recovery.[3] Current treatment approaches are commonly restricted by the time elapsed since witnessed symptom onset. For intravenous tissue plasminogen activator (IV tPA), the currently approved treatment window is 3 to 4.5 hours from the time of stroke onset.[4,5] For intraarterial therapy, the time window is typically 0 to 6 hours for thrombolytic agents and 0 to 8 hours for mechanical therapies.[6–8] Beyond these traditional time-based treatment approaches, recent clinical trials are evaluating whether or not it is safe to give IV tPA to patients with unwitnessed symptom onset and MR imaging evidence of early ischemic changes (eg, MR WITNESS trial; clinicaltrials.gov/show/NCT0128224).

The clinical diagnosis of acute stroke is inaccurate in approximately 10% to 30% of cases.[9–12] Furthermore, conditions such as encephalitis, mass lesions, seizures, hypoglycemia, drug toxicity, and metabolic disturbances may demonstrate clinical and imaging appearances that mimic acute infarction.[9–11] The emergency

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radiologist, therefore, plays a critical role in the evaluation and triage of patients with symptoms of acute ischemic stroke, particularly with respect to the selection and rapid implementation of proper imaging techniques, recognition of early ischemic changes, and differentiation of stroke from other brain disorders.

This article focuses on the radiologic approach to the evaluation of the patient with acute ischemic stroke, including a brief overview of cerebral vascular territories, practical imaging recommendations for patients presenting with symptoms suggesting acute ischemic stroke, and the imaging appearance of acute infarcts on CT and MR imaging.

NORMAL CEREBROVASCULAR ANATOMY AND DISTRIBUTIONS

The intracranial circulation can be divided conveniently into the anterior and posterior circulations, which anastomose through the circle of Willis in the majority of cases. The anterior circulation consists of the intradural internal carotid artery (ICA) and major branches, namely, the anterior cerebral artery (ACA), the middle cerebral artery (MCA), the ophthalmic artery, and the anterior choroidal artery. The anterior communicating artery connecting the 2 ACAs, and the left and right posterior communicating arteries connecting the ipsilateral ICA to the ipsilateral posterior cerebral artery are also considered part of the anterior circulation.[13] The posterior circulation includes the vertebral arteries, the basilar artery, the cerebellar arteries, and the terminal bifurcation of the basilar artery into the right and left posterior cerebral arteries.[13] Deep penetrating branches of the major intracranial arteries supply the deep gray nuclei and the brainstem. These include the medial lenticulostriate arteries (arising from the A1 segment of the ACA), lateral lenticulostriate arteries (arising from the M1 segment of the MCA), peduncular perforating, thalamogeniculate, and thalamoperforating arteries (arising from the posterior communicating arteries and the P1 segment of the posterior cerebral artery), and the pontine perforating and medullary perforating arteries (arising from the vertebrobasilar system). Approximate vascular territories of the major intracranial arteries are depicted in **Fig. 1**.

IMAGING PROTOCOLS IN ACUTE ISCHEMIC STROKE

Four critical questions should be addressed for appropriate characterization and management of acute stroke.[14–16] (1) Is there intracranial hemorrhage that excludes thrombolytic therapy or a stroke mimic that explains the patient's presentation? (2) Is there thrombus/embolus in a large vessel that can be targeted for endovascular therapy? (3) Is there a nonsalvageable infarct "core" and if so, how large? (4) Is there salvageable "ischemic penumbra" or severely ischemic but potentially viable brain tissue? Imaging protocols vary from institution to institution and are based on access to different imaging modalities, preferences of treating physicians, and the availability of neurointerventional therapy on an emergent basis.[17,18] **Fig. 2** illustrates an experience and evidence-based imaging algorithm to select acute stroke patients for IV tPA and endovascular therapy used at our institution. Eventually, however, the practical challenge for the emergency radiologist is to define a standardized imaging algorithm, taking into account the resources available at his or her local institution that allow for improved patient outcomes without delaying treatment.

IMAGING OF THE BRAIN PARENCHYMA

Both CT and MR imaging can be used to evaluate the cerebral parenchyma in acute stroke. The goals of both modalities are to (1) exclude the presence of intracranial hemorrhage and mimics of stroke that would preclude the patient from receiving thrombolytic therapy[19] and (2) detect and quantify infarcted tissue. The imaging time courses for CT and MR imaging in infarction are summarized in **Table 1**.

Noncontrast Computed Tomography

Noncontrast CT (NCCT) of the head offers several practical advantages over MR imaging in the acute setting (**Table 2**) and is usually the first imaging modality used to assess acute stroke in the majority of emergency departments in the United States.[20,21]

Exclusion of hemorrhage

The presence of intracranial hemorrhage is an absolute contraindication to the administration of IV tPA. NCCT has been considered the accepted standard-of-care imaging modality for exclusion of intracranial hemorrhage based on data from early CT scanners and practical experience[22,23]; however, formal studies that have used a true reference standard, such as surgical or pathologic confirmation to support level I evidence, are lacking and the actual sensitivity and specificity of NCCT in detecting intracranial hemorrhage are unknown.[24] Furthermore, recent studies have suggested that the accuracy of MR imaging techniques for detection of intracranial hemorrhage in the acute stroke setting (within 6 hours) is