Brain Ischemia: CT and MRI Techniques in Acute Stroke

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Introduction

Computed tomography (CT) and magnetic resonance imaging (MRI) protocols both provide excellent tools for evaluating acute ischemic stroke [1]. The choice of modality is driven by many factors, which must balance practical availability, clinical urgency, critical information required, and range of possible interventions under consideration. Although there is controversy about which method is best, fortunately, both methods can be effectively used and refined to optimize diagnosis and patient management [2, 3]. Whether based on CT or MRI, comprehensive stroke imaging protocols can be used to triage patients to rational therapy based on individual vascular anatomy and physiology. Parenchymal imaging establishes the diagnosis and extent of ischemia, CT or MR angiography (CTA or MRA) determines site of occlusion and interventional access options, and perfusion studies provide a view of collateral flow and autoregulation. Refinements and guidelines for advanced imaging techniques are still being worked out in clinical trials, but these tools already play a role in clinical practice. Here we review new developments and concepts in acute stroke imaging, highlight practical aspects of the diagnosis of stroke using basic and advanced CT and MRI protocols, and look at future directions in the field.

CT Protocols in Acute Stroke

CT is the most commonly used imaging technique employed worldwide for acute neurologic problems. Although CT is not as sensitive for detecting ischemia as MRI with diffusion-weighted imaging (DWI), it is an efficient, readily available diagnostic tool in emergency situations. As acute stroke protocols must focus first and foremost on identifying candidates for intravenously administered tissue plasminogen activator (tPA) therapy, the practicality and evidence base for CT has kept it front line for acute treatment decisions in many hospitals [4].

A directed review of the native noncontrast CT in acute stroke bleans key diagnostic information in <1 min. For tPA decisions, patients with any hemorrhage or signs of extended cortical ischemia [e.g., more than one third of the middle cerebral artery (MCA)] must be excluded. The recently described Alberta Stroke Program Emergency CT (ASPECT) score provides an easy structured method to facilitate acute stroke CT reading and tPA triage (Fig. 1). This divides the middle cerebral territory into ten areas (six cortical and four deep). The reader takes a point off for each region showing ischemic changes and tallies the result. A normal score is therefore 10, and complete territorial infarction is an ASPECT score = 0. When scans from several large trial databases were scored using ASPECT, scores ≤7 were found to correlate with poor outcome, either with or without subsequent therapy [5]. This serves to remind us that patients with large infarcts at baseline are unlikely to do well with therapy whether images are read qualitatively or with a scoring system. The state of the parenchyma needs to be carefully evaluated as acute treatment decisions are weighed, as thrombolytic treatment of large ischemic lesions is not only fruitless but potentially dangerous.

The hyperdense artery sign on CT (and corresponding T2* clot sign on MRI) can also be helpful for diagnosis and may also prompt consideration of intraarterial revascularization in the acute setting. Patients with proximal clot [internal carotid artery (ICA) or M1-segment MCA], and especially extensive clot burden (e.g., clot length >5-8 mm) are unlikely to recanalize with intravenous administration of tPA [6, 7]. The noncontrast CT done at 5-mm increments is only about one third sensitive for detecting the hyperdense (HD) MCA sign, but thin sections will double the HD MCA detection rate. Complementary CTA can directly show not only the location of vascular occlusion but also more proximal (and treatable) clot sources, such as atherosclerosis of the carotid bifurcation or cervicocarotid dissection. Many experts suggest that good tPA candidates with proximal clot or occlusion should still receive IV tPA acutely, but they should simultaneously be considered for immediate endovascular therapy (using clot suction/retrieval devices, thrombolytics, or combinations).
The Golden Hour of Stroke Triage

The timing of comprehensive neurovascular studies may be critical not only for acute tPA decisions but for additional practical management reasons. The concept of the golden hour in trauma evaluation grew from French military data from World War I, suggesting that delay to treatment beyond 1 h reduced the likelihood of survival. As about 1.9 million neurons per minute are lost in an acute MCA occlusion, “time is brain”, and stroke must be thought of as urgently as trauma triage and treatment [8].

If we are to meet a “door to needle” target of <60 min for tPA delivery, current guidelines suggest acute imaging be completed within 25 min and interpreted within 20 min. However, this first hour is also a golden opportunity to get beyond the tPA decision and use comprehensive imaging to help with definitive clinical management. Getting beyond the basic CT or MRI, vascular and perfusion imaging can help establish diagnosis, prognosis, and underlying cause and identify treatable causes in a timely fashion. For example, timely detection and treatment of cervical carotid disease in a stroke or transient ischemic attack (TIA) patient can reduce the risk of second stroke. In the well-intended rush to make the tPA decision, the larger role of imaging must also be considered in an attempt to efficiently and quickly provide more complete data to help with global management. Advanced centers have found that multimodal imaging need not delay time to treatment for tPA [9]. Deployment of fast, streamlined workflow for comprehensive CT and MRI protocols also provides an imaging foundation to facilitate triage and management of patients with either ischemic or hemorrhagic stroke.

Overview of Perfusion Techniques in Stroke

It is increasingly important to understand the physiology of brain perfusion and its complementary role alongside anatomy and vasculature in acute stroke protocols (Fig. 2). The neurovascular unit of the brain (a working assemblage of neurons, astrocytes, and vascular capillary endothelium) actively adjusts local cerebral blood flow (CBF) according to neural activity and overall metabolic needs. Below the normal CBF threshold of approximately 55 ml/100 g of tissue per minute, compensatory mechanisms such as recruitment of collaterals and elevation of blood volumes can help maintain overall brain function, even in the face of falling systemic perfusion pressures. Below a critical ischemic CBF threshold of approximately 15-20 ml/100 g/min, the brain becomes ischemic, clinical deficits appear, and there is rapid progression to infarction unless flow is restored quickly. These perfusion changes can be seen immediately in acute stroke, whereas traditional parenchymal imaging signs of cytotoxic edema will take at least minutes (DWI) to hours [CT, T2, fluid-attenuated inversion recovery (FLAIR)] to appear.

The dynamic nature of blood delivery can be captured using CT and MRI bolus perfusion studies. Using a small intravenous injection of contrast material, the first pass of either iodine (for CT) or gadolinium (for MRI) is measured every 1-2 s for about 1 min, covering as much of the brain as possible for the particular scanner. CT protocols typically cover about half the brain, and MRI using echo planar T2* sequences usually encompass the entire brain. Resulting data sets are analyzed using tracer kinetic modeling to produce various parameter maps related to the time of arrival or transit in seconds [e.g., mean transit time (MTT),