Stroke is a leading cause of death and disability in the developed world. More than 750,000 strokes occur in the US annually,\(^1\,^2\) and one third of these patients die in the first few months after their strokes. For the patient, a stroke is devastating, with problems including loss of mobility, independence, and communication and comprehension skills, leading to a huge cost in health care and lost productivity. Acute stroke treatment is now a reality. Both intravenous (IV)\(^1\) and intra-arterial (IA)\(^3\) thrombolysis have been shown to be effective treatment options that improve patient outcomes.

Unfortunately, because of a narrow therapeutic window, most patients receive no acute stroke treatment. As hospitals change from providing support care to acute treatment, we must increase public awareness that stroke is an acute medical emergency. Time is brain. Establishing acute stroke teams and centers and educating family practitioners and emergency room physicians is imperative for progress to be made in acute stroke treatment and cannot be overstated.

A wide range of endovascular techniques and devices are now at the disposal of the interventionist, giving the interventional radiologist a pivotal role in one of the most common diseases.

**CLINICAL PRESENTATION**

Patients present with a wide variety of symptoms depending on the vascular territory involved, the amount of clot present, and the presence or absence of collateral vessels. Common symptoms include weakness, numbness, dizziness, blurred vision, and speech and comprehension problems. Stroke is painless, and most patients are unaware of their symptoms, which delays presentation during the critical first few hours. The National Institute of Health Stroke Scale converts the neurologic....

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**Figure 1.** CTA showing vascular pathology in the form of a proximal left MCA stenosis (arrows).

**Figure 2.** A right middle cerebral artery (MCA) occlusion (arrows) on MRA, ideal for acute treatment with a perfusion/diffusion mismatch.
examination into a reproducible guide to treatment and prognosis. Patients with scores <4 are usually not treated, and patients with scores >20 have a poor prognosis. A multidisciplinary approach is key. Stroke intervention teams streamline diagnosis and therapy to improve patient outcomes.4

PATHOPHYSIOLOGY OF ISCHEMIC STROKE
The majority of ischemic strokes are due to cardiogenic embolism and atherosclerotic occlusions of the cranial vessels, which produce a core of infarcted brain tissue that is surrounded by hypoxic but potentially salvageable tissue called the ischemic penumbra.5 The goal of treatment is rapid restoration of blood flow to preserve the ischemic penumbra.

IMAGING
The goal of imaging is to first confirm diagnosis and rule out other conditions that can mimic stroke. In addition, we can now accurately assess brain, metabolism, perfusion, and anatomy to see who will benefit from treatment and in whom thrombolytic treatment should be avoided. If acute treatment is being considered, there is little time to perform such physiologic and anatomic imaging.

CT
CT is readily available, rapid, and ideally suitable for stroke imaging. A stroke protocol generally includes noncontrast CT, CT angiography, and CT perfusion.

Noncontrast CT is performed to diagnose hemorrhagic stroke and to rule out other conditions such as subarachnoid hemorrhage.6 Physicians should look for the subtle signs of cerebral infarction, including hypointensity of the gray matter—in effect, blurring of the gray-white matter junction, sulcal compression, and hyperattenuating arteries. If these findings are present in more than one third of the MCA territory, thrombolysis will likely result in a poor outcome.1

CTA should be performed from the aortic arch to the skull vertex. It will detect large-vessel occlusions with high sensitivity and will confirm clot location and surrounding vascular pathology—all of which can help to plan for intervention (Figure 1).

CT perfusion reveals the hemodynamic status of the brain and the quality of the collateral vessels. Time to peak and cerebral blood flow are thought to represent the ischemic area, and cerebral blood volume presents a core infarct and correlates well with the final infarct size. A cerebral blood flow/volume mismatch represents salvageable tissue. This concept may be oversimplified, but in general this method can be applied.

MRI
Diffusion-weighted imaging (DWI) is based on the micromolecular motion of water. Ischemic areas appear as hyperintense on DWI and hypointense on apparent diffusion coefficient maps. DWI is more sensitive and specific than CT for detection of ischemia during the first few hours after a stroke; it is a better predictor of the ischemic core. MRI is ideal for assessment of the posterior fossa and brainstem, which is not possible with CT due to bony artifacts.

Problems do arise when using MRI in the setting of acute stroke. These include lack of availability, contraindications, longer scanning time, and motion artifacts in an uncooperative patient.

Most protocols include DWI, perfusion-weighted imaging, Flair, T2, T2*, MR angiography, and postgadolinium imaging. These modalities can be time-consuming and nonproductive in a uncooperative patient. A hyper-
acute protocol with DWI and perfusion-weighted imaging can often be used to decide if urgent IA thrombolysis is appropriate.

In most cases, DWI shows irreversible ischemia; perfusion imaging shows the entire ischemic region. A diffusion-perfusion mismatch represents the ischemic penumbra or salvageable tissue (Figure 2).8

Catheter Angiography

It is important to fully understand brain perfusion prior to any intervention. Cerebral angiography will better define the degree of occlusion and will reveal the morphology of the thrombus. Determining the presence or absence of patent communicating vessels and collateral pathways is critical before administration of thrombolytic treatment. If the CT or MRI does not view the aorta, it is necessary to perform arch arteriography, which will save time and contrast in navigating through difficult vasculature. Carefully examining the parenchymal phase of the cerebral angiogram is an inexpensive but dynamic perfusion study. Crossing occluded carotids is dangerous and unnecessary if adequate collateral vessels in the circle of Willis are present. In this situation, breaking up thrombus can worsen brain perfusion.

“Although the ideal thrombolytic agent, dose, and timing are still unknown, acute stroke treatment using thrombolytic agents—both IV and IA—is effective and safe in selected patients.”

IV THROMBOLYSIS

As a result of the findings of the NIND-IV tPA trial, IV tPA has been licensed since 1996. IV tPA is safe and effective for treating stroke within 3 hours from the onset of symptoms. Patients who receive treatment are 30% more likely to have minimal or no disability.1 Other trials using IV thrombolytics >3 hours after the onset of symptoms have shown no benefit.9-11 Unfortunately, because of this narrow time window, only 3% to 5% of patients in the US receive IV treatment.11 IV thrombolytics have also shown to be less effective when the clot burden is large.12

IA THROMBOLYSIS

Intracranial thrombolytic treatment is effective, and improves patient outcomes,3,13 and it can be administered
in the anterior circulation up to 6 hours after the onset of symptoms. Stroke in the posterior circulation has a dismal outcome. Basilar occlusion has an 80% to 90% mortality rate, and because of this high rate, intervention in the posterior circulation is considered reasonable even up to 24 hours after the onset of symptoms. This larger therapeutic window means more patients are potentially treatable. The re-establishment of blood flow can be seen using this modality, allowing for drug infusion to be stopped. Higher, local-drug concentrations in the occluded vessel and lower systemic concentrations can be achieved. In addition, a higher rate of recanalization compared to IV thrombolytics has been reported.

Unfortunately, IA thrombolytic treatment is costly, and not every center can provide 24-hour coverage. Compared to IV treatment, the need to assemble the interventional team can cause a delay. Several trials have shown promise in a combined IV and IA approach. However, if this combined approach involves transferring patients, it usually takes longer than planned.

ENDOVASCULAR OPTIONS

There are many ways to augment thrombolyis (Table 1). Multiple techniques and devices are available to the interventional radiologist. Mechanical thrombolsis may be used to remove the occluding thrombus and rapidly restore blood flow. This may lead to a reduction or elimination of the use of potentially harmful thrombolytic drugs. However, intracranial navigation of these devices can be difficult, and there is an increased risk of vessel wall damage, perforation, and device fracture.

POSTPROCEDURE

The immediate postprocedure management is as crucial as the treatment itself. Patients should be transferred to an intensive care unit or a specialized stroke unit capable of performing rapid and frequent neurological assessment. Urgent CT should be readily available. The management of intracranial pressure, blood pressure, temperature, and blood glucose is critical. Anticoagulation or aspirin have not been shown to improve outcomes.

TREATING STROKE IN COMMUNITY HOSPITALS

It is unrealistic and unlikely that all acute hospitals can provide 24-hour interventional radiology services. There are simply not adequately trained staff or equipment available, which leads to the concept of appropriate levels of intervention for these types of hospitals. The interventional radiologist can administer tPA from the proximal internal carotid artery for MCA occlusion or the vertebral artery origin for basilar thrombosis with reasonable success (Figure 4).

CONCLUSION

Although the ideal thrombolytic agent, dose, and timing are still unknown, acute stroke treatment using thrombolytic agents—both IV and IA—is effective and safe in selected patients. A narrow therapeutic window requires streamlined diagnosis and treatment. A variety of endovascular techniques and devices are now available to augment thrombolsis in the brain. Hospitals need to provide acute stroke treatment at a level that is appropriate for their staff and equipment. By providing a stroke service, the interventional radiologist is a fundamental element in improving patient outcomes after a potentially devastating event.

Gerald Wyse, MD, is with the Department of Interventional Neuroradiology at Johns Hopkins University School of Medicine in Baltimore, Maryland. He has disclosed that he...
holds no financial interest in any product or manufacturer mentioned herein. Dr. Wyse may be reached at (443) 226-0881; gwyse1@jhmi.edu.

Kieran P. Murphy, MD, is with the Department of Interventional Neuroradiology at Johns Hopkins University School of Medicine in Baltimore, Maryland. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Murphy may be reached at (410) 955-8525; kmurphy@jhmi.edu.