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Commentary

CT Angiography in Acute Ischemic Stroke: The Right Tool for the Job?

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When you've got a new hammer, everything looks like a nail.

—Minor modification of an old aphorism

The edifice of peer-reviewed literature, particularly in neuroradiology, has new technology as one of its major building blocks. Indeed, one of the easiest paths to publication is the application of a new technological "toy" to a neurodiagnostic problem, or a refinement of that toy to allow a new application (take if from one with shameless experience). For example, with each new iteration of technology, a large number of articles dealing with the pituitary gland has been republished, sometimes even by the same authors. Thus, literature on pluridirectional tomography of the pituitary fossa was followed by articles on computed tomography (CT) evaluation of the pituitary gland, which in turn were supplemented by reports on "dynamic" CT evaluation of the pituitary fossa with reformations, only to be replaced by magnetic resonance (MR) imaging of the pituitary, and (not surprisingly) more recently by "dynamic" MR imaging of the pituitary gland. It is also the fate of literature dealing with evaluation of the cerebrovascular system, particularly in the setting of ischemic stroke. The advent of the digital age brought the first alternative to conventional angiography, with intravenous digital subtracted angiography receiving a great deal of attention in the early 1980s, a promise unfulfilled. At that time, when dynamic table incrementation was developed for CT scanners, the concept of CT angiography was proposed (1). However, only duplex ultrasound and MR angiography have seen widespread use alongside conventional angiography for the evaluation of the cervicocranial vessels.

Now comes the most recent wrinkle in the technology continuum. Slip-ring capabilities and higher-heat loading capacity of X-ray tubes have been combined in the CT instrument to allow continuous table translation in respect to the CT gantry while the tube spins. An intravenously injected contrast bolus can thus be "chased" in its early transit, while still concentrated, through the cerebrovascular arterial system. Two articles in this issue of the *AJNR* (2, 3) demonstrate beautifully the resulting image quality and potential of this technique in evaluating the intracranial vasculature when assessing patients with acute stroke. The authors are to be congratulated for providing level 2 data for CT angiography in Thornbury's model of diagnostic efficacy (4).

However, as with other promising techniques that provided high-quality images, the question must be asked whether the typical early enthusiasm of pioneering workers will hold up in the long run. To answer this question, another question needs to be asked: What do we need to know in the earliest stages of acute ischemia in order to direct patient treatment? After excluding hemorrhage, the first and most important piece of information needed for proper treatment is whether the ischemic insult is still reversible or already permanent. Next, the cause of the ischemic insult needs to be determined if possible. If vascular, is the lesion proximal (a high-grade preocclusive or occlusive cervical carotid lesion), a dissection at the skull base, an occlusive lesion in one of the major vessels leading to the circle of Willis, or a lesion in one of the major vessels distal to the circle of Willis, such as the M1 segment of the middle cerebral artery? Based on the answers, the next management steps might include investigation of the heart as a possible source of embolus, conventional angiography (when the noninvasive examinations fail to reveal a cause of the symptoms), or perhaps even an attempt at endovascular intervention.

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How well does CT angiography, so beautifully demonstrated in the current issue, stand up to these tasks? Certainly, CT rapidly excludes hemorrhage but is somewhat insensitive to acute cerebral ischemia. Subtle alteration of gray–white matter contrast (particularly in the insular ribbon) and subtle asymmetries of sulcal size are the earliest manifestations of cerebral ischemia and can be equivocal even under the best of circumstances in very early infarcts. The bolus-contrast technique may help suggest the presence of a zone of ischemia by virtue of nonopacification of the vascular space in the region, but this still does not help differentiate reversible ischemia from infarction. The latter can be a contraindication to aggressive endovascular intervention, the former an indication for just such an approach.

As for the cause of the ischemic lesion, the articles by Shrier et al (2) and Knauth et al (3) demonstrate the strong potential of CT angiography in documenting intracranial vessel occlusive disease. However, heat-load limits of the X-ray tube and consequent inability to evaluate the cervical vasculature pose a significant limitation, particularly in comparison with MR angiography. When the intracranial circulation appears normal on CT angiography, including the intracranial carotid segment, a significant lesion in the cervical carotid might still have caused the embolic event. Also, a high cervical dissection causing a transient event would not be delineated. Even a complete carotid occlusion, producing a distal embolus, might be completely missed because back flow down the occluded carotid artery's distal segment can simulate patency, and directionality of flow is not addressed by CT angiography (as the third case in Shrier et al's series illustrates). Indeed, a proximally occluded middle cerebral artery amenable to potential intraarterial thrombolytic therapy might conceivably be missed given the presence of collateral flow in retrograde fashion through the sylvian branches back to the proximal middle cerebral artery segment. Admittedly, these are uncommon sources of error, but they need to be kept in mind, especially when choosing between alternative methods.

The bolus injection of contrast is another relative disadvantage. The authors address the ill-documented early warnings regarding the possible neurotoxicity of iodinated contrast agents given in large doses in the setting of a disrupted blood-brain barrier. It is quite likely that the newer nonionic and less hyperosmolar agents pose less of a threat to the brain than the older iodinated agents, particularly in the acute stages of ischemia before full breakdown of the blood-brain barrier. Nevertheless, the administration of iodinated agents with relatively large bolus technique in any setting is potentially problematic and has received little attention with the newer agents, despite difficulties associated with osmolar loads, including arrhythmias, well documented with the older agents. Assuming these fears are unwarranted, the introduction of relatively large amounts of contrast still poses some concern when a second procedure with iodinated agents needs to be performed, such as conventional angiography for purposes of planning endovascular intervention.

Finally, timeliness is important in the earliest stages of ischemic insult, particularly when decisions regarding thrombolytic therapy need to be made. The reconstruction time necessary for the depiction of angiographic morphology with CT angiography is problematic. Shrier et al indicate that their 30-minute average reconstruction time for CT angiography can be reduced to 15 minutes when performed by an experienced technologist. I would think that their technologists, with over 145 CT angiographic studies to their credit, would be as experienced as anyone. The additional 10 minutes of scan time means that 40 minutes is needed (at least in Shrier et al's hands) before the report can be generated. When the window of opportunity for intravenous thrombolytic therapy is as short as 3 hours after symptom onset, such a segment of the timeline can be significant.

These potential limitations of what is otherwise a marked advance in CT technology for evaluation of acute stroke would be relatively minor when not competing with another noninvasive modality. MR imaging can now be used to exclude subarachnoid and intraparenchymal hemorrhage sensitively in the earliest phases (5), while providing better sensitivity to ischemic change than CT. Particularly, with a subminute diffusion sequence, such sensitivity has been optimized. MR angiography has already proved its value not only in the intracranial circulation, where major vessel occlusions are sensitively detected (6, 7), but in the extracranial circulation, where it outperforms duplex ultrasound and rivals conventional angiography (8–10). The addition of perfusion imaging can,

in fact, come close to the Holy Grail of allowing differentiation of reversible ischemia from infarction (or at least optimal selection of patients for potential endovascular thrombolytic therapy). Although not all centers are equipped with MR imagers capable of diffusion/perfusion imaging, even conventional MR imagers are more sensitive in the early stages of ischemia than CT scanners, and can perform routine two- and three-dimensional time-of-flight angiography within 20 minutes. It must be remembered that slip-ring "helical" CT scanning is not available in many institutions at this writing. As for patient tolerance, in the experience at our institution, where MR is used routinely in evaluating stroke patients from the emergency department (even with a helical CT on hand), and even in the experience of Shrier et al, who are able to study 27 patients with MR angiography, patient intolerance has not been a major problem.

In summary, given MR's superior sensitivity to ischemia and its usefulness for evaluating not just the intracranial but the extracranial circulation in a short time, and even potentially for triage of some patients with acute ischemic insults and distinguishing those amenable from those not amenable to thrombolytic therapy, the beautiful images offered by CT angiography still must take second place. Thus, I would soften the conclusion of Shrier et al from "CT angiography *should* be used in patients with symptoms of acute stroke for whom evaluation of the intracranial vasculature is desirable" to "CT angiography *can* be used in patients with symptoms of acute stroke when MR and MR angiography are unavailable or inadvisable for reasons of patient instrumentation or intolerance." Nevertheless, the exemplary early work of Knauth et al and Shrier et al have alerted us all to the availability of a very useful tool in this setting.

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