Over the last decade, CT angiography has increasingly been used for the early diagnosis and detection of ruptured intracranial aneurysms,1-7 and most recently for the detection and treatment planning of nonruptured aneurysms.8-12 The current accepted gold standard imaging modality for the evaluation of suspected aneurysms is digital subtraction angiography; however, DSA is an invasive study with a small but significant 4% risk of complication13,14 and 0.07% to 1% reported risk of persistent neurological deficit.13,15

CTA provides a much desired noninvasive method of intracranial angiography that allows for multiple techniques of 2D and 3D viewing, including multiplanar reformation (MPR), maximum intensity projection (MIP), shaded surface display (SSD), and direct volume rendering (dVR).

The recent introduction of multidetector-row CT has allowed great advances in CTA imaging. Compared with single-section CT scanners, multislice CT scanners offer faster speed, longer distance, and thinner slice thickness as well as volumetric acquisition with considerable improvement in quality and spatial resolution.16,17 MSCT systems have evolved from four- to 16- and now 64-channel detector row scanners. With the increase in the number of detectors, partial volume effect can likely be reduced due to more isotropic voxel data being available, further increasing the quality of CTA images.18

Advances in MSCT scanning have significantly improved the ability of CTA to identify and characterize intracranial aneurysms, as compared with DSA, possibly allowing

Upon completion of this activity, participants should be able to:

• Describe CT imaging protocols typically used for the screening of intracranial aneurysms.
• Explain the postprocessing methods available for visualization of CT angiography data sets.
• Summarize the results of comparison studies of CT angiography with gold standard digital subtraction angiography in screening for intracranial aneurysms.
• Describe how complications of aneurismal rupture can be imaged using CT.

Who will benefit:

Physicians, physician assistants, nurses, and radiologic technologists will benefit from the information in this educational activity and can receive Continuing Medical Education credit by completing the post test and evaluation provided.

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CTA to replace DSA as the preferred method for imaging aneurysms.

**CTA Imaging Protocols for Intracranial Aneurysms**

At our institution, the typical CTA protocol used on our 64-slice CT scanner (Lightspeed VCT; GE Medical Systems, Milwaukee) in patients with suspected or known intracranial aneurysm is as follows: spiral mode, 0.4-second gantry rotation time, detector collimation of 64 x 0.625 mm, pitch of 0.984:1, 0.625-mm slice thickness, 0.5-mm reconstruction interval, and 120 kVp/240 mA acquisition parameters. A caudocranial scanning direction is selected, covering the whole brain down to 1 cm below the foramen magnum, in order to encompass the posterior inferior cerebellar arteries in the volume analysis. Seventy milliliters of iohexol (Omnipaque, Amersham Health, Princeton, NJ; 300 mg/mL of iodine) are administered into an antecubital vein using a power injector at an injection rate of 5 mL/sec.

CTA protocols for intracranial aneurysms reported in the literature are very similar. The main variations relate to the amount of contrast administered and the injection rate and to the method used to obtain proper timing of the CTA acquisition with respect to the injection of contrast. To achieve appropriate timing of the CTA acquisition, we typically use a test bolus technique, while others use a bolus tracking technique or precalculated standard delay time.

**Visualization Methods**

One advantage of CTA is that several postprocessing methods are available for both 2D and 3D visualization, including MPR, MIP, SSD, dVR, and endoscopic mode. Each method provides different advantages for reviewing CTA images (Figures 1 through 3).

- **Maximum intensity projection.** With MIP, only the brightest voxels of a volume from any given angle are collected and used to create an image. MIP involves collapsing voxels from different volumes into one plane, giving 2D images. Depth information is often lost, making it difficult to tell the orientation of a structure based on a single MIP image. MIP does have the advantages of being able to avoid any thresholding selection and to differentiate calcium from vascular contrast enhancement.

- **Shaded surface display.** SSD provides 3D visualization of CTA images and requires the user to define upper and lower thresholds for the selected voxels depending on their attenuation. SSD provides valuable information about the 3D shape of an object, but because all structures are shown in the same color, information about each structure's attenuation is lost. For this reason, it is not possible to distinguish arterial calcifications on SSD images. Using SSD and MIP concurrently may give the best information about 3D shape of intracranial aneurysms.

- **Multiplanar reformation.** MPR allows for the creation of reconstructed images from any angle or plane with a defined depth of volume. In contrast to MIP, SSD, and dVR, MPR has the advantage of being able to include all information from source images in the reconstructed images. MPR is the easiest way to analyze volumetric data and is helpful as the method of first choice for the examination of CTA data.
ENT upon many variables such as user experience, the quality of the postprocessing workstation, and the applied rendering algorithm.24

Endoscopic mode. In cases where nearby bony structures make it difficult to evaluate a potential aneurysm, using the endoscopic mode with CTA imaging may provide clarification. The endoscopic mode makes it possible to more clearly delineate the relationship of the aneurysm to neighboring bone structures, adjacent veins, parent arteries, and structures at the skull base.25 Knowing the precise location of these potential obstacles in relation to the aneurysm(s) can make CTA invaluable in planning treatments and surgical procedures.

CTA VERSUS DSA IN DETECTING INTRACRANIAL ANEURYSMS

A previous review of studies published between 1988 and 1998 demonstrated CTA to have an average sensitivity of about 90% for the detection of intracranial aneurysms, with aneurysms ≤3 mm being detected in 61% of cases, and higher sensitivity (up to 96%) for larger diameter aneurysms.26

More recently, studies published between 2004 and 2007 reported sensitivities of 89% to 94% on a per-aneurysm basis and 86% to 100% on a per-patient basis.8,10,12,27,28 The highest sensitivities were reported in studies using DSA as a gold standard for comparison.10,12 In one study using surgery as the gold standard of reference, CTA was found to have a sensitivity equal to that of DSA on a per-aneurysm basis (88.7% versus 87.8%, respectively). Corresponding specificities were reported as 93% to 100% on a per-aneurysm basis8,10 and 88% to 93% on a per-patient basis, with reported accuracies of 92% to 98%.9,10,12 Observer experience has been shown to be critical in the successful evaluation of images acquired with CTA.8,29

The success of CTA in detecting intracranial aneurysms is strongly dependent on aneurysm size. In recent studies, its reported sensitivity for small aneurysms (<3 to 4 mm) ranged from 67% to 84%, while the sensitivity for aneurysms larger than 3 mm was 93% to 100%.4,10,12 Typically, aneurysms of the posterior communicating artery have proven difficult to diagnose with CTA and often are missed or mistaken for infundibular dilations.4,12 Aneurysms that are located near bony structures, are attached to the posterior clinoid process, or demonstrate a “kissing vessel” artifact have also proven difficult to diagnose on CTA.10,11,27,30

CTA has, however, shown 100% sensitivity in detecting aneurysms in the anterior communicating artery and middle cerebral artery bifurcation, regardless of aneurismal size.3,9,31 CTA also has an acceptable sensitivity for the diagnosis of aneurysms responsible for subarachnoid hemorrhage, although DSA is still required with negative CTA because of its poor negative predictive value.32

IMPACT OF CTA IMAGING ON TREATMENT

One major advantage of DSA is the ability to avoid venous contamination on imaging. Although faster multidetector-row scanners may be able to accomplish pure arterial phase CTA,33 often depiction of venous structures cannot be avoided. This feature of CTA may actually serve as an advantage, however, since information regarding nearby vasculature can play an important role in treatment planning.

Another major advantage of CTA is the ability to depict neighboring bone structures, which has been demonstrated to be of great value in treatment and surgical planning.34 Finally, CTA can be performed immediately after conventional CT, which is extremely advantageous in the emergency setting.
MODERN MULTISLICE CT IMAGING OF INTRACRANIAL ANEURYSMS

CT FOR COMPLICATIONS FOLLOWING ANEURYSM RUPTURE

In patients with aneurysmal subarachnoid hemorrhaging, the risk of vasospasm poses a major threat. Vasospasm occurs with a prevalence as high as 70% in the first two weeks following subarachnoid hemorrhaging, and it represents the leading cause of death and disability in patients who survive the initial hemorrhagic event. Early recognition and treatment of vasospasm can greatly improve the neurological outcome. CTA has previously been reported to have a sensitivity of 64% and specificity of 96% in assessing the presence or absence, location, and severity of vasospasm after subarachnoid hemorrhaging.

Recently, we investigated the potential of CTA combined with perfusion CT to represent a noninvasive alternative to DSA for detection of vasospasm after subarachnoid hemorrhaging. This study demonstrated an excellent correlation of...
CTA/perfusion CT with DSA. Although CTA results alone lacked sensitivity per presence/absence of vasospasm, they were very specific (96.3%). The study also found, however, that the perfusion CT value of mean transit time (MTT) showed excellent sensitivity (95.1%). The study thus suggested that using a combination of a sensitive MTT threshold for vasospasm screening with CTA as a specific confirmatory test could serve as an accurate noninvasive predictor of angiographic vasospasm (Figure 4).

CONCLUSION

Modern multislice CTA is a sensitive technique to screen for intracranial aneurysms, and it is able to provide complete aneurysm characterization. Image acquisition and processing can be performed rapidly on commercially available devices. CTA image information has been shown to assist in treatment selection and planning.

REFERENCES


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