

Spiral CT angiography in diagnosis of cerebral aneurysms of cases with acute subarachnoid hemorrhage

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PURPOSE

To investigate the diagnostic accuracy of spiral CT angiography (CTA) in detection of cerebral aneurysms in cases with acute subarachnoid hemorrhage (SAH).

MATERIALS AND METHODS

Spiral CT angiography and DSA examinations were performed in 32 cases due to non-traumatic SAH. CTA data were obtained by maximum intensity projection (MIP) method. CTA and DSA findings were evaluated and compared in terms of existence of aneurysm, size and location.

RESULTS

In 32 patients, DSA detected 34 aneurysms with diameters ranging from 3 to 13 mm while four cases were free of aneurysms. With CTA, an aneurysm at anterior communicating artery location could not be demonstrated. In all other cases CTA correlated well with DSA in detecting the site, size and orientation of the aneurysms. It was found that CTA sensitivity was 97% and specificity was 100% in diagnosis of intracranial aneurysms.

CONCLUSION

Spiral CTA is a highly accurate, cheap and non-invasive imaging method in diagnosis of intracranial aneurysms in cases with SAH and can be used as a safe alternative method to DSA when emergency surgery is needed.

Key words: • intracranial aneurysm • subarachnoid hemorrhage • tomography, spiral computed

Mortality is high in subarachnoid hemorrhages (SAH) due to rupture of aneurysms. Most deaths occur due to the first bleeding or repetitive bleeding (1, 2). For this reason, fast and accurate evaluation of the patients is of great importance in planning the therapeutic interventions. For the time being, selective digital subtraction angiography (DSA) is used as the standard method in diagnosis and preoperative evaluation of cerebral aneurysms. Although the permanent neurologic complication risk is low (0.07%-0.5%) in DSA exams performed in cases with suspected cerebral aneurysms, this method is invasive, time consuming and expensive (3). DSA has high sensitivity and specificity values in diagnosis of cerebral aneurysms while false negative results ranging from 5% to 10% have been reported in the literature (4). The main reason for this is, not being able to obtain the optimal projections necessary for diagnosis of some aneurysms due to physical limitations rather than the insufficiency of spatial resolution of the angiography machine (5). When compared to DSA, spiral CT angiography (CTA) is a faster and a more easily applied method. In contrast to another non-invasive imaging method, magnetic resonance angiography (MRA), spiral CTA enables faster acquisition of three dimensional images related to the cerebral vascular anatomy without patient motion artifacts or artifacts due to flow rate. Another advantage of CTA is its applicability following routine non-enhanced cranial computed tomography (CT) in patients with suspected SAH in emergency conditions. In this study, we aimed to compare the effectiveness of single detector spiral CTA to DSA in diagnosis and evaluation of intracranial aneurysms in cases with acute SAH.

Materials and methods

Thirty-two cases who had CTAs and DSAs with suspicion of aneurysm due to SAH detected by non-enhanced cranial CT between September 2002 and May 2004 were included in the study. There were 17 women and 15 men, ages ranging from 32-75 (mean, 45.5) years. All CTA examinations were performed with spiral technique by a single row detector CT machine (General Electric Hi-Speed, Milwaukee, WI, USA). After detection of the location from lateral scanogram, slices parallel to orbitomeatal line were obtained in caudo-cranial direction starting from 1 cm below the base of sella turcica up to the level of lateral ventricles. Spiral CTA was obtained with 1 mm collimation, 1.5:1 pitch, 120 kV, 150 mAs and 25 cm field-of-view. Slice reconstruction thickness was 0.5 mm. One hundred and twenty ml non-ionic iodinated contrast (Iomeron 400, Bracco Diagnostic, Milan, Italy) was administered through a 20 G needle from the antecubital vein with a rate of 3 ml/second. Acquisition of images started after 15 seconds and examination lasted for about 40-60 seconds. No allergic reaction occurred in any cases. Spiral CTA images were

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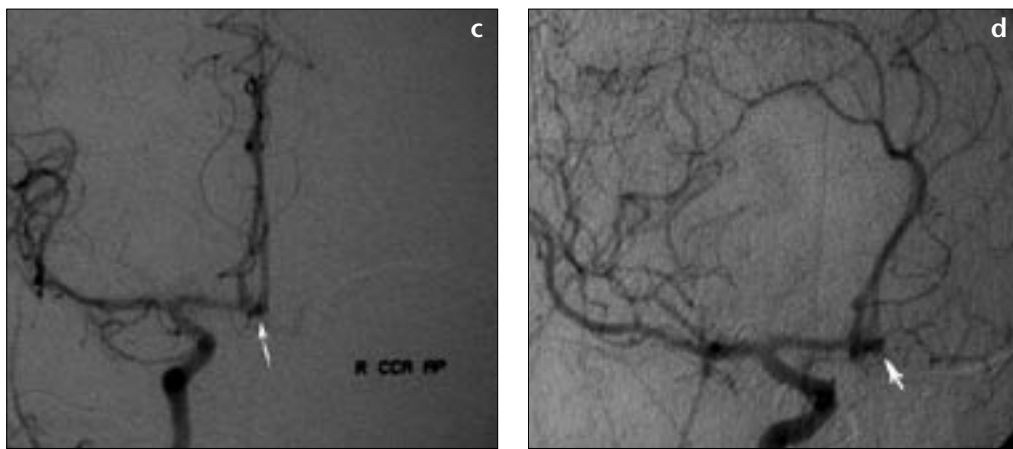
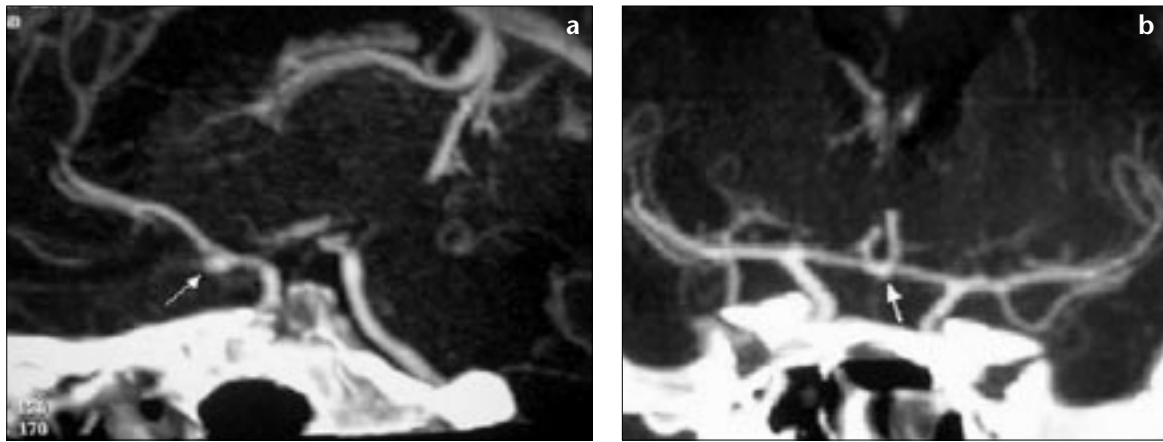


Figure 1. a-d. Spiral CTA (a, antero-posterior view and b, sagittal view) reveals 3-mm sized anterior communicating artery aneurysm with antero-inferior orientation (white arrows). DSA (c, right CCA antero-posterior view and d, right CCA left posterior oblique view) reveals this aneurysm to be in the same location (white arrows).

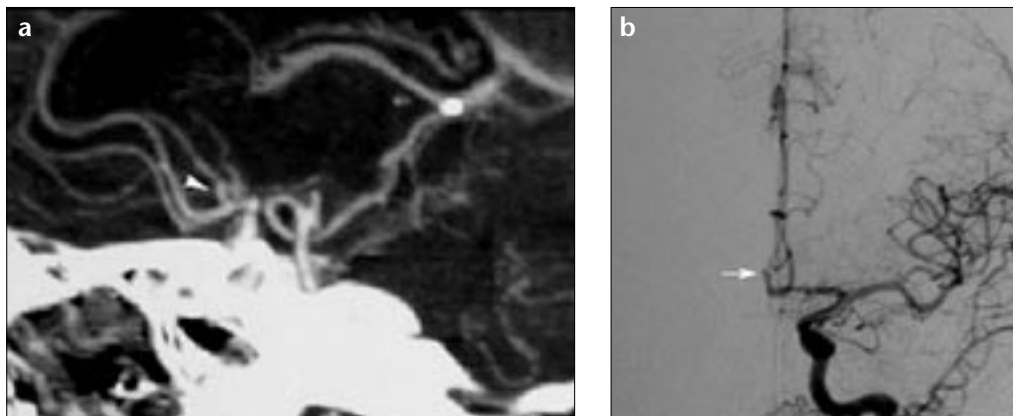


Figure 2. a, b. The case that spiral CTA (a, sagittal view) evaluation revealed a negative result for aneurysm. An anterior communicating artery aneurysm (white arrow) with superior orientation and a narrow neck in DSA examination was shown (b, left CCA antero-posterior view).

processed from the obtained source images using the maximum intensity projection (MIP) technique. Minimum three planes of MIP images in sagittal, coronal and axial planes were obtained in all cases. Images in different planes with oblique angles were reconstructed in four cases for better demonstration of the aneurysm's neck. Time spent for obtaining CTA images in three planes using the MIP technique ranged from 6 to 8 minutes. Obtained images were transferred to a workstation where they were evaluated by two radiologists blind-

ed to the DSA findings. They evaluated images in "cine" mode using different density levels and formed a common decision at the end. Evaluation of images took 10-20 minutes. Presence of an aneurysm, location, number, size and orientation were detected in MIP images. Aneurysm size is determined by measuring the widest dimension.

Cerebral DSA (Philips V 3000, Best, The Netherlands) examination was performed in another center outside our hospital with Seldinger method and percutaneous femoral catheterization. A

total of 33 DSA examinations were performed with one case having a second DSA for follow-up. Magnified images were obtained besides conventional images in cases with aneurysms. No complications occurred during DSA procedures. DSA images were evaluated by a radiologist uninformed of spiral CTA findings. Student paired t test was used to compare the sizes of aneurysms demonstrated by DSA and CTA.

Results

With DSA, a total of 34 aneurysms

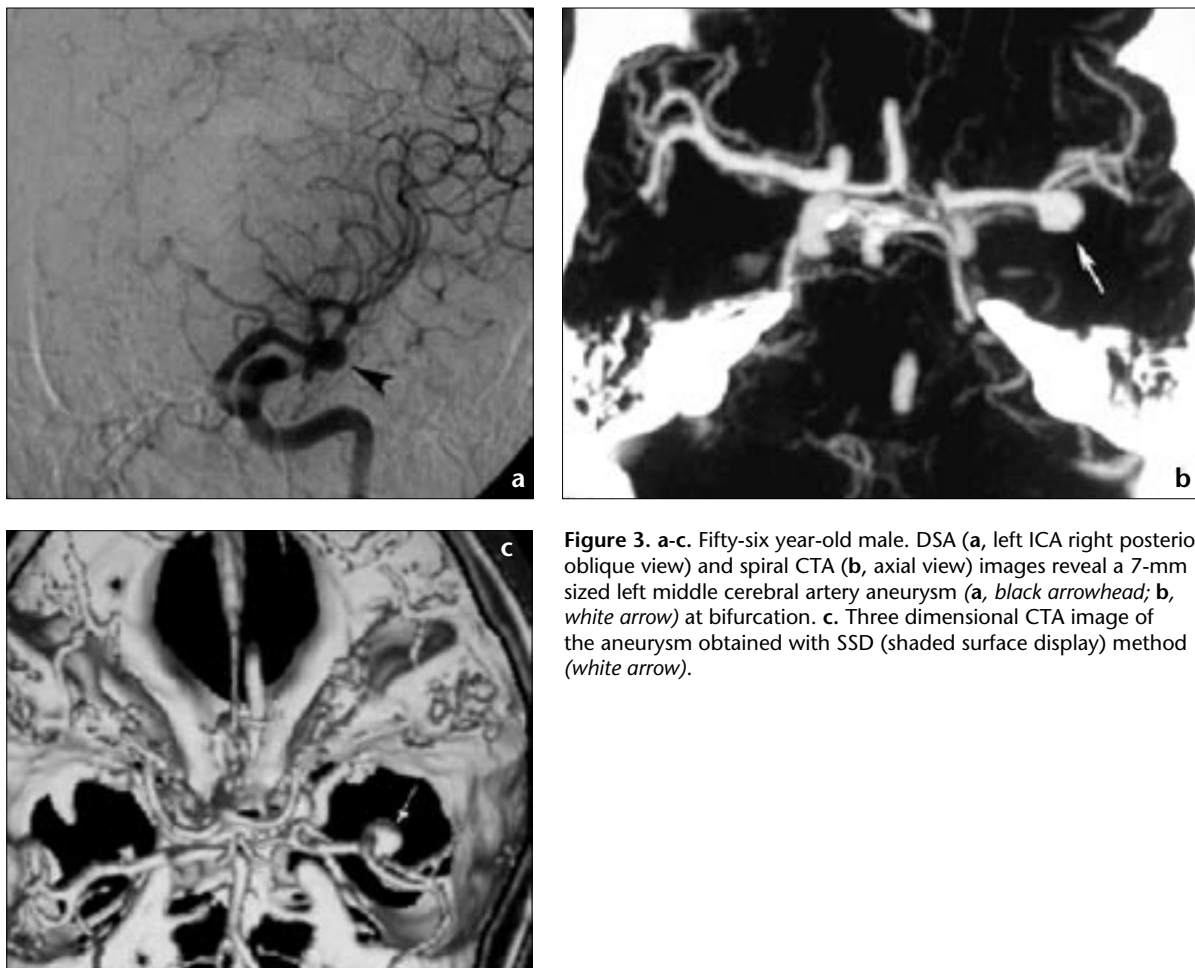


Figure 3. a-c. Fifty-six year-old male. DSA (a, left ICA right posterior oblique view) and spiral CTA (b, axial view) images reveal a 7-mm sized left middle cerebral artery aneurysm (a, black arrowhead; b, white arrow) at bifurcation. c. Three dimensional CTA image of the aneurysm obtained with SSD (shaded surface display) method (white arrow).

were detected in 28 of the 32 cases involved in the study while no aneurysm was detected in 4 cases. Of the 5 cases in whom multiple aneurysms were detected, four had two aneurysms and one had three aneurysms. Thirteen aneurysms (38%) at anterior communicating artery (Figures 1 and 2), 11 (32%) at middle cerebral artery (Figure 3), 6 (17%) at internal carotid artery (Figure 4), 1 (3%) at anterior cerebral artery, 1 (3%) at posterior cerebral artery, 1 (3%) at superior cerebellar artery, 1 (3%) at basilar artery were detected. Smallest aneurysm measured 3 mm and largest measured 13 mm (mean, 6.05 mm).

A total of 33 aneurysms were detected in 28 of 32 cases with CTA. Smallest aneurysm detected with CTA was 3 mm and largest was 13 mm (mean size, 5.93 mm). There were 18 (53%) aneurysms measured between 3 to 5 mm while 16 (47%) of them were larger than 5 mm. When compared to DSA, the sensitivity of CTA in diagnosing aneurysms between 3

to 5 mm was found to be 94% and 100% in aneurysms larger than 5 mm. Only a 4-mm anterior communicating aneurysm detected at DSA could not be visualized by CTA (Figure 2). Except this case, all the aneurysms detected by DSA were detected at the same locations by CTA.

Thirty-one of the 34 aneurysms detected by DSA were surgically clipped and one was treated by coil embolization. Two cases died before operation.

Discussion

Based on autopsy and angiography studies, incidence of intracranial aneurysms were reported ranging from 1% to 7% (6). Eighty percent to 90% of symptomatic intracranial aneurysms present with SAH. Due to high mortality and morbidity rates, early diagnosis and anatomic characterization of ruptured aneurysms have a vital importance for both surgical and endovascular treatment options. DSA is accepted as the gold standard imaging modality in diagnosis and evalua-

tion of aneurysms. On the other hand, DSA is a time consuming, expensive invasive procedure that may lead to complications in 1% and permanent neurologic deficit in 0.5% (7). Recently, there has been a search for an alternative, non-invasive and quick method for diagnosis of intracranial aneurysms. MRA and CTA are among these alternative imaging modalities. Performance of spiral CTA is improving with technologic developments in multi slice CT machines.

Depending on different studies in the literature, it was reported that the sensitivity of CTA in diagnosing intracranial aneurysms ranges between 67% to 100% and specificity between 50% to 100% (8-11). Maximum intensity projection (MIP), shaded surface display (SSD) and volume rendering (VR) are among methods for processing the source images obtained at CTA examination. In MIP method, brightest voxels within the inspected volume are used to create an image. In MIP, two-dimensional images are

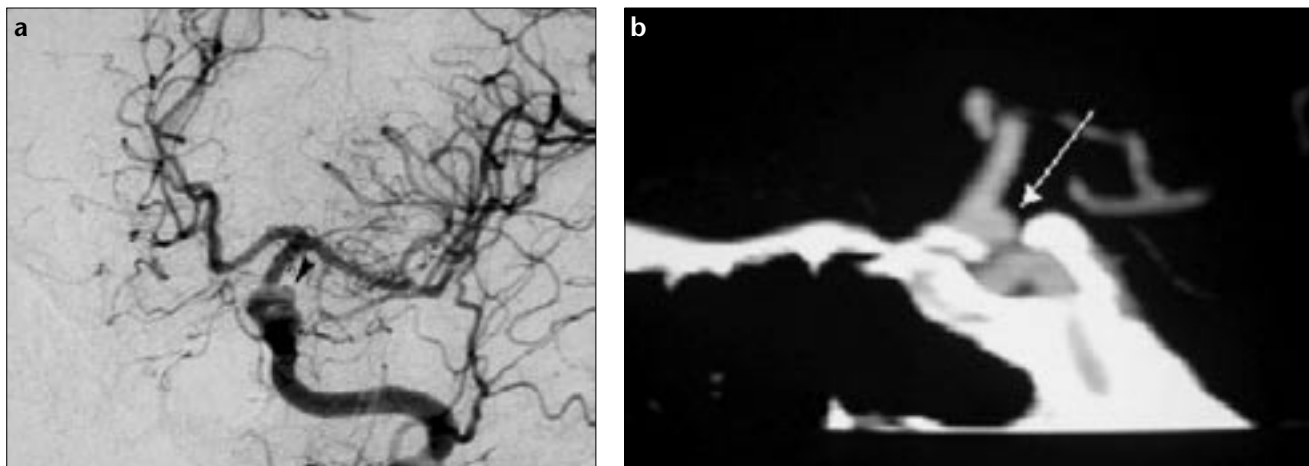


Figure 4. a, b. Thirty-four year old female. DSA (a, left CCA oblique view) and spiral CTA (b, sagittal view) images reveal the 4-mm aneurysm (a, black arrowhead; b, white arrow) at the supraclinoid segment of left internal carotid artery.

obtained in a single plane from voxels in different locations within a defined volume. However, information about depth is lost so definitive evaluation of the relation of the aneurysm with surrounding structures is not possible in three-dimensional space. Nevertheless, advantages such as independence from threshold values and easy formation of the images exist and interactive evaluation with thin slices in alternating planes at the work station are very useful in investigation of aneurysms (12). Alberico et al. stated that they could visualize 23 out of 24 aneurysms with MIP angiograms in a prospective study of 68 cases (13). This research did not include the posterior fossa and mean aneurysm size was 8 mm. Lenhart et al. stated that CTA had supplied additional information to DSA in their study that had found the sensitivity of MIP angiograms as 98% (14). White et al., in their research of 142 cases published in 2001, had found CTA sensitivity as 69% and specificity as 80% in detection of intracranial aneurysms (9).

In SSD, by defining a threshold level, information is obtained from voxels with certain attenuation values (Hounsfield units). Three-dimensional surface images of the objects are formed by converting the obtained volumetric information to surface information. However, small vessels may not be detected by SSD method. Also, aneurysm detection sensitivity of SSD is low for aneurysms close to bony structures and within cavernous sinuses. In their study involving 50 cases, Ogawa et al. reported that they had visualized 73 aneurysms with shaded surface display

(SSD) and the sensitivity of CTA was 94% in detection of aneurysms between 3 to 5 mm (11). CTA sensitivity was reported to be 100% by Preda et al. in 1998 (8) and Matsumoto et al. (15) in their studies for which they used MIP and SSD methods in combination. Preda et al. had reported that CTA had supplied enough information in pre-operative diagnosis and evaluation of cases with intracranial aneurysms in their research comparing CTA, DSA and surgical outcomes and stated that CTA was a promising method to replace DSA. In this article, they had also reported that MIP reconstructions correlated better with DSA findings than SSD images in detection of aneurysms of the circle of Willis.

For the more recently developed method, VR, all information in the raw data is used. Relationship of the vessels is better evaluated with the reconstructed three-dimensional images (8, 16, 17). In their study using the VR method, Korogi et al. had grouped aneurysms as very small, small (3-4 mm), medium (5-12 mm) and large (>13 mm) and reported CTA sensitivity as 64%, 83%, 95%, and 100%, respectively (18). In their study involving 42 aneurysms less than 5 mm in diameter, CTA sensitivity was reported as 98%-100% and specificity as 100% by Villablanca et al. (19).

In our study, with MIP method, sensitivity of CTA in comparison to DSA, in detection of aneurysms measuring 3 mm or more is 97% and specificity is 100%. With MIP method it is possible to evaluate intraluminal thrombus, aneurysmal wall calcification and rela-

tion of the calcification to the neck of the aneurysm (16). Also, it is possible to detect small aneurysms near bony structures with this method. In our study, only one case with an aneurysm near a bony structure was present. This 3 mm sized aneurysm originating from supraclinoid segment of the internal carotid artery (ICA) was easily distinguished from the posterior clinoid process with appropriate window settings (Figure 3).

CTA's most important advantage is reconstruction of three dimensional angiography images in any desired plane or angle. With multiple projections obtained in CTA, it is possible to better evaluate aneurysmal size, neck, orientation and relationship with surrounding structures than DSA, where limited number of projections are obtained (16, 17, 19). CTA shows the relationship between the aneurysm and bony structures like skull base, sella turcica or clinoid process. This is important additional information for surgical intervention (14, 20).

High sensitivity of CTA in detection of calcification is important for surgery. That is because a possible calcification located at the neck of an aneurysm may lead to difficulties in surgical clipping. CTA is superior to DSA in demonstration of existence of intraluminal thrombus which increases the risk of distal embolization and may change the surgical approach in giant aneurysms (17, 21). In our study, we had detected no calcification at the wall or thrombus within the lumen of an aneurysm.

Although there is no determined criti-

cal size for rupture of an aneurysm, it is a known fact that rupture risk increases with increasing aneurysm size. Aneurysm size is an important factor in planning surgical or endovascular treatment because it affects the size of the clip or coil that is going to be used (16). Alberico et al. reported that CTA and DSA have no significant difference in measurement of aneurysm sizes (13). In our study mean aneurysm size measured by CTA (5.93) and DSA (6.05) had no statistically significant difference.

CTA has some limitations. Because of the low spatial resolution, small arteries that are important for surgical approach, like anterior choroidal artery or thalamoperforate arteries cannot be visualized. CTA cannot demonstrate the collateral flow that can be evaluated by DSA. Differentiation of small aneurysms from bone that are located near the bony structures at the skull base (e. g., posterior communicating artery, basilar artery, etc.) may not be possible in some cases. Cavernous segment aneurysms of ICA may be obscured by opacified blood in the cavernous sinus. Small aneurysms located at bifurcation of middle cerebral artery (MCA) may be overlooked by CTA due to branching of vascular structure. Another reason for aneurysms to remain undetected is confusing them with vascular kinks (8, 15, 22, 23). Another disadvantage of CTA is that only the images of a specific phase of circulation may be obtained. However, DSA can demonstrate changes in cerebral vascular flow, such as collaterals and vasospasm.

The only false negative case, a 4-mm anterior communicating artery aneurysm in our study could be retrospectively detected, especially in sagittal plane, after DSA evaluation (Figure 1). It was not diagnosed as an aneurysm by CTA previously (false negative) due to its superior orientation, its linear configuration instead of a saccular shape and its superposition over vascular structures. For that reason, in order to prevent false evaluations, detailed examination in axial, coronal and sagittal planes with additional oblique planes in some cases, are necessary. Superposition of venous structures in determination of aneurysms was misleading only in this case and no such problems occurred in the other cases in our study.

Another limitation in our study was that our field of view did not include whole posterior circulation vascula-

ture. However, none of the cases in our study had vertebral artery aneurysms at DSA examinations. Another limitation was that no aneurysm less than 3 mm in size was detected in our study, so ability of CTA in detection of aneurysms less than 3 mm could not be evaluated.

CTA has the same general risks as the other enhanced CT examinations. Contrast agents with iodine must be cautiously used in cases with high risk factors such as poor renal function, congestive heart failure or hypersensitivity to contrast agents. Serious anaphylaxis risk to contrast agents with iodine always exists. Radiation dose in CTA is more than routine cranial CT but significantly less than DSA (18).

MR angiography is another non-invasive imaging method supplying important information about location and characterization of intracranial aneurysms while displaying vascular structures without harmful x-rays and without any need for contrast agents. The primary advantage of MRA is its ability to obtain very thin submillimetric source images that may be reconstructed as two or three-dimensional images later on. In the prospective study comparing CTA and MRA in detection of intracranial aneurysms, White et al. reported that no significant difference in diagnostic performance of these modalities exists. However, they also reported that sensitivity of both methods was limited in detection of small aneurysms (24). The most important disadvantages of MRA are long examination time and artifacts due to flow phenomenon and patient movement. When compared to MRA, despite having disadvantages of radiation exposure and iodinated contrast agents, CTA has many advantages such as short examination duration, less motion artifacts, applicability to claustrophobic patients and cases using life support or monitoring devices, and clear visualization of calcification, thrombus and bony landmarks.

As an outcome of recent improvements in multi-slice CT technology, significant progression in the area of CTA has been made. Broader anatomic locations can be scanned in a shorter time period and with thinner slices by means of lowering gantry rotation time to 0.5 seconds and ability to obtain slices thinner than 1 mm by multi-slice CT (25). Ability to use sub-

millimetric reconstruction gap enables us to obtain better quality images by means of increased spatial resolution. Shorter examination time enables us to decrease the amount of contrast agent by means of increasing arterial enhancement while minimizing the risk of confusing findings due to venous structures at the same time (26).

Kato et al. reported that multi-slice CTA was superior to single detector CT in diagnosis and evaluation of aneurysms, supplying more anatomic information than DSA that is sufficient for surgical interventions (25). Ahmetoğlu et al., in their article published in 2003, reported multi-slice CTA sensitivity as 97.7% and specificity as 87.5% in the diagnosis of cerebral aneurysms (27). In their study comparing multi-slice CT (4 row-detector) with DSA for diagnosis of intracranial aneurysms, Mahesh et al. found CTA sensitivity and specificity for the first observer to be 90% and 93% and for the second observer to be 81% and 93%, respectively. The smallest of aneurysms in the study was reported to be 2.2 mm and all aneurysms were detected by CTA during retrospective evaluation (28).

In conclusion, spiral CTA is a highly sensitive, specific, fast and non-invasive imaging method for diagnosis and evaluation of aneurysms in cases with acute SAH with suspected intracranial aneurysms.

References

1. Broderick JP, Brott TG, Duldner JE, et al. Initial and recurrent bleeding are the major causes of death following subarachnoid hemorrhage. *Stroke* 1994; 25:1342-1347.
2. Hugenholtz H, Elgie RG. Consideration in early surgery on good-risk patients with ruptured intracranial aneurysms. *J Neurosurg* 1982; 56:180-185.
3. Cloft HJ, Joseph GJ, Dion JE. Risks of cerebral angiography in patients with subarachnoid hemorrhage, cerebral aneurysm, and arteriovenous malformation: a meta-analysis. *Stroke* 1999; 30:317-320.
4. Tatter SB, Crowell RM, Ogilvy CS. Aneurysmal and microaneurysmal "angio-negative" subarachnoid hemorrhage. *Neurosurgery* 1995; 37:48-55.
5. Zouaoui A, Sahel M, Marro B, et al. Three dimensional computed tomographic angiography in detection of cerebral aneurysms in acute subarachnoid hemorrhage. *Neurosurgery* 1997; 41:125-130.
6. Osborn AG. *Diagnostic Cerebral Angiography*. 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 1999; 3:193,241-274.
7. Heiserman JE, Dean BL, Hodak JA, et al. Neurologic complications of cerebral angiography. *AJNR Am J Neuradiol* 1994; 15: 1401-1411.

8. Preda L, Gaetani P, Baena R et al. Spiral CT angiography and surgical correlations in the evaluation of intracranial aneurysms. *Eur J Radiol* 1998; 8:739-745.
9. White P, Teasdale E, Wardlaw J, Easton V. Intracranial aneurysms: CT Angiography and MR Angiography for detection-prospective blinded comparison in a large patient cohort. *Radiology* 2001; 219:739-749.
10. Hope JKA, Wilson JL, Thomson FJ. Three-dimensional CT Angiography in the detection and characterization of intracranial berry aneurysms. *AJNR Am J Neuradiol* 1996; 17:439-445.
11. Ogawa T, Okudera T, Noguchi K et al. Cerebral aneurysms: evaluation with three dimensional CT angiography. *AJNR Am J Neuradiol* 1996; 17:447-454.
12. Prokop M, Shin HO, Schanz A, Schaefer-Prokop CM. Use of maximum intensity projections in CT angiography: a basic review. *Radiographics* 1997; 17:433-451.
13. Alberico RA, Patel M, Casey S, Jacobs B, Maguire W, Decker R. Evaluation of the circle of Willis with three-dimensional CT angiography in patients with suspected intracranial aneurysms. *AJNR Am J Neuradiol* 1995; 16:1571-1578.
14. Lenhart M, Bretschneider T, Gmeinwieser J, et al. Cerebral CT angiography in the diagnosis of acute subarachnoid hemorrhage. *Acta Radiol* 1997; 38:791-796.
15. Matsumoto M, Sato M, Nakano M, et al. Three-dimensional computerized tomography angiography-guided surgery of acutely ruptured cerebral aneurysms. *J Neurosurg* 2001; 94:718-727.
16. Ng S, Wong H, Ko S, et al. CT angiography of intracranial aneurysms: advantages and pitfalls. *Eur J Radiol* 1997; 25:14-19.
17. Kuszyk BS, Heath DG, Ney DR, et al. CT angiography with volume rendering: imaging findings. *AJR Am J Roentgenol* 1995; 165:445-448.
18. Korogi Y, Takahashi M, Katada K, et al. Intracranial aneurysms: detection with three dimensional CT angiography with volume rendering-comparison with conventional angiographic and surgical findings. *Radiology* 1999; 211:497-506.
19. Villablanca JP, Martin N, Jahan R, et al. Volume rendered helical computerized tomography angiography in the detection and characterisation of intracranial aneurysms. *J Neurosurg* 2000; 93:254-264.
20. Yaşargil MG. *Microneurosurgery*. Vol. II. Stuttgart Thieme, 1984; 1,2,44,78.
21. Anderson GB, Findlay JM, Steinke DE, et al. Experience with computed tomographic angiography for the detection intracranial aneurysms in the setting of acute subarachnoid hemorrhage. *Neurosurgery* 1997; 41:522-528.
22. Vieco P, Shuman WP, Alsofrom GF, Gross CE. Detection of circle of Willis aneurysms in patients with subarachnoid hemorrhage. A comparison of CT angiography and digital subtraction angiography. *AJR Am J Roentgenol* 1995; 165:425-430.
23. Velthuis BK, Rinkel GJ, Ramos LP, et al. Subarachnoid hemorrhage: aneurysm detection and preoperative evaluation with CT angiography. *Radiology* 1998; 208:423-430.
24. White PM, Teasdale EM, Wardlaw JM, Easton V. Intracranial aneurysms: CT angiography and MR angiography for detection prospective blinded comparison in a large patient cohort. *Radiology* 2001; 219(3): 739-749.
25. Kato Y, Nair S, Sano H, Sanjaykumar MS, et al. Multi-slice 3D-CTA: an improvement over single slice helical CTA for cerebral aneurysms. *Acta Neurochir (Wien)* 2002; 144:715-722.
26. Wintermark M, Uske A, Chalaron M, et al. Multislice computerized tomography angiography in the evaluation of intracranial aneurysms: a comparison with intraarterial digital subtraction angiography. *J Neurosurg* 2003; 98:828-836.
27. Ahmetoğlu A, Koşucu P, Dinç H, Sarı A, et al. Multi-slice CT angiography in the diagnosis and characterization of cerebral aneurysms. *Tani Girisim Radyol* 2003; 9:411-417.
28. Jayaraman MV, Mayo-Smith WW, Tung GA, et al. Detection of aneurysms; multi-detector row CT angiography compared with DSA. *Radiology* 2004; 230:510-518.