The Efficacy of Computed Tomographic Angiography in Identification of Intracranial Aneurysms

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Abstract: **Objective:** Computed tomographic angiography (CTA) has surfaced as a valuable non-invasive diagnostic modality in the management of intracranial aneurysms (IAs). In this study, the author reports the accuracy of CTA versus digital subtraction angiography (DSA) in the assessment of patients with IAs. **Methods:** A retrospective review was conducted for all patients investigated for IAs with both CTA and DSA using standard imaging protocols at king Abdulaziz university hospital between January 2008 and December 2013. Thirty-one patients with IAs underwent evaluation with CTA and DSA during the study period. Comparison between the two modalities included accuracy of detection of IAs was assessed. **Results:** Patient's age ranged from 17 and 70 years (average 42.8 ± 7.9 years), and 20 patients (64.5%) were females. SAH was the initial presentation in 20 patients (64.5%), five patients (16%) with headache and seizures disorder had a mass lesion on CT scans demonstrating a large IAs, and CT scans were normal in 6 patients (19.4%). Both of CTA and DSA studies detected 29 IAs in 28 patients (90.3%). Three patients had no IAs detected in both CTA and DSA examinations, in one patient operated for repeated SAH with intracerbral hematoma, a small internal carotid artery blister was detected intraoperatively and clipped. Twenty-two patients (78.6%) underwent craniotomy and microsurgical clipping of IAs, and endovascular coiling was performed in 6 patients. CTA was effective in the post-treatment follow up and evaluation of IAs; however, in two patients CTA was not accurate in assessing the recurrence of the aneurysms. **Conclusion:** CTA provides accurate and valuable information for patients with cerebral aneurysms. It can be used alone for the diagnosis, treatment planning, and post-treatment follow up of IAs.

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1.Introduction

Traditionally, digital subtraction angiography (DSA) is considered the gold standard modality in the evaluation of the etiology of spontaneous subarachnoid hemorrhage (SAH) [1]. However, it became the least desirable as a screening tool for intracranial aneurysms (IAs) partly because of it is invasive, time consuming, and expensive procedure, and partly due to the associated risk of stroke and aneurysm rupture [1-3].

Lately, Computed Tomographic Angiography has emerged as an accurate, valuable noninvasive modality in detecting IAs [4-9]. CTA has several advantages: it is minimally invasive, performed quickly, less susceptible to motion artifacts than magnetic resonance imaging (MRA), less dependent on hemodynamic effects compared to MRA, and more widely available in the general community than MRA and DSA.

Few studies have examined the accuracy of CTA to detect [10-15], moreover, as an important planning tool that guides treatment of IAs with surgical clipping or endovascular stenting or coiling [15-17]. However, debate continues regarding whether CTA has sufficient sensitivity to replace DSA [18].

The aim of this study is to examine the accuracy of CTA in evaluating IAs as compared with DSA as the gold standard.

2. Methods

Patients' study

A retrospective review was conducted of the charts of all patients who underwent CTA and DSA for diagnosis of IAs at king Abdulaziz university hospital between January 2008 to December 2013. Inclusion criteria to the study included: (1) patients admitted in with subarachnoid hemorrhage (SAH) and (2) patients who are suspected having, or screened for, IAs. Other types of IAs (traumatic and infectious), ecstatic vascular abnormalities, and vascular malformations were excluded. Of the total number of patients identified with a suspected diagnosis of cerebral aneurysm during the study period, 31 patients had undergone diagnostic evaluation with both CTA and DSA.

Image Acquisition:

On admission, non-contrast CT scan was performed in all patients to rule out the presence of SAH, mass lesion, and other types of hematoma, hydrocephalus, or ischemia. Localization to the site of an aneurysm in the CT scan of patients with SAH was suggested by the higher concentration of blood in a specific cistern and/or by the presence of intracerebral hematoma that has a direct anatomical contact with one of the cisterns possibly carrying an aneurysm. When CT scan was negative for both SAH and mass lesions in patients with clinical manifestations highly suggestive of SAH, a lumbar puncture for detection of blood products in the cerebrospinal fluid was performed.

Patients with suspected cerebral aneurysm were studied with multidetector helical CT and CTA using Siemens Somatom definition flash, 256 slices, Dual source scanner (2x128 Slice). The acquisition volume was angled parallel to the superior orbito-meatal baseline, with the inferior margin at the superior surface of the posterior arch of the C1 vertebra (to include the posterior-inferior cerebellar arteries), and extended superiorly to above the level of the peri-callosal arteries. Patients were injected with 50 ml of non-ionic water-soluble contrast material (Ultravist 370) and 30 ml of saline chase using a dual injector (Medrad Stellant CT injector) at a rate of 4 ml/sec with bonus tracking method. (ROI placed in the arch of aorta and a cut off of 100 HU used as the reference limit). CT examination parameters were variable-KV using CareDose with maximum tube current allowed, 512x512 matrix, 205mm field of view, collimation thickness of 2 mm, and Pitch of 1.2, direction craniocaudal.

Transverse sections were reconstructed at 0.6 mm interval, and reconstructed sagittal and coronal images were performed. Reformatting of source images was performed on an offline workstation (Siemens SyngoVia 2). They include multi-planar reconstruction, 3D volume rendering (VR), and maximum-intensity projection (MIP) images. CT table and bone editing was performed by thresholding and manual cutting to maximize visualization of cerebral vessels.

All DSA studies were performed using either biplanar fluoroscopy in customized General Electric angiography suite, with digital GE acquisition software and standard orthogonal and oblique views as required.

Image interpretation:

The CTA and DSA studies reports were reviewed for detection of aneurysms by analyzing the original reads by the neuroradiologists for consistency and accuracy. In addition, more information was obtained regarding the aneurysm size, shape, direction, neck, and the relation to the parent and surrounding arteries.

Aneurysm Treatment:

Treatment of the included patients in this study was performed in all detected IAs with either craniotomy and microsurgical clipping or endovascular coiling of the aneurysm. CTA findings were used to decide if the aneurysm was suitable for surgical clipping or endovascular coiling. The author prefers endovascular coiling, if feasible and according to the availability of the interventional radiologist, as a first option of treatment. The following criteria were used to make the endovascular decision: an aneurysm was considered coilable if the aneurysm neck was considered narrow enough compared with the dome width to place coils within the aneurysm sack without coil protrusion into the parent artery, and there were no vessel branches originating from the aneurysm above the neck level that might be occluded by the coil package. Endovascular treatment with Guglielmi detachable coils (GDC) was performed under general anesthesia. Surgical clipping was offered only if the anatomy shown on the angiogram appeared unfavorable for endovascular therapy, partially thrombosed aneurysm, or the presence of a mass effect/hematoma. Occasionally, endovascular coiling can be offered due to unavailability of an interventional radiologist, and surgical clipping was adopted. Pterional craniotomies were performed for all clipped aneurysms using titanium clips.

Statistical Analysis:

Because DSA is considered as the gold standard in the study, the diagnostic accuracy of CTA was compared to DSA, and intraoperative findings were used. Correlation, sensitivity, specificity, positive predictive values and accuracy were calculated using DSA as the reference standard. Statistical evaluation was carried out by Stata 9.2 for Windows (Stata Corp., USA). Comparisons between groups were made by Fisher exact test. Differences with a *P* value less than 0.05 were considered significant.

3. Results

Thirty-one patients were included with suspected IAs who had both diagnostic modalities. Twenty patients (64.5%) were females and 11 were males. Age ranged from 17 and 70 years (average 42.8 ±7.9 years).

Twenty patients presented clinically with SAH; 6 patients presented with headache or seizures, and 5 patients were asymptomatic and underwent screening for IAs. Of the thirty-one patients included in the study, the initial non-contrast CT scans detected the presence of SAH in 20 patients (64.5%). Five patients (16%) had a mass lesion on CT scans demonstrating a large IAs, and CT scans were normal in 6 patients (19.4%).

Both of CTA and DSA studies detected 29 IAs in 28 patients (90.3%). The distributions of IAs were summarized in table 1. Two patients had no IAs detected in both CTA and DSA examinations. In this study, there were no instances where an aneurysm was seen on DSA, but not visualized on CTA or vise versa. In fact, one aneurysm initially missed on both studies and was demonstrated on emergency surgery. This patient presented with SAH had initially false negative CTA and DSA examination. He deteriorated after another attach of SAH with temporal intracerebral hematoma. He underwent emergency craniotomy for evacuation of the hematoma; right-sided carotid artery intraoperative exploration demonstrated a small supraclinoid carotid artery blister (infundibulum) aneurysm, which was successfully clipped.

Table 1: Site and size of IAs in the study detected by CTA and DSA studies.

Observation		Number (Total 31 patients) (%)
Site	A-Com A	**9** (29)
	Distal ACA	**1** (3.2)
	MCA	**3** (9.7)
	P-Com A	**5** (16.1)
	ICA-Ophthalmic	**3** (9.7)
	Bifurcation	**2** (6.5)
	Basilar	**1** (3.2)
	PCA	**2** (6.5)
	SCA	**1** (3.2)
	PICA	**1** (3.2)
	Vertebral	**1** (3.2)
	None	**2** (6.5)
	*Mid-ICA	**1** (3.2)
Size (n=29) (mm)	Smaller than 10	**20** (71.4)
	10-20	**7** (25)
	Larger than 20	**1** (3.6)

Abbreviations: A-ComA: anterior communicating artery, ACA: anterior cerebral artery, MCA: middle cerebral artery, ICA: internal carotid artery, P-ComA: posterior communicating artery, PCA: posterior cerebral artery, SCA: superior cerebral artery PICA: posterior inferior cerebellar artery. *Aneurysm was detected during intraoperative exploration but was not demonstrated on CTA or DSA. **One patient had 2 aneurysms.

CTA and DSA were equally effective in demonstrating IAs in 28 patients with sensitivity and specificity of 96.5% and 100% respectively, and positive predictor value and accuracy of 100 and 97 respectively. The observations of CTA regarding the site, shape, and direction of the aneurysms were similar to those of DSA and to the intra-operative findings. However, CTA provided an excellent view for the condition of brain parenchyma e.g. hemorrhage, edema, ischemia, and hydrocephalus. CTA also defined the anatomical relationship between the aneurysm and the bony landmarks of skull base, information necessary for operative planning.

Out the 28 patients with IAs, 22 patients (78.6%) underwent craniotomy and microsurgical clipping of IAs (Figure 1). The information provided by DSA added no additional information on the morphology of IAs, and CTA was adequate for surgical planning.

Six patients underwent endovascular treatment and coiling of IAs (Figure 2). Pre-procedural CTA evaluation of the neck and size of the aneurysm was effective in estimating the volume of the aneurysm to assess the number of coils needed to fill the aneurysm. One patient with two IAs, no treatment offered for the asymptomatic 3 mm carotid artery aneurysm.

The overall Glasgow outcome score (GOC) of the treated cases (n=28) in relation to the pre-operative clinical condition was good in 25 patients (89%). One important factor was whether the aneurysm has ruptured or not ($p < 0.005$). One patient with ruptured IA died two weeks after surgery from the sequelae of severe vasospasm. Two patients had poor GOS with disabling stroke and required extensive physiotherapy and rehabilitation.

All patients had 48–hrs and one-year postoperative CTA follow up; no residual aneurysm was seen. Two patients with coiled IAs with CTA uncertainty of residual aneurysms had DSA; one aneurysm had no filling and additional coiling was required for the other with good outcome.

4. Discussion

Over the last decade, there was a substantial evolution in the relative roles of CTA compared with DSA for the diagnostic workup of IAs [4-21]. At the author's center, CTA has been employed as a first-line diagnostic imaging test when suspecting IAs, particularly in the setting of SAH. In this situation, CTA provides several advantages over DSA of been quick, non-invasive, involves less use of contrast dye compared with DSA, relatively economic, and involves mobilization of fewer personnel and resources. In addition, the localizing feature of CT scan, which is based upon the distribution of subarachnoid blood, is of great importance. CTA also allows the display of adjacent bony landmarks in 3 dimensions, which is useful for neurosurgical planning for microsurgical clipping or endovascular application of stent or coiling of IAs. On the other hand, DSA still has its most clinical value in situations where physiologic arterial flow patterns were of importance. One of the common examples, identification of the arterial supply of the anterior communicating artery aneurysm and distal anterior cerebral branches via the two A1 segments was felt to be relevant to choosing the side of the approach and for consideration in clip application. Another example is valuable information regarding the relative contributions of the vertebral arteries to the basilar artery. This flow-related information is also useful information in planning the surgical approach to facilitate proximal control, as well as to estimate the risk of cerebral infarction due to temporary or permanent arterial occlusion.

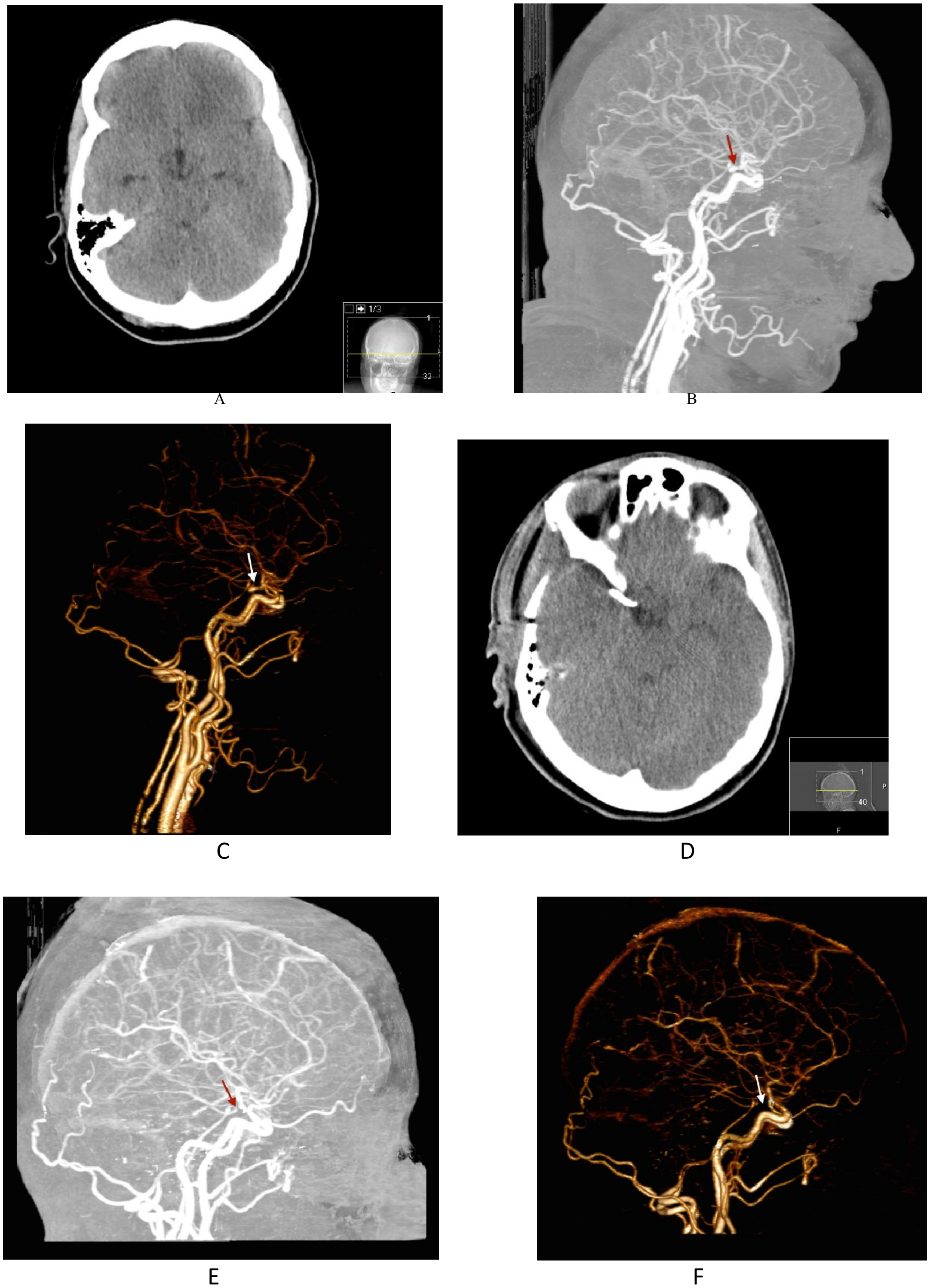

Figure 1: Axial CT scan **(A)** of a 43-yr-old female patient demonstrating SAH and small subdural hematoma. MIP **(B)** and VR **(C)** images from CTA demonstrated a 12 mm right P-Com-A aneurysm (arrow). The patient underwent right pterional craniotomy and clipping of the aneurysm and postoperative CT scan **(D)** was unremarkable. Postoperative MIP **(E)** and VR **(F)** images from CTA demonstrated successful obliteration of the aneurysm.

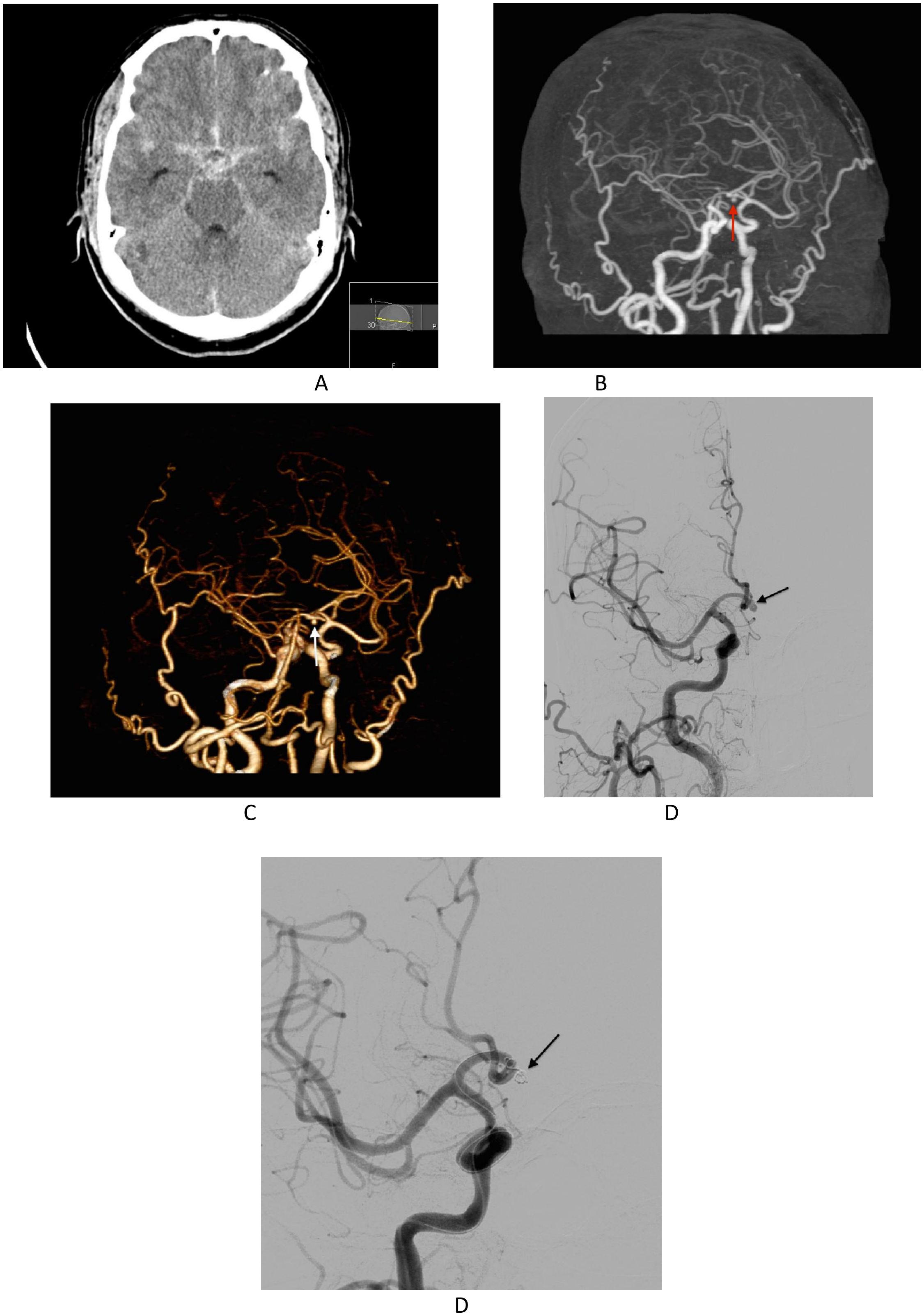

Figure 2: Axial CT scan **(A)** of a 37-yr-old male patient demonstrating SAH. MIP **(B)** and VR **(C)** images from CTA demonstrated a 7 mm A-Comm-A aneurysm. Oblique view from DSA revealed the aneurysm **(D),** which was treated with endovascular coiling of the aneurysm **(E)**.

In our study, CT successfully referred to the sites of aneurysms in 36 (88%) out of the 44 patients proved to have aneurysms by CA. Furthermore, other authors documented the presence of aneurysms in SAH patients with two negative angiograms by surgical exploration based upon this localizing feature of CT scan [22]. On the other hand, the results of our study and those of others have showed the difficulty to differentiate large aneurysms from enhancing extra-axial tumors, as meningioma and pituitary adenomas, based on routine CT examination [23]. CTA and MRA are highly recommended for enhancing lesions around the sella region to avoid intraoperative catastrophic incidence.

In this study, CTA and DSA were truly negative in 2 patients who had the same test repeated after 10 days and remained so. However, we have one case of false negative CTA as well as DSA in a patient with a small blister IAs involving the carotid artery. At emergency craniotomy from repeated SAH, temporal lobe hematoma was evacuated and during exploration of the carotid artery and its territories, the blister aneurysm was identified and clipped. The accuracy of CTA in detecting small IAs (less than 3 mm) remains an important issue. Gsughen et al. recently reported the utility of CTA in detection of 6 cases of supracliniodal internal carotid artery blister aneurysm [24]. They were able prospectively to identify 4 (67%); one was demonstrated after a follow up CTA and on the retrospective review of first CTA, and DSA identified the other IAs.

Zouaoui *et al.,* found that the sensitivity of three-dimensional CTA was comparable with that of DSA, and its specificity was 100% [9}. In our study, CTA had a sensitivity of 96.5% a specificity of 100 %, and using a combination of DSA and intraoperative findings as the gold standard, this can yield a sensitivity and specificity of 100% for CTA. Although, in our limited study, no lesions were missed on CTA, larger series have shown a small false negative rate compared to DSA, generally with small < 3 mm aneurysms [9, 11, 21, 22]. This would certainly need to be taken into consideration in a situation to perform DSA, where workup for subarachnoid hemorrhage by CTA is negative, or in cases where there is a high index of suspicion for an aneurysm or another vascular lesion.

Advances in CTA resolutions and Multidetector (four rows) CT scanners are now up to eight times faster than conventional single-section helical CT scanners. The benefits of quad-section CT relative to single-section helical CT are considerable. They include improved temporal & spatial resolution, increased concentration of intravascular contrast material, decreased image noise, efficient x-ray tube use, and longer anatomic coverage. These factors substantially increase the diagnostic accuracy of the examination [25].

In our study, using multidetector (four rows) CT scanner, the sensitivity of CTA in the detection of cerebral aneurysms was 96.5%. Our results are similar to those reported by Kangasniemi *et al.,* [26]. They used two-dimensional and three-dimensional multislice helical CTA to improve the sensitivity and specificity of CTA in the detection of intracranial aneurysms. Using this method, the sensitivity and specificity of CTA for aneurysm detection were 0.96 and 0.97, respectively. However, according to their experience, the first generation of multislice computed tomographic technology does not improve CTA to surpass DSA for the detection of small aneurysms of 1 to 2 mm. Furthermore, the result of our study and those of others showed that multislice CTA detected vasospasm in the cerebral vessels after SAH with accuracy equal to that of DSA [27].

In addition to its diagnostic value, in the detection of cerebral aneurysm, CTA can play other roles in the management of such critical patients. Van Loon et al, used CTA as postoperative control examinations after clipping of cerebral aneurysms with titanium clips [28]. In their opinion, CTA could be a valuable aid in the postoperative evaluation of clipped aneurysms, and they recommend its routine performance. However, they recommended the use of postoperative DSA when CTA reveals abnormalities, when the neck of the aneurysm cannot be evaluated because the clip overlays it, or when, intraoperatively, imperfect clipping is suspected, and intraoperative angiography cannot be performed. In our study, only 2-coiled aneurysms were not well visualized; DSA confirmed complete obliteration of a PICA aneurysm, and A-comm-A aneurysm had refilling after 6 moths and required recoiling.

Other authors demonstrated that CTA provides more precise surgical anatomy and helps in the surgical planning for patient with cerebral aneurysms. Villavicencio et al, indicated that three-dimensional CTA was a useful tool for assessing critical anatomic relationships and represented an adjunct to conventional angiography in the planning of individualized, precisely tailored, cranial base approaches to the vertebrobasilar system [29]. Also, Nievas et al. found that CTA examination of the vertebrobasilar complex provided a higher rate of aneurysm detection and improved the optical definition and anatomic projection of these aneurysms, compared with DSA scanning alone [30]. This also found to facilitate therapeutic decision-making (surgical versus endovascular procedures) and allows them to use more restricted surgical exposures. In another study, Gonzalez *et al.,* used CTA to differentiate between paraclinoid and cavernous sinus aneurysms [31]. They observed that the optic strut, as identified with CTA, provided a reliable anatomic landmark for accurate discrimination between intradural and extradural (cavernous sinus) aneurysms.

One of limitations of multidetector CT angiography includes that they are operator dependent, and aneurysms close to the skull base (like intracavernous and vertebral aneurysms) can be overlapped by bone [32, 33]. Abrahams *et al.,* developed a method for bone-free rendering using iterative relative fuzzy connectedness (IRFC) of 3-D-CTA to examine the cerebral vasculature without the intervening cranial base. Their findings suggested that the bone obscuration could be overcome through appropriate computer algorithms [32].

Conclusion

This study has confirmed the clinical value of CTA as the primary imaging technique in the diagnosing and the planning of microsurgical clipping or endovascular coiling or stenting of IAs.

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References

1. Mayberg MR, Batjer HH, Dacey R, Diringer M, Haley EC, Heros RC, *et al.* Guidelines for the management of aneurismal sub-arachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. Stroke 1994; 25: 2315-28.
2. Cloft HJ, Joseph GJ, Dion JE. Risk of cerebral angiography in patients with sub-arachnoid hemorrhage, cerebral aneurysm, and arteriovenous malformation: a meta-analysis. Stroke 1999; 30:317-20.
3. Komiyama M, Tamura K, Nagata Y, Fu Y, Yagura H, Ysui T: Aneurysmal rupture during anghiography. Neurosurg 33: 798-803, 1993.
4. Anderson G, Steinke D, Petruk K, Ashforth R, Findlay J: Computed tomographic angiography versus digital subtraction angiography for the diagnosis and early treatment of ruptured intracranial aneurysms. Neurosurg 45: 1315-1322, 1999.
5. Aoki S, Sasaki Y, Machida T, Ohkubo T, Minami M. Cerebral aneurysms: detection and delineation using 3-D-CT angiography. AJNR Am JNeuroradiol 1992; 13:1115-20.
6. Hoh B, Cheung A, Rabinov J, Pryor J, Carter B, Ogilvy C: Results of a prospective protocol of computed tomographic angiography in place of catheter angiography as the only diagnostic and pretreatment planning study for cerebral aneurysms by a combined neurovascular team. Neurosurg 54: 1329-1342, 2004
7. Goddard AJ, Tan G, Becker J. Computed tomography angiography for the detection and characterization of intra-cranial aneurysms: current status. Clin Radiol 2005; 60:1221-36.
8. Harbaugh RE, Schlusselberg DS, Jeffery R, Hayden S, Cromwell LD, Pluta D. Three dimensional computerized tomography angiography in the diagnosis of cerebrovascular disease. J Neurosurg 1992; 76:408-14.
9. Zouaoui A, M.D., Sahel M, Marro B, Clemenceau S, Dargent N, Bitar A, Faillot T, Capelle L, Marsault C: Three-dimensional computed tomographic angiography in detection of cerebral aneurysms in acute subarachnoid Hemorrhage. Neurosurg 41: 125-130, 1997.
10. Dehdashti AR, Rufenacht DA, Delavelle J, Reverdin A, DE Tribolet N. Therapeutic decision and management of aneurysmal subarachnoid haemorrhage based oncomputed tomographic angiography [J]. Br J Neurosurg 2003; 17(1):46-53.
11. Donmez H, Serifov E, Kahriman G, Mavili E, Durak AC, Menku A. Comparison of 16-row multislice CT angiography with conventional angiography for detection and evaluation of intracranial aneurysms [J]. European journal of radiology 2010.
12. Chen W, Wang J, Xing W, Xu Q, Qiu J, Huang Q, *et al.* Accuracy of 16-row multislice computerized tomography angiography for assessment of intracranial aneurysms. Surgical neurology 2009; 71(1): 32-42.
13. Li Q, Lv F, Li Y, Li K, Luo T, Xie P. Subtraction CT angiography for evaluation of intracranial aneurysms: comparison with conventional CT angiography. European radiology 2009; 19(9): 2261-7.
14. Mohan S, Lee W, Tan JT, Wee LK, Hui FK, Sitoh YY. Multi-detector computer tomography angiography in the initial assessment of patients acutely suspected of having intracranial aneurysm rupture. Ann Acad Med Singapore.2009 Sep; 38(9): 769-73.
15. Chen W, Yang Y, Xing W, Peng Y, Qiu J, He Z, Wang Q. Applications of multislice CT angiography in the surgical clipping and endovascular coiling of intracranial aneurysms. J Biomed Res. 2010 Nov; 24(6): 467-73.

16. Farsad K, Mamourian AC, Eskey CJ, Friedman JA. Computed tomographic angiography as an adjunct to digital subtraction angiography for the pre-operative assessment of cerebral aneurysms. Open Neurol J. 2009 Jan 28; 3:1-7.
17. Kumar A, Kato Y, Motoharu H, Sifang C, Junpei O, Takeya W, Shuei I, Daikichi O, Yuichi H. An update on three-dimensional ct angiography in aneurysms: a useful modality for a neurosurgeon. Turk Neurosurg. 2013; 23(3): 304-11.
18. Kangasniemi M, Mäkelä T, Koskinen S, Porras M, Poussa K, Hernesniemi J: detection of intracranial aneurysms with two-dimensional and three-dimensional multislice helical computed tomographic angiography. Neurosurg 54: 336-341, 2004.
19. Chappell E, Moure F, Good M: Comparison of computed tomographic angiography with digital subtraction angiography in the diagnosis of cerebral aneurysms: A meta-analysis. Neurosurg 52: 624-631, 2003.
20. van Gelder JM. Computed tomographic angiography for detecting cerebral aneurysms. Implications of aneurysm size distribution for the sensitivity, specificity, and likelihood ratios. Neurosurgery 2003; 53(3): 597-605.
21. Tipper G, U-King-Im JM, Price SJ, *et al.* Detection and evaluation of intracranial aneurysms with 16-row multislice CT angiography. Clin Radiol 2005; 60(5): 565-572.
22. Tater S, Crowell R, Ogilvy C: Aneurysmal and microaneurysmal angiogram-negative subarachnoid hemorrhage. Neurosurg 37:48-55, 1995.
23. Belec L, Cesaro P, Brugeires P: Tumor-simulating giant serpentine aneurysm of the posterior cerebral artery. Surg Neurol 29:210-215, 1988.
24. Gaughen JR Jr, Raghavan P, Jensen ME, Hasan D, Pfeffer AN, Evans AJ. Utility of CT angiography in the identification and characterization of supraclinoid internal carotid artery blister aneurysms. AJNR Am J Neuroradiol 2010 Apr; 31(4): 640-4.
25. Hochmuth A, Spetzger U, Schumacher M: Comparison of three–dimensional rotational angiography with digital subtraction angiography in the assessment of ruptured cerebral aneurysms. AJNR 23:1199-1205, 2002.
26. Kangasniemi M, Mäkelä T, Koskinen S, Porras M, Poussa K, Hernesniemi J: detection of intracranial aneurysms with two-dimensional and three-dimensional multislice helical computed tomographic angiography. Neurosurg 54: 336-341, 2004.
27. Otawara Y, Ogasawara K, Ogawa A, Sasaki M, Takahashi K: Evaluation of vasospasm after subarachnoid hemorrhage by use of multislice computed tomographic angiography. Neurosurg 51: 939-943, 2002.
28. van Loon J, Yousry T, Fink U, Seelos K, Reulen K, Steiger H: Postoperative spiral computed tomography and magnetic resonance angiography after aneurysm clipping with titanium clips. Neurosurg 41: 851-857, 1997.
29. Villavicencio A, Gray L, Leveque J, Fukushima T, Kureshi S, Friedman A: Utility of three-dimensional computed tomographic angiography for assessment of relationships between the vertebrobasilar system and the cranial base. Neurosurgery 48: 318-327, 2001.
30. Nievas M, Haas E, Hollerhage H, Drathen C: Complementary use of computed tomographic angiography in treatment planning for posterior fossa subarachnoid hemorrhage. Neurosurg 50:1283-1289, 2002.
31. Gonzalez L, Walker M, Zabramski J, Partovi S, Wallace R, Spetzler R: Distinction between paraclinoid and cavernous sinus aneurysms with computed tomographic angiography. Neurosurg 52: 1131-1139, 2003.
32. Abrahams J, Saha P, Hurst R, LeRoux P, Udupa J: Three-dimentional bone-rendering of the cerebral circulation by use of computed tomographic angiography and fuzzy connectedness. Neurosurg 51:264-269, 2002.
33. Vieco P, Shuman W, Alsofrom G, Gross C: Detection of circle of Willis aneurysms in patients with acute subarachnoid hemorrhage: A comparison of CT angiography and digital subtraction angiography. AJR 165:425-430, 1995.

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