Evolution from invasive arterial puncture to a venous access for cerebral angiography: "Cath Lab to CT suite"

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ABSTRACT

Background: Digital subtraction angiography (DSA) is considered as the gold standard in the evaluation of intracranial aneurysms. This study was undertaken to evaluate the effectiveness of computed tomogram angiography (CTA) in the detection and accurate characterization of intracranial aneurysms in suspected cases of nontraumatic subarachnoid hemorrhage. The importance of three-dimensional volume rendering of the intracranial vasculature and it's used as an aid in improving diagnostic capabilities with regards to intracranial aneurysms in multi-detector computed tomography angiography (MDCTA), was stressed upon. This study also tried to probe whether MDCTA alone can be used in detection and treatment of intracranial aneurysms in emergency situations. **Materials and Methods:** Suspected cases of nontraumatic acute subarachnoid hemorrhage, over an 18 months period, underwent CTA in 16-slice-computed tomography suite. Fifty cases where CTA demonstrated intracranial aneurysms were studied. A set protocol of three-dimensional reconstruction was followed. Comparison of findings of MDCTA with surgical notes was performed. DSA was done in ambiguous cases. **Results:** Aneurysm was confidently diagnosed by CTA in 48 cases, and further confirmed on surgery. In doubtful cases, DSA was performed and then diagnosed as aneurysm. Thus, the sensitivity of CTA is diagnosing aneurysm is 96.6%, with a specificity of 100%. **Conclusions:** Digital subtraction angiography is an invasive, relatively costly, procedure to be done by highly skilled personnel with serious complication rate of 1%. This can be replaced by MDCTA, which is noninvasive, cost effective and easy to perform, and DSA can be reserved for doubtful or difficult cases. Following a set protocol of three-dimensional reconstruction helps in reducing errors.

Key words: Aneurysm, digital subtraction angiography, multi-detector computed tomography angiography, three dimensional reconstruction

INTRODUCTION

Digital subtraction angiography (DSA) is considered as gold standard for detection of intracranial aneurysms.[1] The invasiveness of arterial puncture, the risk of complications associated with angiography that is approximately 1% and grievous complete permanent neurologic deficit of 0.07-1%[2,3] are known disadvantages of DSA. There is also utmost dependence on the professional skills and the high cost involved in DSA.[3,4] In simple terms, there is an immense extra burden on the disease stricken patient towards his/her management for intracranial aneurysms with conventional DSA.

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Computed tomography angiography (CTA) for diagnosis of intracranial aneurysms is an example of significant technical advancement in diagnostic imaging. A simple venous access and injecting a high volume of contrast at high rate of injection in the computed tomography (CT) suite can opacify the vessels optimally, and three-dimensional reconstruction from the volume of images can create optimal angiography images. This study stresses upon the usefulness of noninvasive CTA in the aneurysmal detection, localization, characterization in terms of size, neck and dome dimensions in relation to adjacent important vessels and bony structures. This study also examines whether conventional DSA could be replaced by CTA for intracranial aneurysms with the help of postprocessing techniques like volume rendering (VR), three-dimensional reconstructions, for diagnosis and treatment decisions.

MATERIALS AND METHODS

Suspected cases of nontraumatic acute subarachnoid

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hemorrhage underwent CT-head. Subarachnoid hemorrhage was confirmed on plain CT head. CTA was performed in 16-slice (GE Bright Speed, USA) CT machine in our institution over a period of 18 months. Informed consent was obtained from all patients or their legal representatives. No patient in our study was contraindicated to use of contrast agent.

Patients with postaneurysmal clipping were excluded from the study, because this study aimed at imaging newly detected cases of aneurysms only. Fifty "positive" cases where CTA demonstrated intracranial aneurysms were included in this study.

Initially, topogram and a plain CT brain images were obtained and the axial sections for CTA was planned accordingly in caudocranial direction from the level of arch of the aorta to the vertex with section interval of 0.625 mm. Nonionic contrast Material (Iohexol, GE Healthcare) was used, and 100 ml of contrast was injected via power injector at the rate of 4 ml/s. Delay time of around 15–17 s was given according to bolus tracking technique. Exposure factors used were 320 mA and 120 kvp. Time taken for each study of CT cerebral angiography was approximately 90 s. Once the raw axial images were obtained, processing was done in all cases after transferring the images to work station (GE Adw Advantage Workstation 4.2, GE Healthcare, USA). Time required for reformatting the images was around 15 min for each case. Section interval for reformatting used was 0.310 mm.

Postprocessing was done three-dimensional reconstructions, VR and maximum intensity projection (MIP) image techniques in all cases by the same radiologist or trained technologists under the supervision of the radiologist. A standard protocol of reconstructions were followed, systematically depicting the vasculature in sequence, so that all the arteries are screened axial collapsed MIPs of the circle of Willis, thick oblique MIPs of the anterior cerebral artery (ACA), middle cerebral artery (MCA) and posterior cerebral artery (PCA). Thin MIPs of the basilar artery, vertebral arteries and thin MIPs of the anterior communicating artery (Acom) and posterior communicating artery (Pcom) were recorded in sequence. Based on presence and location of the aneurysm, different three-dimensional color images were obtained in different views and angles like stereoscopic view from above and below, antero-posterior, posterior, postero-anterior and oblique views, which best showed the aneurysm and it's relation with other adjacent structures.

Comparison of findings of multi-detector computed tomogram angiography (MDCTA) with surgical findings was performed where possible. In cases where CT cerebral angiography was inconclusive, but had a high index of suspicion, (N-2) DSA was performed in the Cath Lab (Digital Catheterization Lab).

RESULTS AND ANALYSIS

A total number of 50 cases were included in this study. About 54% of the patients were above 70 years of age. Forty percent of cases were in the fifth and sixth decade. There was a sex predilection with 64% of patients being female.

Statistically the most common location was the Acom [Table 1]. More than 52% of the aneurysms were in the 3-6 mm range [Table 2].

In total, 55 aneurysms were identified from 50 patients who underwent CT brain angiography. In one case, conventional angiography was undertaken because of doubtful aneurysm in left Pcom [Figure 1], which was confirmed on conventional angiography. Five patients were found to have double aneurysms. False negative results were not reported as any doubts of tortuous vessels masquerading as aneurysms were surpassed by detailed double reading and three-dimensional reconstructions.

There were four patients who had partially thrombosed aneurysm and three patients with complete thrombosis

Table 1: Distribution chart based on arteries involved

Artery	Right	Left
ICA	04	06
MCA	08	05
ACA	02	04
PCA	00	01
Pcom	02	03
VA	01	01
Acom	09	
Basilar tip	05	
Vertebrobasilar junction	03	

ICA – Internal carotid artery; MCA – Middle cerebral artery; ACA – Anteriro cerebral artery; PCA – Posterior cerebral artery; Pcom – Posterior communicating artery; VA – Vertebral artery; Acom – Anterior communicating artery

Table 2: Distribution of aneurysms according to size of neck and dome

Size of neck (in millimeter)	Number of aneurysms	Size of dome (in millimeter)	Number of aneurysms
0-2.9	07	0-2.9	02
3-5.9	29	3-5.9	17
6-8.9	05	6-8.9	17
9-11.9	08	9-11.9	10
12-14.9	04	12-14.9	05
>15	02	>15	03
Total	55	Total	55

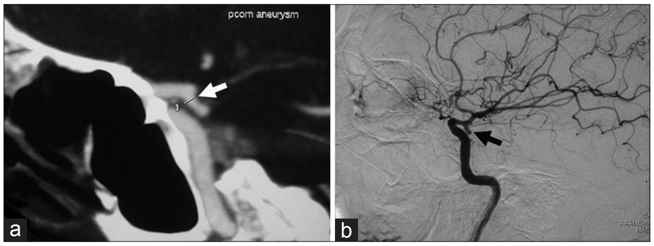

Figure 1: Comparison of maximum intensity projection image of computed tomography angiography with digital subtraction angiography (DSA) image; (a) which shows a doubtful bleb (white arrow), not cleary delineated separately from a vascular loop, (b) DSA images confirms it to be a posterior communicating artery aneurysm

of aneurysms. There was no case where CTA depicted an aneurysm and was not detected intra-operatively. There was no case where newer aneurysms were detected intra-operatively. All the aneurysms were confirmed on the same location as reported on the CTA. The measurements of the neck and dome corresponded to the CTA findings.

In our study, aneurysm was picked up by CTA confidently in 48 patients that were confirmed on surgery. Only two cases that were doubtful were taken up for DSA. If we take this as a negative study in CTA and positive in DSA, then the sensitivity of CTA is 96.6%, and specificity is 100%. A limitation of the study was that there was no direct correlation of CT angiography with DSA for every case and the results are retrospective.

DISCUSSION

The advent of MDCT has revolutionized the evaluation of intracranial hemorrhage and angiography is being performed routinely in the evaluation of intracranial aneurysms.[5] As compared to single detector row CT or 4-slice CT scanning, 16-slice MDCT showed better delineation of the aneurysm that goes well with the previous literature. The ability to diagnose cerebral aneurysms is reported to be 90-97% on magnetic resonance angiography (MRA) and 95-100% on three-dimensional CTA.[6-8]

Many studies have shown that CTA can easily identify aneurysm size which are above 3 mm.[9] Only few studies have shown accuracy of detection of intracranial aneurysms less than 3 mm.[10] With the help of VR, not only the exact location of the aneurysm can be assessed but also, the smallest of aneurysms can be picked up and thereby decreasing the false negative rate in CTA. In our study on 50 patients, the smallest aneurysm size detected was 2 mm. So according to the literature, aneurysms >3 mm are easily picked up and aneurysms <3 mm require special postprocessing techniques to make them visible on cerebral CTA which is also consistent with the present study.[9,10]

Reported prevalence of having intracranial aneurysm in the general population is between 6% and 7%. Data on risk of rupture vary considerably according to study design, study population and aneurysm characteristics. For adults without risk factors for subarachnoid hemorrhage, the vast majority of these aneurysms are small (=10 mm) and have an annual risk of rupture of approximately 0.7%.[11,12]

Another advantage of choosing cerebral CTA over conventional angiography is the availability of more information on vascular variations, like fetal PCA, hypoplastic arteries, thrombosis and calcifications in aneurysms.

Bendszus *et al*. documented that diffusion-weighted magnetic resonance imaging performed immediately after conventional catheter angiography depicted silent embolisms in approximately 26% of patients,[13] indicating that the complication rate of conventional angiography were more frequent than that of the apparent neurological deficits. So, conventional angiography can sometimes become add-on problem to tackle with, for the treating physicians/surgeons. So CTA can surpass these above mentioned disadvantages of conventional angiography and help patient both in clinical and economical perspective.

Moreover, any aneurysm with calcification or partially thrombosed, can very well be depicted on CT rather than on MRA. We had four cases out of 50 with complete/partially thrombosed aneurysm. This is important because any calcification at or near the neck would preclude use of surgical clipping.[6]

Maximum intensity projection images are the type of reconstruction images wherein the highest attenuation voxel in the parallel rays along region of interest are taken into consideration and image is formed. This avoids overlapping of the vessels with a clear depiction of the vessel of interest. However, bones have to be edited as they also have high attenuation. Editing of bones can be done by cutting functions and region growing algorithms. But depth perception provided by MIP images is inadequate. Also, MIP images do not allow visualization of hypoattenuating intraluminal abnormalities. So, MIP images have to be always correlated with raw axial images and VR images to come to the conclusion[14] [Figure 2].

Axial collapsed MIPs of the circle of Willis [Figure 3] would give a quick assessment of the circle of Willis. Following a set protocol of reconstruction as ours - thick oblique MIPs of the ACA, MCA and PCA would help in reducing errors. Thin MIPs of the basilar artery, vertebral arteries and thin MIPs of the Acom and Pcom are to be surveyed and double read. In VR images, the voxel attenuation is rendered by means of grey scale

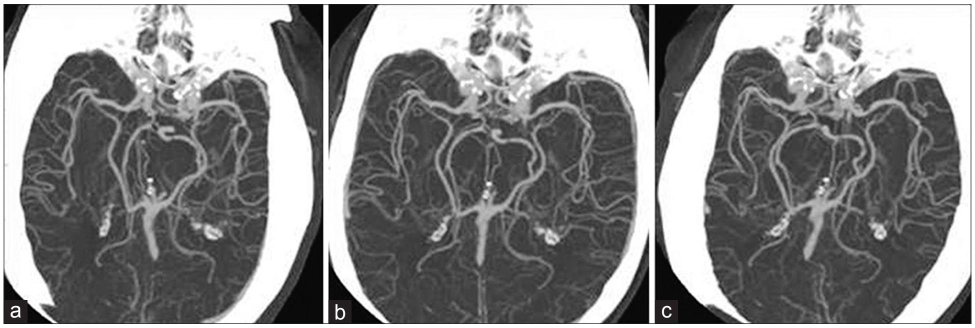

Figure 2: Collapsed maximum intensity projections of the circle of views in inferior and oblique views (a-c) gives a rapid assessment of the circle of Willis at the base of the cerebral hemispheres

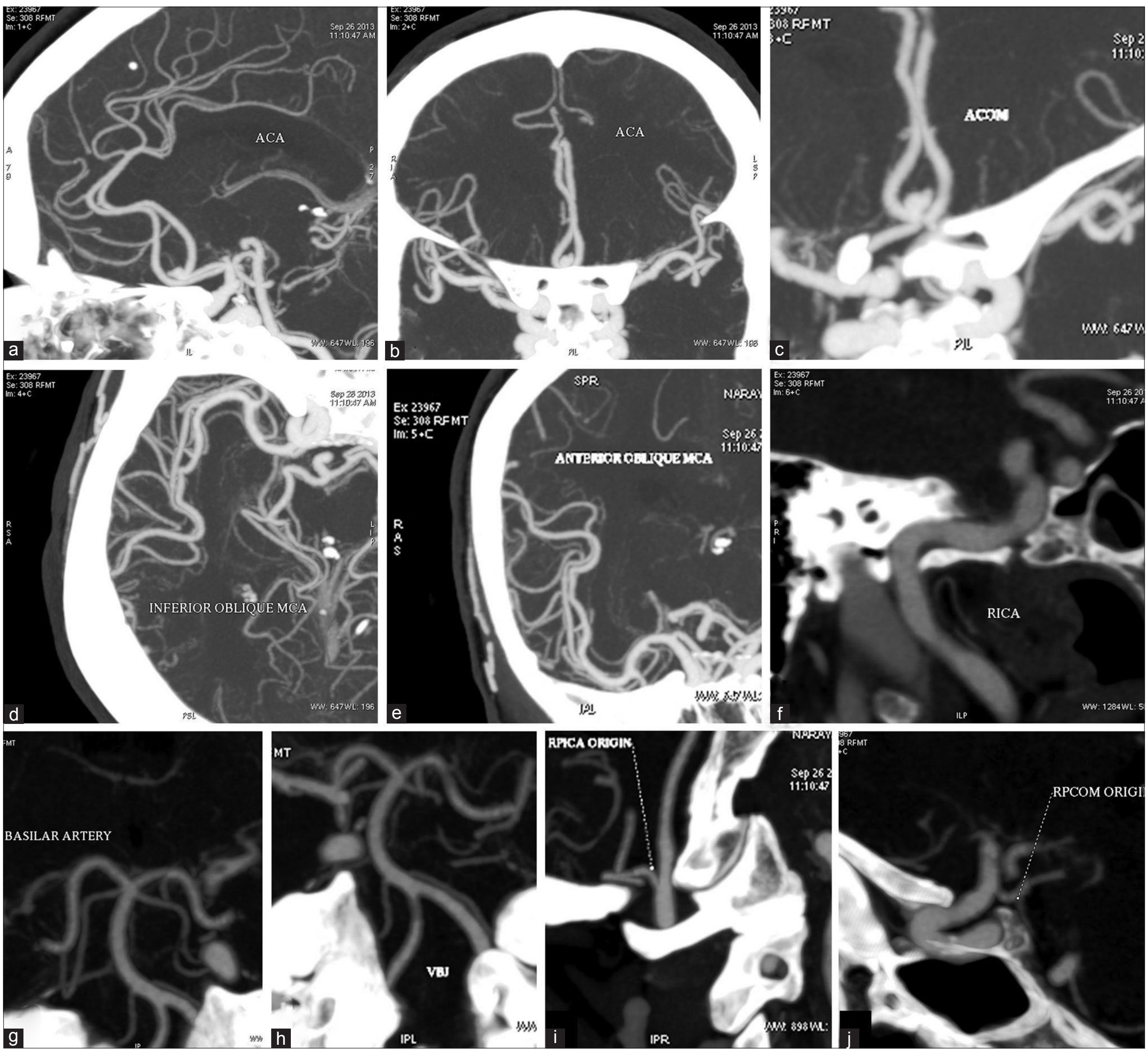

Figure 3: Standard protocol of maximum intensity projections of the vessels of the cerebral vasculature with appropriate annotations

images that are more accurate than in the surface shaded display [Figure 4]. The VR images use percentage classification that more closely approximates the actual contents of voxels that represent various tissues or volume averages. Thus, the final image is represented according to the different tissue component present in each voxel accounted for as a percentage of the whole voxel.[15] In our study, VR of the data was done in all cases that eased the interpretation of the aneurysm giving exact location and relation of the aneurysm. The VR images maintain the original anatomic spatial relationship which is helpful from a surgical view point also.

Adopting a systematic approach of standard reformatted MIP views helps in studying the vessels in detail. Accurate depiction of such aneurysms in considerable less time and in a noninvasive method can be done by MDCTA and using postprocessing techniques.

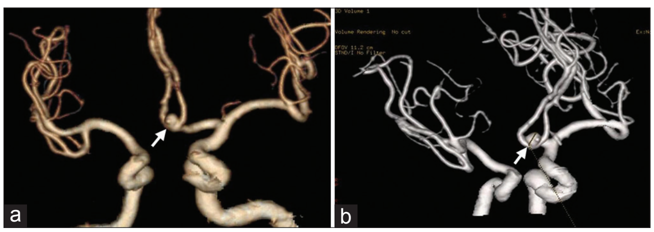

Figure 4: Volume rendered images of a patient with anterior communicating artery aneurysm in oblique planes demonstrating the aneurysm (white arrow) characteristics like surface, tit, dome and neck

The disadvantage of CTA is radiation exposure as compared to MRA. However, the radiation involved is much less as compared to conventional DSA.[11] CTA is contraindicated in patients with renal failure/high creatinine levels, heart failure patients and hypersensitivity to iodinated contrast. CTA requires a high volume of iodinated contrast as compared to DSA that is a limitation. The volume rendered, and MIP images play a significant role in delineating the anatomic location. The workstation and software available for processing the raw images should be optimally employed to create excellent "angio-like" images. A limitation of our study was that there was no direct correlation of CTA findings with DSA for every case in view of extended resources involved in performing both investigations on the same patients.

Magnetic resonance angiography is a time consuming procedure which may not be useful in acute setting of spontaneous subarachnoid hemorrhage due to aneurysmal rupture, and hence CTA is preferred because the procedure takes lesser time. Moreover, the movement artefacts cannot be avoided and cortical aneurysms are rarely depicted on MRA compared to CTA. Sometimes large aneurysms can be missed on MRA due to turbulent flow voids.

Digital subtraction angiography remains the gold standard for evaluation of intracranial aneurysms. MDCTA has clearly demonstrated its high sensitivity and specificity

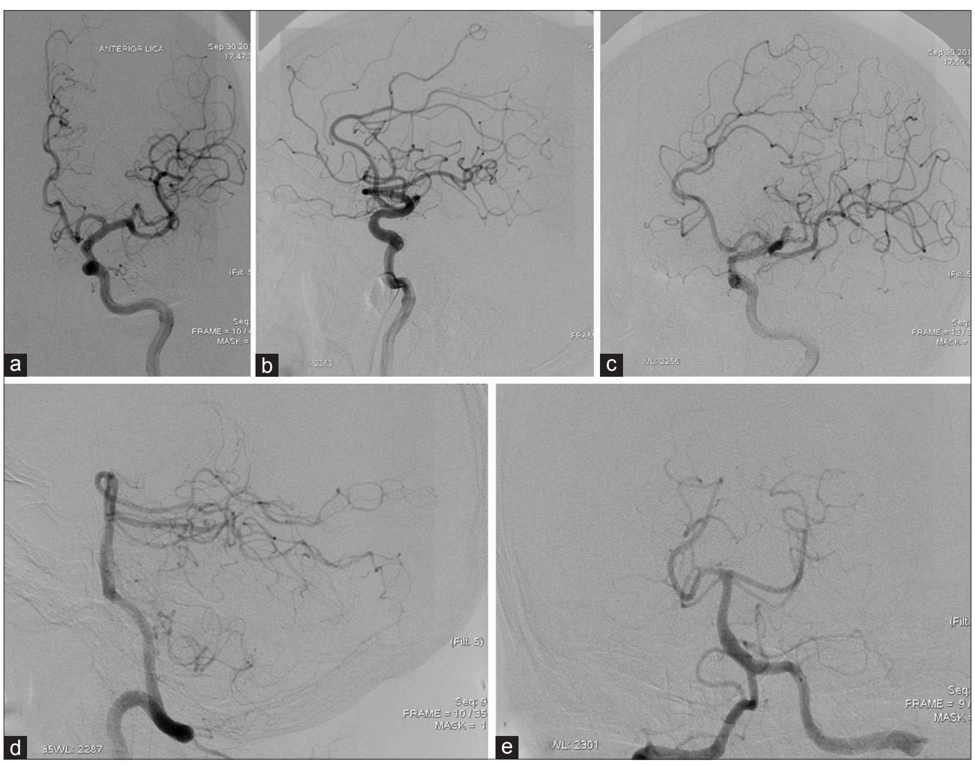

Figure 5: (a-e) Digital subtraction angiography snapshots of the cerebral vasculature in standard planes

to detect aneurysms.[16] The high spatial resolution of the vessels is an advantage. DSA [Figure 5], which is an invasive, relatively costly, procedure done by highly skilled personnel with serious complication rate of 1%, can be replaced by noninvasive, cost-effective, easily to perform MDCTA, for intracranial vascular assessment and aneurysm detection. It can be safely concluded that DSA can be reserved for any difficult and uncertain cases. It has been a natural evolution from the complicated invasive arterial puncture to a simple venous access for cerebral angiography. The journey is complete - "Cath Lab to CT suite."

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