Diagnosis and Technical Consideration of CT Angiography for Intracranial Aneurysm

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Computed tomographic angiography (CTA) for diagnosing intracranial aneurysms in patients with spontaneous subarachnoid hemorrhages (SAH) has been well documented and widely accepted. In this study, we retrospectively documented a large series of 92 patients with spontaneous SAH in our hospital on whom CTA was performed for the diagnosis of intracranial vascular lesion. We correlated the CTA results with operative findings, and furthermore, focused on discussion of three-dimensional (3D) image post-processing and diagnostic methods. During a 3-year period from July 1995 through January 1999, we performed CTA for 92 patients diagnosed as spontaneous SAH. Forty-six aneurysms were disclosed in 43 patients (47.3%), three of the patients had two aneurysms each. The aneurysms ranged in size from 1.6 to 17.3 mm. Six other patients were noted with arteriovenous malformation (AVM, 6.6%), and the remaining 42 patients had negative results for CTA survey (46.1%). The CT equipment used was a Hi-Speed Advantage Spiral CT scanner (GE Medical Systems, U.S.A.), along with post-processing software (Advantage Window version 1.2, GE Medical Systems, U.S.A.) running on a Sparc 20 workstation (Sun Microsystems, Inc. U.S.A.). All the procedures of post-processing and diagnosis were performed by a radiologist. We tried to set up five routine projections, apply free rotation, correlate with the original axial images, and make diagnoses of the vascular lesions on the workstation. Among the 43 patients diagnosed with intracranial aneurysms, 30 of them were operated on by neurosurgeons. Finally, 30 aneurysms were found in 29 patients, and no aneurysm could be found in one patient. Corresponding to the operative findings, the correct predictive rate of the CTA was 96.8%. According to our results, with some improvement of the image post-processing and the diagnostic method, we made the diagnoses of small intracranial aneurysms (2 to 5 mm) using CTA with more confidence. With CTA, we located the origins of the aneurysms as well as the direction of domes. Such improvements of CTA offers much information for neurosurgeons to proceed to operation without the need of conventional angiography.

Key words: CT angiography, 3-D reconstruction, Intracranial aneurysm, Subarachnoid hemorrhage

In patients with spontaneous subarachnoid hemorrhage (SAH), the role of computed tomographic angiography (CTA) to evaluate whether intracranial aneurysm is present has been widely discussed and well accepted [1-3]. After introducing spiral computed tomography (spiral CT) accompanied by an autoinjector, applying a thinly sliced continuous scan at the right time of hemodynamic arterial phase occurred. Three-
dimensional (3D) image reconstruction and post-processing was performed in the computer thereafter. These combinations made the CTA available and reproducible. The radiologists were able to freely rotate the 3D object of intracranial arteries and search for possible aneurysms. Numerous functions were offered by different software with various post-processing and image display methods, such as 3D reconstruction to remove the skull using the voxel subtraction method which allowed for the presentation with pure vascular images. Another allowed free rotation of the 3D object with the presence of both bony and vascular structures and an application of a cut plane at any position to see the vascular structures. Another program used a special 3D display method named “see-through” to penetrate the bony calvarium and search for vascular anomalies.

The role of CTA in the diagnosis of patients with intracranial aneurysms is still controversial. Owing to the wealth of previous research and clinical usage, using conventional digital subtractive angiography (DSA) as the standard for comparison, around 85% [4] to 96% [1] of intracranial aneurysms should be diagnosed using CTA alone. Among the studies using different CTA protocols and manufacturers, the sizes of aneurysms detected using the CTA were larger than 3 mm. Even though the detectable sizes were reasonable, aneurysms between 3 mm and 6 mm still tended to be missed [2,4]. The purposes of our efforts were to make our own CTA protocol for imaging and diagnosis, and to seek some possible factors for improvement.

MATERIALS AND METHODS

We retrospectively documented the patients with spontaneous SAH who were diagnosed either using brain CT or lumbar puncture and then had CTA arranged as soon as available. From July 1995 through January 1999, the records of 92 patients were collected, with ages ranging from 16 to 83 years. The CT scanner used for CTA was a Hi-Speed Advantage Spiral CT scanner (GE Medical Systems, U.S.A.) utilizing post-processing software (Advantage Window version 1.2, GE Medical Systems, U.S.A.) running on a Sparc 20 workstation (Sun Microsystems, Inc., U.S.A.).

Protocol of acquisition CT scanning

We tilted the gantry cephalically to the superior orbitomastoid line (SOM line) and set the spiral scan beginning from the skull base upwardly. That covered most of the arteries from the anterior cranial fossa to the posterior cranial fossa. Even more, it reduced the overall acquisition length in Z-axis during scanning. Continuous spiral scans were applied, with a collimation of 1 mm. The rotational time of the gantry was 1 sec/cycle, and pitch set was 1 (that is, the table would move at the speed of 1 mm/sec). The scanning coverage in Z-axis was totally 40 to 45 mm from the skull base upward. The field-of-view (FOV) was set as 18 to 20 cm depending on the cranial size, with the central position located in the sella turcica. Non-ionic iodinized contrast medium (Ultravist 370, Iodine concentration: 370 mg/ml, Schering AG, Germany) was administrated via a preset 20 G intravenous lock at the antecubital vein. The injection rate was 2 cc/sec, with continuous injection for 40 seconds, for a total of 80 cc of contrast medium injected. The injection-scan delay was normally 20 seconds, and gradually increased to 25 seconds in senile patients or patients with congestive heart disease, but did not exceed above 25 seconds. The scanning time was only 40 to 45 seconds, and totally 60 to 70 seconds including the injection-scan delay. Thereafter, the patients left the CT room without any further procedures.

Reconstruction of the CT images from the raw data took place subsequently, producing the original axial images with 50% overlapping. That is, the images with 1 mm slice thickness were reproduced every 0.5 mm. Then all of the 80 to 90 original images were sent to the workstation (Sparc 20) via a Local Area Network (LAN). We did both the post-processing and diagnosis as a whole, this was done by a radiologist. It took 20 to 40 minutes to complete one exam. The post-processing method we used was voxel subtraction to remove the bony calvarium, thus the soft tissue of the brain and enhanced arteries were residual. All of the arteries were clearly presented with MIP display. We created five routine projections, applying free rotation and making diagnosis. The five-step post-processing method is detailed below:

**Step One: Forming 3D Object A**

Firstly, construct the original axial images into a 3D object A, which include all the voxels in the
space, for instance, the scalp, bony skull, brain parenchyma, and the enhanced arteries.

**Step Two: Forming 3D Object B (initial skull object)**

Make a copy of the object A, and perform further modifications on a new object A. Based on the Hounsfield Unit (HU), choose the voxels with HU more than 160. At that moment, all the bony structure and most of the enhanced arteries were selected. Take an original axial image near the sella turcica for reference. Gradually increase the lower threshold from 160 to the range between 280 and 330, then stop while most of the bony structures are selected, and leave most of the enhanced arteries unselected. The goal is to choose the bony calvarium with the least amount of enhanced arteries. This key step will determine whether the following steps will be successful or not. The threshold of one exam differs from those of the others. That is why we did not apply the same threshold for all of the exams. Apply the threshold, and form the initial object B, which contains most of the bony calvarium and small pieces of more highly enhanced arterial debris.

**Step Three: Forming 3D Object B (final skull object)**

Further modify the initial object B with application of voxel “dilation” by 2 units first, then apply “close gap” by 10 units. Finally, set the cursor at any position on the bony calvarium, and apply “select object.” This will remove all the separate voxels in the space of the object, and the debris of vessels will disappear. The final object B indicates a more dense and compact 3D model of the bony calvarium.

**Step Four: Object A – Object B = Object C**

Using the function for voxel subtraction, the object A is subtracted from the final object B to get a new object, C. The new object C is a 3D model without bony calvarium. Set the cursor at the center of object C, and apply “select object.” This will remove the scalp and attached subcutaneous soft tissue. Consequently, all that remains in object C is the brain parenchyma and enhanced vessels. Finally, set the display method as MIP and adjust the window width and window level. The CTA will be presented and finished.

**Step Five: Rotation and Diagnosis (five routine projections)**

With the finished 3D CTA object, begin to rotate and investigate the object, make a diagnosis, and take images. Corresponding to the conventional angiographic projections, supplemented with some anatomical projections, we set five routine projections ourselves. Based on the five projections rotating gradually and freely, all of the notable anatomical sites well known for aneurysms will be demonstrated. The five routine projections (Fig. 1) are described subsequently: First is the basal view (Fig. 1a). Choosing the inferior projection for the CTA object, characteristic anatomy of the circle of Willis is presented. Bilateral posterior communicating (P-com) arteries is illustrated as well. Applying some rotation anteriorly or posteriorly, the origin of bilateral P-com from the internal carotid arteries (ICA) maybe demonstrated. The relationship between the P-com and bilateral posterior cerebral arteries (PCA) are shown as well. In our patient, the dominant bilateral P-coms were presented with invisible bilateral P1 segments of PCA, perhaps due to hypogenesis or agenesis. The second routine projection is the ACA and MCA view (Fig. 1b). Simply put the cursor at the center of the circle of Willis, choose posterior cut, and thus the voxels posterior to the cursor will disappear. Changing the projection of the object anteriorly, the details of ICA bifurcation to the anterior cerebral arteries (ACA) and middle cerebral arteries (MCA) are presented. Rotating left or right, the area of anterior communicating (A-com) artery is well demonstrated. In addition, the MCA distally to the genu area can be evaluated. The third projection is the basilar artery view (Fig. 1c). Going back to the first basal view projection, with the same cursor position, apply an anterior cut to the object and then change to anterior projection. The basilar artery is shown clearly as well as the bilateral PCAs. While observing the basilar and other adjacent arteries with simple rotation, a basilar tip or PCA aneurysm can be checked and confirmed. The fourth and fifth routine projections are the left and right lateral views (Fig. 1d). Going back to the initial basal view projection, with the same cursor position, apply an anterior cut to the object and then change to anterior projection. The basilar artery is shown clearly as well as the bilateral PCAs. While observing the basilar and other adjacent arteries with simple rotation, a basilar tip or PCA aneurysm can be checked and confirmed. The fourth and fifth routine projections are the left and right lateral views (Fig. 1d). Going back to the initial basal view projection while attempting to observe the left side, put the cursor slightly to the right of the midline and choose right cut. Thus, the left ICA along with the basilar artery is preserved. Changing the projection into either right or left, the image presented is similar to the conventional DSA in the lateral view. The right side is
Figure 1. Five routine projections of the CTA: a. basal view, illustrates the whole circle of Willis, especially bilateral P-com. b. ACA and MCA view, shows the distal ICA bifurcating into the MCA and ACA, and the A-com region. c. basilar artery view, demonstrates the course of the basilar artery as well as bilateral PCA. d. lateral view of the left side, shows a projection similar to that of conventional angiography, typically for evaluating the ICA and P-com aneurysms. The patient is demonstrated with bilateral dominant P-com and supplying both PCA.

Figure 2. Two aneurysms located in the P-com and ICA: dual aneurysm of the patient in both the right P-com and right ICA distal to P-com. a. basal view, illustrates the domes of both aneurysms directing posteriorly and laterally. b. lateral view, demonstrates the two aneurysms distributed along the ICA.
Figure 3. Aneurysm of A-com: a. ACA and MCA view, shows the aneurysm originating from the transition of A1 to A-com, with the dome directing downward and right. The left A1 segment is not demonstrated, due to hypogenesis or agenesis. b. lateral view of the right side, demonstrates the aneurysm in different projection. Interruption of the ICA siphon is also illustrated.

Figure 4. Aneurysm of the PCA: a. basal view, and b. basilar artery view. Illustrates the right PCA aneurysm in two different projections. The aneurysm is located in the P2 to P3 segment, with fusiform shape.

Figure 5. Erroneous diagnosis of the ACA aneurysm: a. ACA and MCA view, b. lateral view of the right side. The initially misleading ACA aneurysm is located in the proximal pericallosal artery. Also duplicating artifacts demonstrated in the ICA due to involuntary movement of the patient in the beginning. The patient stayed calm thereafter and the upper 2/3 of the vessels remain clear. Subsequently incomplete coverage in the superior margin of Z-
processed in the same manner. In this view, the traditional ICA and P-com aneurysms can be well evaluated.

In case of any out-pouching vascular lesion identified, we further rotated the picture to demonstrate the parent artery and measure the size of aneurysm. To assure the diagnostic accuracy, we double-checked to confirm the aneurysms using both the 3D object as well as the original axial images. After observing the original sequential axial images, the aneurysm was further confirmed as a blind-ended lesion arising from the parent artery. When only an infundibular dilatation was noted, a normal artery may have been continuing from the vascular pouch, especially at the P-com orifice. Other overlapping density that mimics the aneurysm should be excluded similarly. After this procedure, we greatly increased the confidence level of the diagnosis.

We documented all of the aneurysms diagnosed, along with the origin, size and direction. Some of the patients diagnosed with aneurysms underwent operations. Thereafter, we correlated the CTA results with the operative findings, and calculated the correct predictive rate of the CTA. The rate was defined as A/B times 100%, where ‘A’ was the number of surgical confirmed aneurysms diagnosed using CTA, and ‘B’ was all the number of aneurysms diagnosed using CTA proceeding surgery.

**RESULTS**

Among the 92 patient who underwent CTA (Table 1), 43 patients were diagnosed with intracranial aneurysms (47.3%) (11 male patients and 32 female patients). Three of the 43 patients had two aneurysms. Six other patients were diagnosed with AVM (6.6%), and 42 patients had negative diagnoses (46.1%). The size of aneurysm ranged from 1.6 to 17.3 mm (Table 2). The smallest two aneurysms were less than 2 mm, but not surgically approved. The smallest aneurysm detected using our CTA with surgical approval was 2.3 mm in size and was located in the ICA. Twenty-five small aneurysms diagnosed using CTA, with size less than 5 mm, comprised 54.3% of all the diagnosed aneurysms.

The locations of the 46 aneurysms are illustrated in Table 3. Twenty-three of them were located in the P-com and ICA (Fig. 2), accounting for 50%. A total of 16 (34.8%) aneurysms were located in the A-com (Fig. 3) and ACA, two in the MCA (4.3%), and one in the PCA (Fig. 4). The remaining four aneurysms included two in the basilar artery and each in the vertebral artery (VA) and posterior inferior cerebellar artery (PICA).

Thirty of the patients with aneurysms underwent operations. Among the 30 patients, 31 aneurysms were disclosed using CTA. One of them had two aneurysms (Fig. 2), which were located in the right P-com and right ICA distal to the P-com, respectively. Using surgery, 30 aneurysms were clipped or wrapped in 29 patients; all of the locations and origins of aneurysms were consistent with CTA findings. However in one patient, no aneurysm was found during the operation. The CTA of this patient disclosed an aneurysm located in the proximal A3 segment of ACA, with the dome directed upward and the size measuring 2.7 mm. After reviewing the 3D object of CTA and the original axial images, this was concluded to be a mis-diagnosis (Fig. 5), reassessed as a normal proximal pericallosal artery. Due to involuntary motion of the patient raising his head at the beginning of the CTA scan, the ICA was partially dual-scanned and reproducing the duplicated images. In this situation, less coverage of Z-axis in the upper margin also occurred, which made the proximal pericallosal artery truncated in the beginning. Consequently, the truncated artery looked like a blind-ended vascular pouch, leading to the error in diagnosis. Within all the 31 aneurysms diagnosed using CTA and confirmed during operation, there was only one false positive, and the residual 30 aneurysms were all proved. The correct predictive rate of our CTA was 96.8%.

**DISCUSSION**

CTA in the diagnosis of intracranial aneurysms is an alternative method to the conventional
angiography. Although some convincing results have been well documented, along with the convenience and efficiency of the procedure, many neurosurgeons and radiologists still hesitate to accept it. Our analysis indicated some important reasons for concern. Initially, the amount of confidence radiologists have in CTA is not known. For instance, when a radiologist discloses an aneurysm on the CTA, he may be concerned about the chance of it being a false-positive. However based on our results, our correct predictive rate was as high as 96.8%, which is a quite acceptable rate. In the study of CT angiography with SSD for detection of intracranial aneurysms, Liang et al. [6] reported a positive predictive value as high as 93.7%, respectively, in a series of 23 patients. Thus we can say, when the quality control and technique of CTA are accurate, the diagnoses of aneurysms using CTA are reliable. Furthermore, not only the aneurysms diagnosed using the CTA, but also the origin, direction, and size were well demonstrated. This allows neurosurgeons and radiologists to be confident and go ahead with surgery. As all the important information of an aneurysm was collected using CTA, further conventional angiography for confirmation may not be necessary for every CTA-positive patient. Among our 30 patients who underwent operations, only the initial 11 patients received both methods. The later 19 patients underwent surgery with only the CTA results. That means CTA-positive diagnosis for aneurysms are being gradually accepted by our neurosurgeons.

We must emphasize that our on-line diagnosing procedure was conducted on the workstation. We managed the 3D objects, and correlated them with the original axial images, instead of waiting for the 3D object to be finished by technicians. In our opinion, we significantly improved the diagnostic accuracy and avoided possibly overlooking aneurysms. That is why we chose more complex and time-consuming procedure. When a radiologist makes a CTA diagnosis only using the images printed automatically or made by the technicians, the information from 3D free rotation of the CTA will be absent, because the printed images are only made from the routine, fixed post-processing procedure. Under such circumstances, aneurysms tend to be overlooked. The use of the software on the workstation may be very helpful for the radiologist to make the diagnosis by himself. The use of simultaneous cursors is to be emphasized. The simultaneous cursors present both the 3D object and original axial images. When we changed the position of each cursor, the simultaneous cursor was updated immediately. Thus, we had much more confidence with the corresponding points in both the 3D CTA object and the original axial images without any hesitation or confusion. For the CTA negative patients, we arrange for conventional angiography. If the results were negative again, follow-up CTA or conventional angiography was performed 7 to 10 days after the initial test for further confirmation. It has been the previously accepted protocol to use conventional angiography for the possibility of thrombosis or vascular spasm. One of our patients was diagnosed with an A-com aneurysm during the 2nd follow-up CTA and then proven by operation. Since both the initial CTA and conventional angiography revealed no obvious aneurysms, it was possibly due to thrombosis or regional spasm.

Regarding the limitation of the size of aneurysm to be diagnosed using CTA, quite different results were reported based on each study. Generally speaking, aneurysms tended to be missed when the sizes ranged between 3 mm and 6 mm [2]. As for the smallest limitation, some authors reported around 2 mm [1,6]. This could be explained by the CTA raw data. Making the original axial image direction as X-axis and Y-axis, the matrix (axial resolution) was set as 512 × 512, along with the FOV as 20 cm. The resolution on the X-Y plane should be around 0.4 mm/pixel. For an aneurysm with a size of 2 mm, at least five pixels demonstrated the scale, and it is possible to be disclosed without problem. The weak point of CTA resolution is in the direction of Z-axis. Constrained by the CT collimation,
only 1 mm could be reached at the thinnest, that is to say, the resolution in Z-axis would be around 1 mm. Some may think that many more images could be reconstructed from the spiral raw data into smaller distances rather than 1 mm. In our protocol, we reconstructed them into the distance of 0.5 mm. However, it only creates overlapping images with the same slice thickness of 1 mm, rather than truly 0.5mm-slice-thickness ones. This only makes the later 3D object more smooth with less zigzag artifacts in the Z-axis, but it does not improve the spatial resolution. In other words, if an aneurysm with the size of 2 mm is mainly along the X-Y plane, there will be better chance to demonstrate. For example, small aneurysms in the P-com or A-com may present such a condition. However, if the small aneurysm is directed mainly upward or downward, it will be much more difficult to pick up. With the introduction of a newer multi-sliced helical CT scanner, thinner sections could be applied, and this will undoubtedly increase the resolution in Z-axis.

As previously mentioned, the methods of the post-processing procedure of the CTA may differ according to different hardware and software. Some programs preserve only the bony calvarium and enhanced arteries presented by surface shaded display (SSD). Another may have MIP projection and apply cut-planes while preserving all 3D voxels. The method we chose was to eliminate the bony calvarium only, preserve all the residual voxels, and display with MIP.

Kallmes et al [8]. made a phantom of vascular branching and aneurysms, then performed CTA to evaluate both MIP and SSD displays. They concluded that SSD was better than MIP for diagnosis. We are not in complete agreement with such opinion. Since the actual conditions and tissue relationship of intracranial arteries are not as ideal as in the vascular model, they differ from person to person. With different hemodynamics among patients, the HU of voxels on the enhanced arteries may vary, making the tissue contrast different as well. If we simplify the situation by applying a fixed HU threshold, some of the voxels with lower HU would be omitted, although they were really part of the arteries. Consequently, after this process, the 3D object of the arterial structure will not be ideally complete due to the some voxels omitted. These could locate in the margin or some transitional zones of the arteries, and important for demonstrating small aneurysms. If we preserve both the arteries and bony structure, due to the bony shielding, we cannot freely evaluate the vascular structures at any angle or projection, as we do with the five routine projections. Thus, this method also tends to miss some small aneurysms. These are the reasons we chose our methods for post-processing to prevent any possible factors leading to misdiagnosis.

The weak points of CTA at present are the areas near the base of posterior fossa and sella turcica, [4] since it is very difficult to separate the voxels of bony structure and the adjacent atherosclerotic ICA, as well as potentially decreased image quality due to beam hardening artifact. In our CTA images, all of the siphon portions of the ICA were interrupted due to subtraction while removing the bony structures (Fig. 3b). In our CTA results, all posterior fossa aneurysms, including basilar artery, PICA and VA, consisted of 8.7% of all 46 diagnosed aneurysms. The right way to prevent misdiagnosis is to investigate the original axial images. We had one patient diagnosed with ICA aneurysm, proximal to the P-com, who only presented in the original axial images.

There are two key points for successful CTA scanning: one is the optimal injection-scan delay; the other is to control the patient motion. We routinely applied our experience for setting the delay from 20 to 25 sec, which depended on the patients’ age and whether congestive heart was present. It was difficult to predict the precise injection-scan delay when we did not test for each patient. However, this did not influence our results, since we possibly underestimated only less than 5-6 seconds, that means only the initial 5-6 mm was not well enhanced of the slices from skull base. Usually, our scan coverage was low enough, so only partial VA voxels were omitted. As for the patients’ motions, it is also unpredictable. Usually we kept the patient as comfortable as possible, and used non-ionic contrast medium to minimize the irritation. The most difficult one was the patient who had the false-positive result. Other patients were generally cooperative, only very little fine motion occurred during the 40-second scan time. With our diagnostic method, emphasizing the role of original axial images, we easily differentiated a single-slice motion artifact from a true vascular pouch.

In conclusion, the diagnosis of CTA for
intracranial aneurysms should be emphasized along with the reference on the original axial images, as well as on-line diagnosis of 3D objects, and better display without bony interference. With these techniques, it is possible to improve diagnostic accuracy.

**ABBREVIATIONS**

ACA  Anterior Cerebral Artery  
A2    A2 segment of ACA  
A3    A3 segment of ACA  
A-com Anterior Communicating Artery  
AVM  Arteriovenous Malformation  
CT   Computed Tomography  
CTA  Computed Tomographic Angiography  
DSA  Digital Subtractive Angiography  
ICA  Internal Carotid Artery  
LAN  Local Area Network  
MCA  Middle Cerebral Artery  
MIP  Maximum Intensity Projection  
PCA  Posterior Cerebral Artery  
P1    P1 segment of PCA  
P-com Posterior Communicating Artery  
PICA Posterior Inferior Cerebellar Artery  
SAH  Subarachnoid Hemorrhage  
SSD  Surface Shaded Display  
VA   Vertebral Artery

**REFERENCES**

電腦斷層血管攝影對顱內血管瘤之診斷及技術探討

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電腦斷層血管攝影（CTA）用於自發性蛛網膜下腔出血的病人，以診斷其血管瘤之存在與否，已有不少國內外學者肯定。本文的目的，乃是回溯性統計本院之較大規模使用CTA檢查，診斷出顱內血管瘤的發生位置，與手術結果比較，並加強於立體影像後處理及診斷方式上的探討。

在三年的期間內，我們為臨床上診斷或電腦斷層確定自發性蛛網膜下腔出血的病人，從事CTA之檢查。在所有受檢的92例病患之中，有43人發現了血管瘤（佔47.3%），共46個血管瘤被發現，其中3人分別有兩個血管瘤，大小介於16.6到17.3 mm；另有6例患者為動靜脈畸形（AVM，佔6.6%）；其餘42例並未發現血管異常（佔46.1%）。

我們的電腦斷層掃描儀是採用奇異（GE）公司的Hi-Speed Advantage Spiral CT scanner，配合工作站SUN Sparc 20，執行影像後處理軟體GE Advantage Window, version 1.2。整個CTA的影像後處理及診斷，完全是由放射診斷科醫師親自操作。我們嘗試了出五個常規的投射角度，稍作旋轉，輔以原始影像，實際在工作站上診斷血管病變。

在43例被診斷有血管瘤的病患中，有30例患者接受手術，結果在其中的29位病人找到了30個血管瘤，在1例病人找不到任何血管瘤，手術結果的病人統計，CTA陽性之正確率为96.8%。

根據我們的結果，認為經由影像後處理及診斷方式的改進，使得CTA診斷顱內小血管瘤（介於2-5mm）成為可能，並能確切呈現在大數血管瘤的頭部（neck）及底部（dome）的方向，提供了足夠的資訊，使得不經傳統的血管攝影而直接進行手術成為可能。

關鍵詞：電腦斷層血管攝影、立體影像重組、顱內血管瘤、蛛網膜下腔出血