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Detection of Intracranial Aneurysms Using Multi-detector Row CT 3D-Angiography: Comparison with Operative Findings[1]

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Purpose: To assess the efficacy of three-dimensional CT angiography (3D-CTA) using multi-detector row computed tomography (MDCT) in the evaluation of intracranial aneurysms in patients with non-traumatic acute subarachnoid hemorrhage and to describe those aneurysms which were not found 3D-CTA.

Materials and Methods: 3D-CTA was done in 40 patients with non-traumatic subarachnoid hemorrhage by using a 16-slice MDCT; conventional digital subtraction angiography (DSA) was done in 36 of those patients within 12 hours. The CT and DSA images were reviewed by two radiologists and the site, size and neck of the aneurysms were evaluated. The results from these two modalities were then compared with the operative findings. We calculated the detection rates by 3D-CTA and DSA and evaluated the size differences of aneurysms dignosed with 3D-CTA and those found at surgery. We also analyzed the locations and sizes of aneurysms missed by 3D-CTA and attempted to explain these false negatives.

Results: A total of 55 aneurysms were surgically confirmed in 40 patients. 48 of these were detected pre-operatively by 3D-CTA. Thus, the detection rate by 3D-CTA was 87%. The size difference of aneurysms as calculated by 3-D CTA and found operatively was as follows: less than 1 mm in 17 cases, within 1 - 2 mm in 15 cases, and more than 2 mm in 16 cases. Seven aneurysms were not detected by 3D-CTA. The major cause of these missed aneurysms was their small size. The undetected aneurysms were less than 2 mm in size, except for 2 instances of PCoA aneurysms. One case was not detected due to difficult image evaluation. A possible explanation of the one remaining missed aneurysm was the filling of the aneurismal sac by thrombosis.

Conclusion: Though there were some limitations in the detection of aneurysms, 3D-CTA using 16-channel MDCT may provide sufficient pre-operative information for the management of patients with intracranial aneurysms in cases of emergency operations or DSA-failure.

Index words : Aneurysm, intracranial
Computed tomographic (CT), angiography

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Ruptured aneurysms are the main cause of subarachnoid hemorrhage, and if left untreated have a high risk of rebleeding after initial hemorrhage, thus mandating early surgical or endovascular treatment.

Though DSA remains the gold standard for detecting intracranial aneurysm, many recent studies of 3D-CTA have demonstrated its clinical usefulness. In comparison to DSA, 3D-CTA is a useful method with some superior qualities for detecting intracranial aneurysms.

Some reports, however, have noted the difficulty in detecting aneurysms in some locations and those of a small size by 3D-CTA using single detector helical CT (1). However, recent advances in technology have resulted in better spatial resolution and decreased scanning time by using multi-detector row CT, thus increasing the sensitivity for depicting small aneurysms. There have been several reports comparing the sensitivity of 3D-CTA with multi-detector row CT (MDCT) to DSA, but to the authors' knowledge, no study has compared the results of 3D-CTA with operative findings of intracranial aneurysms.

The purpose of our study was to assess the utility of 3D-CTA using MDCT in the evaluation of intracranial aneurysms in patients with nontraumatic acute subarachnoid hemorrhage and to analyze the aneurysms which were not found on 3D-CTA.

Materials and Methods

Between December 2002 and July 2003, 40 patients presented with subarachnoid hemorrhage on non-contrast CT scan and were thought to have intracranial aneurysms. These patients then had pre-op 3D-CTA evaluations for the suspected aneurysm. Eleven of these cases were men and twenty-nine of them were women with an age distribution ranging from 27 to 79 years. The mean age was 54 years.

CT was performed with a 16-slice multi-detector row CT (Siemens SOMATOM Sensation, Berlin, Germany). 80 - 100 ml of nonionic contrast material (Ultravist 300, Schering, Berlin, Germany) was administered intravenously with a power injector at a rate of 4 ml/sec. The bolus tracking method in the common carotid artery at the level of the C3-4 vertebra was used for CT angiography. Scanning was begun at the point of 100 HU from foramen magnum to mid-lateral ventricle level. Parameters for the CTA acquisition were 120 kV, 100 mA, 0.75 mm collimation, 12 mm speed of table, pitch 1, and 200 FOV. The scan time was about 10 seconds. The 3D-CTA image was obtained from axial source images reconstructed in 1 mm slice thickness by using the volume rendered technique. Angiographic studies were interpreted at a workstation (Syngo; Siemens Medical Systems, Erlangen, Germany) by using volume rendering in several planes. Image reconstructions were done by one neuroradiologist.

DSA was done on 36 patients within 12 hours after or before 3D-CTA. Operations were performed on 4 patients without DSA. In 2 patients, DSA failed as a result of vascular tortuousity. 2 patients underwent emergency operations without DSA because of rebleeding. DSA was performed using a Philips Integris C-2000 (Philips, Eindhoven, Netherlands) with a matrix of 512 ×512 pixels. Bilateral selective carotid angiograms and unilateral/ bilateral vertebral angiograms were obtained in the anterior, lateral and oblique projections.

One neuroradiologist and one radiologist interpreted by consensus 40 CT scans and 3D-CTA and 36 DSA, and evaluated the size, location and neck of the aneurysms. The readers traced the course of large vessels and categorized the site of aneurysms as being in the anterior cerebral artery (ACA), the anterior communicating artery (ACoA), the middle cerebral artery (MCA) and its bifurcating sites, the posterior communicating artery (PCoA), the tip of the basilar artery, the vertebral artery (VA), the posterior inferior cerebellar artery (PICA) or the anterior choroidal artery (AChA). The size of the aneurysms was measured in spherical minimal and maximal diameters, and the necks were evaluated as to whether they were visible or not. The site and the size of the aneurysm and the aneurysmal neck were described for each aneurysm. The time used to interpret each 3D-CTA image was about 5 - 10 minutes.

The operations were performed by an expert neurosurgeon. Usually unilateral craniotomy was performed if the aneurysm appeared unilateral on imaging , and bilateral craniotomy was performed when imaging suggested bilaterality . The size and the other specifics findings found at surgery were described by location. The aneurysms were clipped, wrapped around or left alone in accordance with the surgeon's decision. After operation, the 3-D CTA findings were compared with the operative findings retrospectively. The differences in the size of aneurysms determined by 3D-CTA findings and at surgery were sorted into three categories; less than 1 mm, between 1 - 2 mm, and more than 2 mm. In comparison to the operative findings, we calculated the overall detection rate, and evaluated the missed aneurysms on 3D-CTA retrospectively and analyzed their location, size and the possible causes of their having been missed.

Results

Among the total of 40 intracranial subarachnoid hemorrhage patients, 12 patients (30%) were graded I or II on the Hunt and Hess scale for neurological condition, and the other 28 patients (70%) were graded III, IV or V. Operatively, a total of 55 aneurysms were detected in 40 patients. 30 patients had one aneurysm, 6 patients had two aneurysms, 3 patients had 3 aneurysms and only one patient had 4 aneurysms. No other cause of subarachnoid hemorrhage was found.

3-D CTA detected a total of 48 aneurysms in the 40 patients; the detection rate was 87% (48/55). 43 aneurysms were found on DSA in 36 patients (48 aneurysms); the detection rate was 90% (43/48). DSA was not performed on 4 patients; 2 of these because vascular selection by catheter failed due to vascular tortuosity. The two other patients underwent an emergency operation due to rebleeding. We detected all multiple aneurysms in 5 patients with 3D-CTA, and we also detected all aneurysms in 3 patients with DSA. We failed with DSA to detect aneurysms in one of the above 5 patients with multiple aneurysms.

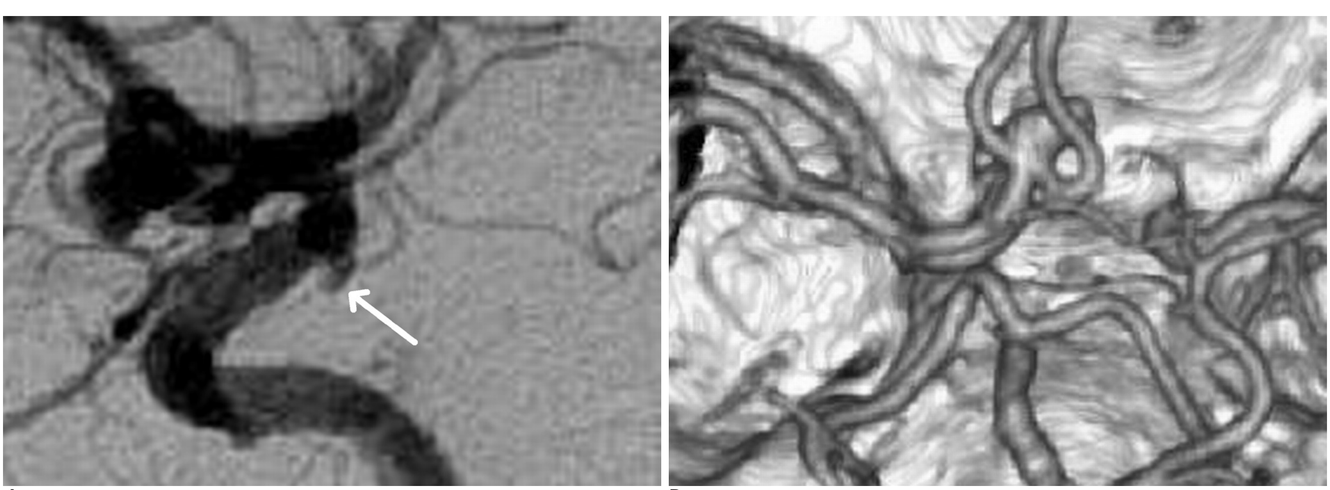
No aneurysm was detected in one patient on either 3D-CTA or DSA images. This aneurysm was too small and wrapped round at operation. Regarding location, the aneurysms were at the ACoA in 13 cases, at the PCoA in 12 cases, at the MCA bifurcating site in 17cases, at the AChA in 3 cases, at the distal ICA in 4 cases, and at the basilar tip in 2 cases. In the remaining cases, the aneurysms were located as follows: two at the M2 bifurcation, one at the A3 segment, and one at PICA (Table 1). Some aneurysms found during operations (2 at the PCoA, 2 at the AChA, 2 at the M2 bifurcation, and 1 at the MCA bifurcation) were not detected on 3-D CTA (Fig. 1). One MCA bifurcation aneurysm detected by 3D-CTA was misinterpreted as an M1 aneurysm and the others were consistent with the operative findings (Fig. 2). In these missed aneurysms, one case was a

Table 1. Number of Aneurysms in Specific Location

(Number of patients)

Location	Operation (40)	3D-CTA (40)	DSA (36)
MCA bifurcation, M1, M2	19	16	15
ACoA	13	13	11
PCoA	12	10	8
AChA	3	1	2
Distal ICA	4	4	4
Basilar tip	2	2	2
PICA	1	1	1
Total	55	48	43

MCA (middle cerebral artery), M1 (primary division of middle cerebral artery), M2 (second division of middle cerebral artery), ACoA (anterior communicating artery), PCoA (posterior communicating artery), AChA (anterior choroidal artery), ICA (internal carotid artery), ACA (anterior cerebral artery), PICA (posterior inferior cerebellar artery), 3D-CTA (3 dimensional computed tomographic angiography), DSA (digital subtraction angiography), N. of pts. (Number of patients)



A B

Fig. 1. Left anterior choroidal artery aneurysm in a 61-year-old woman. Lateral projection DSA image in mid-arterial phase (**A**) shows a small aneurysm (arrow) of the left anterior choroidal artery. On 3D-CTA images, using the volume rendered method (**B**), there is no visible aneurysmal sac of the left anterior choroidal artery.

small AChA aneurysm which was proximate to a large PCoM aneurysm and 4 were too small to detect. One large aneurysm was missed due to difficult image analysised note. One small aneurysm was also not detected on DSA, and was thought to be a thrombosed aneurysm (Table 2). Using DSA, we missed 6 aneurysms, two at the M2 bifurcation (2 mm, 1 mm), one at AChA (2 mm), one at the MCA bifurcation (2 mm), one at ACoA (3 mm), and one at PCoA (3 mm). In patients with undetected aneurysms, the number not found on both 3D-CTA and DSA was five. Two aneurysms were detected only by DSA and one was detected only by 3D-CTA, which was seen as a focal bulging contour (Fig. 3).

The neck of the aneurysms was found primarily to be broad or narrow except in one case of a distal ICA (ophthalmic artery) aneurysm on 3D-CTA where the neck was obscured by the density of the skull base and its large size.

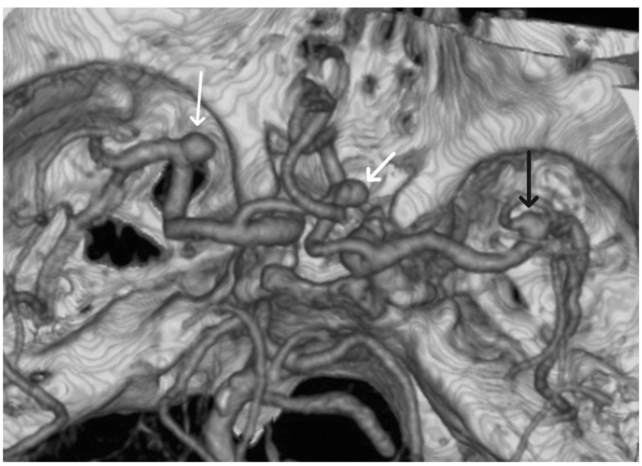


Fig. 2. Anterior communicating artery aneurysm, right middle cerebral artery bifurcation and left middle cerebral artery bifurcation aneurysms in a 79-year-old woman.
3D-CTA image shows three aneurysms; the first one is at the ACoA (short white arrow), the second one is at the left MCA bifurcation (long white arrow), the last one is at the right MCA bifurcation (black arrow). DSA was not performed on this patient due to the failure of vascular selection by catheter.

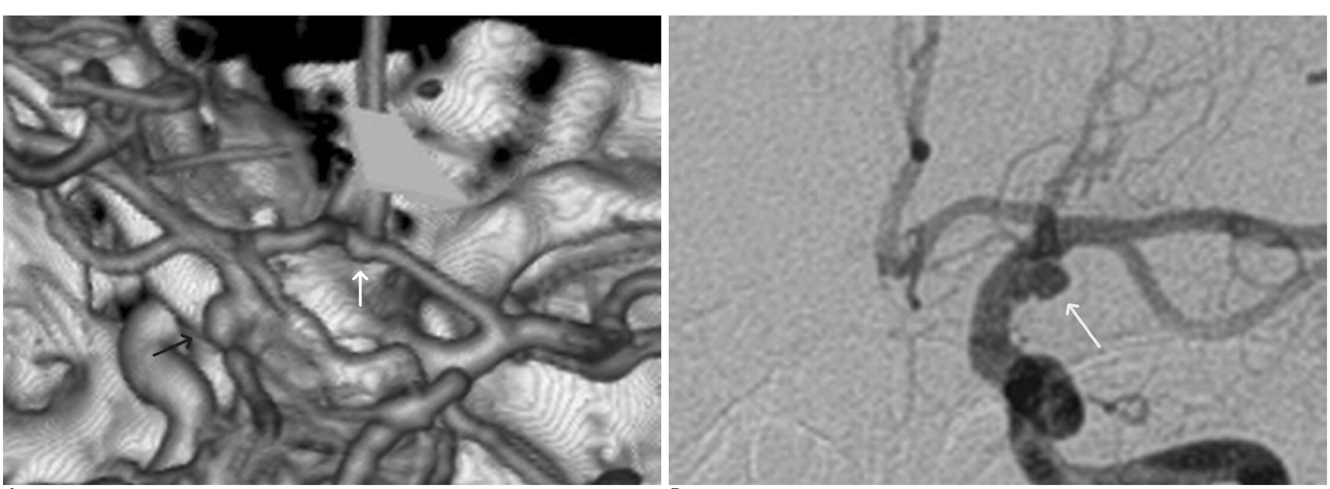
Table 2. Summaries of Missed or Misinterpreted Aneurysms on 3D-CTA

Site *	Size (mm)*	Comments
PCoA	5×7	Difficult image analysis due to venous contamination
AChA	1×1.5	Small in size
AChA	2×2	Obscured by large PCoA neurysm
MCA bifurcation	1×2	Small in size
PCoA	2×3	Suggestive of thrombosed aneurysm
M2 bifurcation	2×2	Small in size
M2 bifurcation	1×1	Small in size
MCA bifurcation	3×2	Misinterpreted as M1 aneurysm due to a non-visualized bifurcating artery

PCoA (posterior communicating artery), AChA (anterior choroidal artery), MCA (middle cerebral artery), M2 (secondary division of middle cerebral artery), *(in operation field)

Table 3. Number of Aneurysms in Each Size Criteria

Size (mm)	Operation	3D-CTA	DSA
≤2	8	9	7
2<, ≤5	25	21	17
5<, ≤10	17	16	18
10<	5	2	1
Total	55	48	43



A B

Fig. 3. Anterior communicating artery aneurysm and left posterior communicating artery aneurysm in 48-year-old woman. An aneurysm with focal bulging contour (white arrow) at ACoA is suggested. The left PCoA aneurysm (black arrow) is noted on 3D-CTA (**A**). DSA (**B**) shows the left PCoA aneurysm (arrow). The ACoA aneurysm is not demonstrated on DSA.

Sizes of the aneurysms were analyzed in each of three modalities (Table 3). Size difference between operative findings and 3D-CTA was less than 1 mm in 17 cases, 1 - 2 mm in 15 cases and more than 2 mm in 16 cases. In each case of an undetected aneurysm on 3D-CTA, the size of the aneurysm was less than 2 mm except for 2 cases of PCoA aneurysms. One of these exceptions measured about 2×3 mm at surgery, and this aneurysm was also not found on DSA. The other case which was identified on DSA was visualized as a suspicious sacular lesion on 3D-CTA in the retrospective review and was measured at about 5×7 mm at the time of operation.

Discussion

Many studies have been performed using single detector spiral CT scans for detection of intracranial aneurysms. Excellent results have been achieved using 3D-CTA for the preoperative detection of aneurysms when compared to DSA (1 - 4), but there is insufficient experience with 3D-CTA to replace DSA in preoperative diagnosis and for the surgical plane determination of aneurysms. DSA remains the gold standard (5). DSA, which has been considered the primary preoperative diagnostic modality, has several disadvantages including invasiveness requiring intra-arterial manipulation and post-procedure complications (6, 7).

Compared with DSA, 3D-CTA is appealing because of its noninvasiveness and conservation of time and cost. Furthermore, patients can be evaluated immediately after a diagnosis of subarachnoid hemorrhage. Additionally, multi-slice technology, using MDCT, has been developed for higher image resolution and thinner slice sections in a shorter scanning time. It provides more definable images by reducing motion artifact and reconstruction with thin sections.

There are several limitations in detecting aneurysms by 3D-CTA. The primary one is location. Detection of aneurysms located near the skull base and surrounded by bone is difficult on 3D-CTA (1, 8). Especially, small PCoA aneurysms and distal ICA aneurysms were difficult to demonstrate due to their proximity to the skull base. The problem of overlapping bone density, though, can be overcome by adjusting the window and level settings during image interpretation in multiple planes (2) and systematic review of all extradural locations for possible skull base lesions using 2D-multiplanar reformatted images or the subtraction method (9, 10).

In our study, 3D-CTA failed to detect seven aneurysms which were less than 2 mm in size and PcoA aneurysms. Those aneurysms were located as follows: two at the AChA, two at the PCoA, two at the second division of the MCA, and one at the bifurcation of the MCA.

A large aneurysm located near the skull base was obscured by bone density; it was impossible to delineate the site of its origin in our study. We could not define the neck of a large ophthalmic artery aneurysm due to obscuration by the skull base density.

Some reports have shown the superiority of 3D-CTA for detecting aneurysms as small as 2 - 3 mm in diameter (1, 6, 11). In a study by Korogi Y et al (1), the highest sensitivity was 71% for aneurysms smaller than 3 mm and 94% for aneuryems 3 - 5 mm in diameter. In a study by Villablanca JP et al (9), sensitivity for a small aneurysm less than 5 mm ranged from 98% to 100%, and specificity was 100%. But other studies demonstrated that 3D-CTA with single-slice technology exhibited lower sensitivity and specificity, as compared to DSA, for aneurysms of less than 3 mm (2 - 4, 8, 9, 12). Kangasniemi M et al (12) conducted a study of 179 patients who underwent CTA followed by surgery (59 aneurysms) and DSA or DSA and surgery. Of 178 verified aneurysms, CTA failed to detect 7 aneurysms 1 to 2 mm in size that were detected on DSA. So although MDCT CTA can detect very small aneurysms, DSA has proved to be more accurate in the identification of such small aneurysms. Also DSA may more accurately reveal the small arteries branching from infundibular enlargements (11).

In our study, there were ten cases of small sized aneurysms measuring less than 3 mm at surgery ; 5 of these were found on 3D-CTA images. The remaining 5 were missed on 3D-CTA images. The detection rate of an aneurysm less than 3 mm was 50%.

3D-CTA did not detect five small aneurysms less than 2 mm in diameter, and four of these were also missed on DSA.

Therefore, the MDCT technology does not improve CTA to the point where it surpasses DSA in the detection of small aneurysms less than 2 mm. In one case of a PcoA aneurysm that was not detected on either 3D-CTA or DSA images, we postulate that the cause of non-visualization of the aneurysm was opacification of the aneurysmal sac by thrombus; however, the operative report did not address this issue.

Another limitation in detection of aneurysms by 3D-CTA is image contamination by venous phase (6). In some cases, early venous pooling was detected simultaneously with the arterial phase, so image analysis interference occurred.

It has been reported that there are some limitations in the resolution of 3D-CTA. Some arteries of small caliber were not visualized on 3D-CTA (13 - 15). This could cause a mistake in locating the aneurysm. Kurokawa Y et al (16) mentioned that the clear demonstration of small arteries by CTA is a great help in accurate diagnosis and in obtaining an excellent surgical cure and has established a routine protocol of imaging using large amounts of the contrast medium with a high iodine concentration to specifically search for small arteries. However, the administration of iodinated agents with a relatively large bolus technique is potentially hazardous (17). Iodinated contrast agents must be used with caution in patients with serious risk factors; such as renal insufficiency, congestive heart failure and hypersensitivity to contrast material.

As has been previously reported, we also could not delineate some small arteries in all cases. The distal ICA branching arteries such as the ophthalmic artery, anterior choroidal artery, and M2 segment artery were not clearly defined, so the localization of the aneurysms was difficult in these cases. The MCA bifurcation aneurysm was mistaken for an aneurysm at the M1 segment because we missed one branch of the bifurcating artery that was not clearly visualized.

There is a large inter-observer difference in 3D-CTA interpretation compared with DSA interpretation; vast experience is required in the reconstruction of 3D images using a workstation and in the interpretation of the images (9). In our study, this inter-observer difference was not analyzed.

In conclusion, 3D-CTA is a useful noninvasive pre-operative technique to define the location, the size and the neck in the evaluation of aneurysms in patients with subarachnoid hemorrhage. There are some limitations of 3D-CTA in the detection of aneurysms smaller than 2 mm, in defining the small vessels, and in identifying aneurysms located at the skull base. Results are operator-dependent, but the technique also offers several advantages. It has a relatively high detection rate and is a time conserving method in emergent patients. Thus, 3D-CTA may provide sufficient preoperative information for the management of patients with intracranial aneurysms in the case of emergency operations or DSA-failure.

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MDCT 삼차원혈관촬영술을 이용한 두개내 동맥류의 발견: 수술 소견과의 비교[1]

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목적: 비외상성 급성 뇌출혈 환자에서 MDCT를 이용한 삼차원 단층혈관조영술(3D - CTA)의 유용성을 알아보고 3D - CTA에서 발견되지 않은 동맥류를 분석하고자 하였다.
대상과 방법: 40명의 비 외상성 거미막하출혈 환자에서 16 - 채널 MDCT를 이용한 3D - CTA를 시행하였고 이중 36명의 환자에서 12시간 내에 디지털감산혈관조영술(DSA)을 시행하였다. 3D - CTA에서의 동맥류의 발견율 계산하였다. 두 명의 방사선과(영상의학과) 의사가 CT와 DSA 영상을 검토하여 동맥류의 위치, 크기와 동맥류경부를 분석하였고 두 방법으로부터의 결과를 수술결과와 비교하였다. 3D - CTA와 DSA에 의한 동맥류의 발견율을 계산하고 3D - CTA와 수술 간의 동맥류 크기의 차이를 분석하였다. 또한, 3D - CTA에서 발견 못한 동맥류의 위치와 크기를 분석하고, 발견 못한 가능한 이유를 설명하고자 하였다.
결과: 40명의 환자에서 전체 55개의 동맥류가 수술로 확인되었고 48개의 동맥류가 3D - CTA에서 발견되었다. 발견율은 87%였다. 3D - CTA와 수술상 동맥류 크기의 차이는 17예 에서 1 mm 이하, 15예에서 1 - 2 mm, 16예에서 2 mm 이상이었다. 7개의 동맥류가 3D - CTA에서 발견되지 않았다. 발견되지 않은 동맥류의 주 원인은 크기가 작아서였고 후교통동맥류 2예를 제외하고는 2 mm 이하 크기의 동맥류였다. 한 경우는 영상의 판독이 어려워서였으며 나머지 발견 안된 한 동맥류는 혈전으로 채워진 것으로 설명될 수 있다.
결론: 동맥류를 진단하는데 있어 몇 가지 제한점이 있지만, 16채널 MDCT를 이용한 3D - CTA는 응급 수술이 필요하거나 DSA가 실패한 경우 두개강내 동맥류를 가진 환자들의 처치에 대한 충분한 수술 전 정보를 제공할 수 있을 것이다.