

Application of computed tomography angiography for evaluating clinical morphology in intracranial aneurysms – monocentric study

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Abstract

Objective: To examine the clinical effect of computed tomography angiography (CTA) on parameters of intracranial aneurysms in different locations and with different sizes using digital subtraction angiography (DSA) as the standard.

Methods: Patients with intracranial aneurysms who underwent CTA examinations at the same center and received DSA examinations within 3 days were analyzed retrospectively. The morphological parameters of the aneurysms and parent arteries were measured with these two methods.

Results: Mean aneurysm size and parent artery diameter were not different between CTA and DSA. The size of microaneurysms was significantly smaller with DSA than with CTA. The aneurysmal neck width was not different between CTA and DSA. DSA could clearly evaluate the relationship between the aneurysmal neck and the parent artery in all cases. However, CTA had a 90% accuracy rate of visualizing this relationship.

Conclusion: The accuracy rates of evaluating aneurysm size and the aneurysmal neck width and parent artery diameter are similar between CTA and DSA. A DSA examination is essential for

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evaluating the relationship among microaneurysms, the aneurysmal neck, and the parent artery. CTA is widely applied and more safe in clinical practice, while DSA has a better guiding effect than CTA for some complicated aneurysms.

Keywords

Computed tomography angiography, clinical morphology, intracranial aneurysm, digital subtraction angiography, parent artery, contrast agent

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Introduction

Because of the high resolution (0.3 mm) of digital subtraction angiography (DSA), it has been considered the gold standard for diagnosis and analysis of intracranial aneurysms.¹⁻⁴ However, the occurrence rates of neurological complications and permanent impairment of DSA are 1.2% to 1.5% and 0.1% to 0.3%, respectively.⁵ With development of radiation technology, computed tomography angiography (CTA) has been extensively applied for clinical screening of intracranial aneurysms because of its high specificity, noninvasiveness, fast operation, and limited examination-related complications. Many studies have reported the detection rates of these two examination methods for intracranial aneurysms and have shown that the detection rates of both methods are similar.^{3,6} However, only a few studies have included contrastive analysis of the morphological indices of intracranial aneurysms after CTA examinations and of the parameters detected by DSA.⁷ These indices are crucial for determining the necessity of treatment of aneurysms, as well as for the choice of treatment method. For CTA examinations, the reference value of measurement indices of aneurysms is unclear. Therefore, this retrospective study aimed to investigate the relationship between CTA and DSA and aneurysm measurement indices, and to

discuss the effect of parameters detected by CTA on clinical work.

Data and methods

Ethical approval

The study was approved by the Institutional Ethics Committee of Linyi Central Hospital and written informed consent was obtained from all participants.

General data

Seventy patients who underwent treatment for aneurysms at Linyi Central Hospital from June 2015 to June 2017 were initially included. Inclusion criteria were as follows: (1) patients were definitively diagnosed with an aneurysm during surgical treatment, without intracranial rupture; (2) patients underwent CTA and DSA examinations at the same center, and the time interval of the two examinations was ≤ 3 days; and (3) imaging data were complete. Exclusion criteria were as follows: (1) the aneurysm rapidly expanded within a short period of time; and (2) ruptured aneurysms.

CTA examination

A computed tomography (CT) scanning system (GE BrightSpeed Elite Select 16 slice spiral CT; GE Healthcare, Milwaukee, WI, USA) was used. Nonionic contrast

agent was injected into the cubital vein at a rate of 3 to 4 mL/second. The data were scanned and sampled continuously. Scanning was conducted after a delay of 10 to 12 seconds. The original data were uploaded to the GEPACS workstation (GE Healthcare). Surface shaded display, volume rendering, and maximum intensity projection were used to process the images after angiography. Scanning parameters were as follows: high-quality scanning was chosen; 220 mA, 120 kV; scanning layer thickness of 1 mm; and a rendering interval of 0.5 mm.

For DSA, a diagnostic apparatus (GE Innova 3100; GE Healthcare) was applied to perform angiography through the patient's femoral artery. The injection speed of the nonionic contrast agent was 3 to 4 mL/second. The image collection time was 10 seconds and the collection speed was 15 frames/second. The bilateral internal and external carotid arteries and bilateral vertebral arteries were examined with anteroposterior and lateral angiography, respectively. Routine DSA images of anteroposterior and lateral objective position images were added if necessary. When three-dimensional (3D) DSA was performed, 40 images/second were obtained. The patient was then rotated to obtain the positioning piece. After resetting, rotation occurred at 40 reps/second to collect the images. During the second rotation, contrast agent was injected into the internal carotid artery or vertebral artery of the patient. The injection speed of the contrast agent was 3 mL/second, with 18 mL 6 seconds. Scanning was initiated after a 0.5-second delay. Continuous development was ensured during rotation of the vertebral artery. Finally, the image was imported into the DSA 3D workstation for image post-processing.

The DSA and CTA results were evaluated and analyzed by two neuroradiology experts according to the original images. The quality of the CTA images was rated on a 4-point scale as follows.^{8,9} Excellent

was defined as clearly visible vasculature and no bone remnants, or the entirety of the intracranial vascular wall was visualized properly. Good was defined as discernible vasculature containing only tiny bone remnants or more than 50% of the anterior or posterior wall of the internal carotid artery (ICA) was visualized properly. Moderate was defined as containing larger bone remnants, or <50% of the anterior or posterior wall of the ICA was visualized properly, but there was no disturbance in visualization of vessels. Poor was defined as large bone remnants or artifacts covering parts of the vessels. The image evaluation indices included aneurysm location (seven-part method),¹⁰ aneurysm size (small: ≤ 3 mm, moderate: 3–10 mm, and large: > 10 mm), aneurysmal neck width, parent artery diameter, and the relationship between the aneurysmal neck and parent artery (0 indicates the aneurysmal neck was not displayed or the display was incomplete; and 1 indicates that the relationship between the aneurysmal neck and parent artery could be shown accurately).

Statistical analysis

SPSS 22.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Descriptive statistical analysis was conducted for all indices, including mean, standard deviation, count, and percentage. Intergroup comparison of the measurement data was conducted with the Kolmogorov–Smirnov test to analyze the distribution of both groups. If a normality test indicated a lack of normal distribution, the Mann–Whitney test was used. Quantitative data are shown as mean \pm standard deviation. The t test was applied to test for differences. Qualitative data are shown as the frequency and percentage. The chi-square test was used to determine correlations. $P < 0.05$ indicates statistical significance.

Results

In this retrospective study, intracranial aneurysms of 38 patients were evaluated. The mean age of the patients was 43.94 ± 13.2 years. There were 29 female patients and nine male patients. Thirty-five patients finally adopted interventional therapy.

Table 1. Baseline information of the patients and aneurysms.

Patients	n = 38	CTA
Age, years	43.94 ± 13.2	
Female sex	29 (76.3)	
Interventional therapy	35 (92.1)	
Location		
C4	6 (15.8)	/
C5	8 (21.1)	/
C6	9 (23.7)	2 URNPs
C7	8 (21.1)	/
BA	4 (10.5)	1 URNP
VA	3 (7.9)	/
Quality of CTA images		
Excellent	29 (76.3)	
Good	8 (21.1)	
Moderate	1 (2.6)	
Poor	0	

Values are mean \pm standard deviation or n (%). CTA: computed tomography angiography; DSA: digital subtraction angiography; URNP: unclear relationship of the neck and parent artery; BA: basilar artery; VA: vertebral artery.

According to CTA imaging, 76.3% of the aneurysm images were considered excellent (Table 1).

Location of the aneurysms

Among the 38 patients, the distribution of the aneurysms was highest in C6, followed by equal distribution in C5 and C7, and then C4, the basilar artery, and the vertebral artery (Table 1). With regard to the relationship between the aneurysmal neck and parent artery, all 38 aneurysms were displayed accurately with DSA. With CTA, 35 (90%) aneurysms were displayed accurately, and the relationship between the aneurysmal neck and parent artery was not displayed completely in three (10%) patients. Among these three patients, two aneurysms were located at C6 and one was located in the vertebral artery. There was no significant difference in a clear relationship between CTA and DSA (Tables 1 and 2).

Aneurysm size, aneurysmal neck width, and parent artery diameter

After grading aneurysm size, DSA and CTA measurement data showed that there were eight microaneurysms. The size of

Table 2. Morphological parameters of aneurysms between DSA and CTA.

Characteristics	CTA (n = 38)	DSA (n = 38)	P value
Aneurysm size (mm)	11.7 ± 6.4	10.8 ± 5.4	0.225
Small, ≤ 3 (n = 8)	2.5 ± 0.5	1.6 ± 0.8	0.033*
Medium, 3–10 (n = 20)	8.7 ± 2.0	8.2 ± 1.6	0.250
Large, > 10 (n = 10)	14.5 ± 4.0	14 ± 3.5	0.455
Location and size			
Anterior circulation (n = 31)	14.3 ± 3.0	13.5 ± 3.0	0.350
Posterior circulation (n = 7)	11.4 ± 5.2	12.1 ± 4.8	0.450
Aneurysmal neck width (mm)	9.6 ± 5.5	8.9 ± 5.0	0.240
Parent artery size (mm)	3.5 ± 1.1	3.7 ± 0.7	0.163
Clear relationship of the neck and parent artery	38(1)	35(0.9)	0.245

Values are mean \pm standard deviation. * $P < 0.05$.

CTA: computed tomography angiography; DSA: digital subtraction angiography.

microaneurysms was significantly smaller with DSA than with CTA ($P=0.033$). There was no significant difference in the size of medium or large aneurysms between the two methods. In one patient, the aneurysm size was different between CTA and DSA (2.9 vs 2.2 mm) (Figure 1). The aneurysms were classified as anterior circulation or posterior circulation aneurysms, with no significant differences in size between DSA and CTA. Most aneurysms were located in the anterior circulation (Table 2).

There were no significant differences in the aneurysmal neck width and parent artery diameter between DSA and CTA (Table 2).

Discussion

Intracranial aneurysms are a common type of clinical cerebrovascular disease. Once an aneurysm ruptures, the disability rate and fatality rate increase. Therefore, early diagnosis of intracranial aneurysms and adopting the most reasonable method for evaluating and preventing high-risk events are necessary. In this study, 38 patients who were diagnosed with nonruptured

aneurysms were analyzed. We compared CTA and DSA examination results and found that these methods were mostly similar for determining intracranial aneurysm indices.

Aneurysm size and location

With regard to sensitivity of an aneurysm examination, some studies have shown that the sensitivity of CTA and DSA are almost equal.¹¹ In our study, some aneurysms that were detected by DSA failed to be detected by CTA, and there was no obvious difference in sensitivity. However, other studies have indicated that the sensitivity CTA to aneurysms in terms of bone structure is lower than that for DSA.^{3,12} In this study, there was no obvious difference in overall aneurysm size between DSA and CTA. However, when measuring microaneurysms, the aneurysm size measured by CTA was slightly larger than that measured by DSA. This result is in agreement with that of previous studies as follows. As the aneurysm size decreases, the detection rate of CTA for aneurysms decreases.^{1,13} When the aneurysm size is <3 mm, CTA sensitivity to aneurysms decreases by 40% to

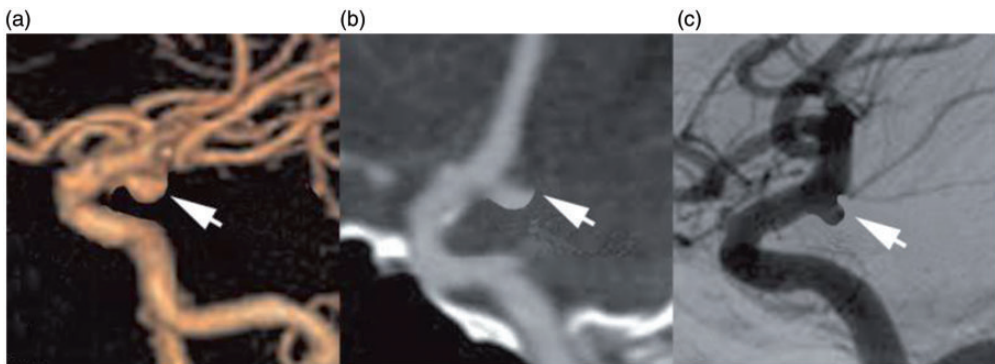


Figure 1. Left posterior communicating aneurysm in a male patient. (a and b) The aneurysm size as measured with a computed tomography angiography examination was 2.9 mm. (c) The aneurysm size as measured with a digital subtraction angiography examination was 2.2 mm. The anatomical location of this aneurysm under the two examinations was consistent. The difference in aneurysm size was obvious between these two methods.

90%.^{3,15,16} This study also showed that, in microaneurysms, the CTA measurement error of aneurysm size increased, which could lead to errors in clinical judgment. CTA examinations may result in poor spatial structure because of the influence of the skull on the aneurysm. During image reconstruction, CTA is affected by factors, such as overlap of the patient's skull. During the treatment process, the operator needs to remove the bone image, which can more fully display the patient's aneurysm, but this needs to be performed by experienced professional technicians. The experience and technical requirements are relatively high and time consuming for CTA.¹⁷ For small intracranial aneurysms, the detection rate of aneurysms with CTA is reduced, and the inaccuracy rate of aneurysm parameters is increased. This can be found in some arteries with a CTA examination. Imaging of tumor lesions should be related to volume effects and image noise. If the lesion is too small, the quality of the detected image is further reduced, which leads to an increase in the measurement bias of the measured aneurysm. Some research has indicated that the threshold value of an aneurysm examination by CTA should be 2 mm.¹⁸⁻²⁰ However, with technical progress and improvements in the level of testing, this standard is uncertain. Screening of microaneurysms and operative treatment strategies should be based on DSA results. A CTA examination increases the negative rate of microaneurysm detection and the monitoring error is large.

A previous study showed that the CTA recognition rate was low for anterior communicating aneurysms, aneurysms within a cavernous sinus segment of the ICAs and middle cerebral arteries, and aneurysms within the basilar artery bifurcation.¹ Our study showed that aneurysms within the arterial ophthalmic segment of the ICA, as well as basilar artery aneurysms, showed a relationship between the aneurysmal neck

and the parent artery that could not be clearly recognized by CTA. This may be related to the deep location of the aneurysm and the high amount of sclerotin.

Contrast volume in CTA and DSA

The volume of contrast agent required by a CTA examination is 1/3 to 1/2 that of DSA, and the radiation dose required for CTA is also much smaller than that required for DSA.^{20,21} CTA can display not only the tumor cavity, but also thrombus in the tumor, which is important for doctors involved in neurosurgery. CTA is also sensitive for aneurysmal width measurements, which is consistent with the results of our study. In our study, aneurysmal neck and parent artery diameter measurements were not significantly different between CTA and DSA. With regard to the relationship between the aneurysmal neck and the parent artery, CTA is inferior to DSA. In the current study, for two aneurysms within the arterial ophthalmic segment, the relationship between the aneurysmal neck and the parent artery was not displayed completely with CTA. Some research has also shown that CTA is not suitable for analyzing the details of fine blood vessels and for recognizing the collateral circulation and direction of blood flow, as well as differentiating cerebral arteries and veins.^{1,15} Application of DSA involves the ability to display the mode of blood flow and active bleeding, as well as the ability to detect arteriovenous malformations. DSA has a high sensitivity and specificity for detecting aneurysms, including posterior circulation aneurysms (<3 mm) that are close to the bone.^{1,2,22} One study showed that only 48% of patients were treated according to CTA results,¹² while another study with a larger sample size showed that 82% of patients were treated directly according to CTA results.¹¹

Limitations

In this study, patients' data from a single center were collected. In the future, more patients from multiple centers need to be studied to provide guidelines with a higher standard. Handling methods of CTA and DSA may also differ. In the future, quantified and standardized machine parameter settings and surgical processes need to be investigated. In this study, data analysis was completed by senior neuroradiology doctors. Therefore, there was likely to be data measurement errors. In the future, machine learning and machine measurement studies are necessary to eliminate this bias.

Conclusion

This study indicates that the aneurysmal parameters provided by CTA are reliable. Clinical CTA data can be used to guide the diagnosis and treatment of intracranial aneurysms. However, for intracranial microaneurysms (≤ 3 mm), CTA measurement parameters can differ from DSA measurement parameters. Under such conditions, the accuracy of CTA is inferior to that of DSA. DSA is still the gold standard for examination of microaneurysms. The convenience, safety, and noninvasive accuracy of CTA will lead to more extensive clinical application of CTA than DSA in the future.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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