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EFFECT OF DIGITAL SUBTRACTION ANGIOGRAPHY DUAL-VOLUME IMAGING IN CRANIOTOMY FOR CLIPPING INTERNAL CAROTID ARTERY ANEURYSMS

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Abstract: Objective: This study aimed to investigate the significance of digital subtraction angiography (DSA) dual-volume imaging in craniotomy for clipping internal carotid artery (ICA) aneurysms. **Methods:** Patients undergoing intervention-assisted clipping of aneurysms in our hospital between January 2014 and February 2015 were studied retrospectively. Relationships between the clip and the aneurysm, and the parent artery were demonstrated using 3D dual-volume reconstruction to evaluate the outcome of aneurysm occlusion and the patency of adjacent blood vessels. **Results:** 20 patients with intracranial ICA aneurysms were enrolled. Mean age was 52 years (range, 36 to 76 years). Baseline Hunt-Hess grades of brain aneurysms were the following: 2 patients grade I, 10 grade II, 7 grade III, and 1 grade IV. Twenty-four intracranial ICA aneurysms were detected. The mean diameter was 6.12±3.50 mm (range, 1.9-15.0 mm). 7 aneurysms were close to or covered by the anterior clinoid process. The aneurysm neck pointed to the anterior/medial side of the ICA in 8 aneurysms and to the posterior/lateral side in 16. In 16 aneurysms (66.7%), the aneurysm neck involved the posterior communicating artery and/or the anterior choroidal artery and ophthalmic artery. Aneurysm clipping was performed after balloon-assisted blocking of the ICA in 6 cases (30.0%). After the initial attempt, 18 aneurysms (75.0%) were occluded completely, but 4 had partial remnants and the aneurysm clip was adjusted. The anterior choroidal artery was developed excellently after adjusting the clip. **Conclusion:** Intraoperative DSA dual-volume imaging is an excellent technique for revealing the complicated anatomy of an intracranial ICA aneurysm and its surrounding structures. Balloon-assisted blocking of the ICA blood flow can improve the success rate and safety of surgery.

Keywords: internal carotid artery aneurysm; digital subtraction angiography; dual-volume reconstruction.

1. INTRODUCTION

Intracranial aneurysm is the most common cause of subarachnoid hemorrhage [1]. The incidence of intracranial internal carotid artery (ICA) aneurysm is the highest, accounting for 24.8% of intracranial aneurysms. Microscopic surgery is an effective treatment method for ICA aneurysm. This type of surgical procedure can cut off the aneurysm from the blood circulation thereby avoiding aneurysm rupture [2,3]. The relationships between the intracranial ICA and its adjacent structures are complicated. Digital subtraction angiography (DSA) and the 3D dual-volume technique can be used to evaluate these relationships in detail before surgery and display the outcome of aneurysm clipping in time for correction during surgery [4,5]. Meanwhile, DSA and the 3D dual-volume technique might improve the prognosis and even avoid a second surgery. Therefore, our study was aimed to evaluate the safety and effect of DSA and 3D dual-volume technique in craniotomy for clipping internal carotid artery aneurysm.

2. MATERIALS AND METHODS

Study population

We performed a retrospective study of patients undergoing aneurysm clipping, intraoperative angiography, and 3D dual-volume reconstruction in our hybrid operating room between January 2014 and February 2015. Among 20 patients with intracranial ICA aneurysms, 8 were male and 12 were female. Their mean age was 52 years (range, 36 to 76 years). The Hunt-Hess grades of brain aneurysms at the time of admission were the following: 2 patients grade I, 10 grade II, 7 grade III, and 1 grade IV (Table 1).

Imaging method

Siemens Highlights Artis zeego angiography system and post-processing workstation were used. During DSA, a flat panel detector was used for scanning without contrast agent being injected to obtain the volumetric data of the tissue. After contrast agent injection the same detector was used for scanning to obtain the volumetric data of the tissue and the blood vessel filled with contrast agent. After reconstruction and processing of these data, the relationships between the aneurysm and its surrounding structures were observed from multiple perspectives.

Surgical procedure

After general anesthesia the patient was placed in the supine position. Intracranial artery angiography was performed after femoral artery catheterization, and then 3D dual-volume reconstruction was carried out. After angiography, the catheter was removed; the sheath remained. The C-arm was removed. Aneurysm clipping was performed via the pterional approach. After complete hemostasis, the wound was covered with sterile dressing and then cerebral angiography was performed. If the outcome of the primary treatment was not satisfactory, the clip was adjusted and angiography was carried out again. The treatment was ended only after the result of angiography was satisfactory.

3. RESULTS

Twenty-four aneurysms were found in the 20 patients. The mean diameter of the aneurysms was 6.12±3.50 mm (range, 1.9-15.0 mm). Seven aneurysms (29.2%) were close to or were covered by the anterior clinoid process. The aneurysm neck pointed to the anterior/medial side of the ICA in 8 aneurysms (33.3%) and to the posterior/lateral side of the ICA in 16 aneurysms (66.7%). In 16 aneurysms (66.7%) the aneurysm neck involved the posterior communicating artery and/or the anterior choroidal artery and ophthalmic artery. After the initial clipping, 18 aneurysms (75.0%) were occluded completely, while 4 aneurysms had partial remnants and the aneurysm clip was adjusted. The anterior choroidal artery was not developed well after clipping one aneurysm (5.2%), but was developed excellently after adjustment of the clip. Aneurysm wrapping was used for one aneurysm (5.2%). None of the patients died. The Glasgow Outcome Scale (GOS) scores were 5 points in 17 patients (85.0%), 4 points in 1 patient (5.0%) and 3 points in 2 patients (10.0%) (Table 1, Figure 1-3).

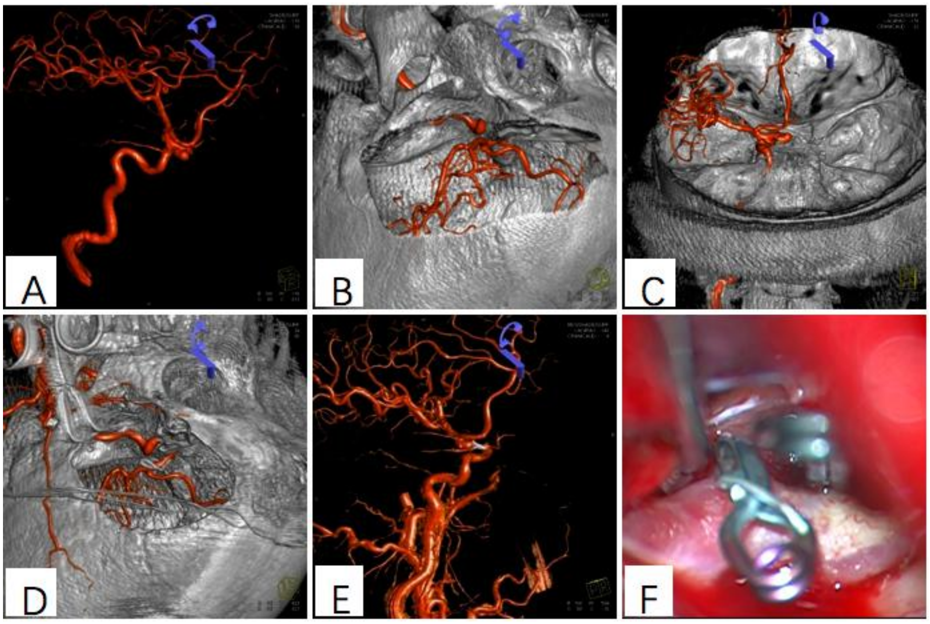

Figure 1 Characteristics of the aneurysm from case 1.

The patient had a cystic aneurysm in the broad base of the posterior communicating artery of the left carotid artery. The size was 7.5 mm × 5.2 mm. Figure A shows that the aneurysm is located inferior to the posterior communicating artery. Figure B is the view of surgical simulation. The aneurysm is blocked by the anterior clinoid process and the ICA. Figure C shows that the aneurysm is located on the medial side of the anterior clinoid process and the ICA. The aneurysm is completely occluded without remnants in Figures D and E. Figure

F is the microscopic view. The aneurysm is located on the dorsal side of the anterior clinoid process and the ICA, and so it is not clearly exposed. After clipping, the presence of remnants could not be identified under the microscope.

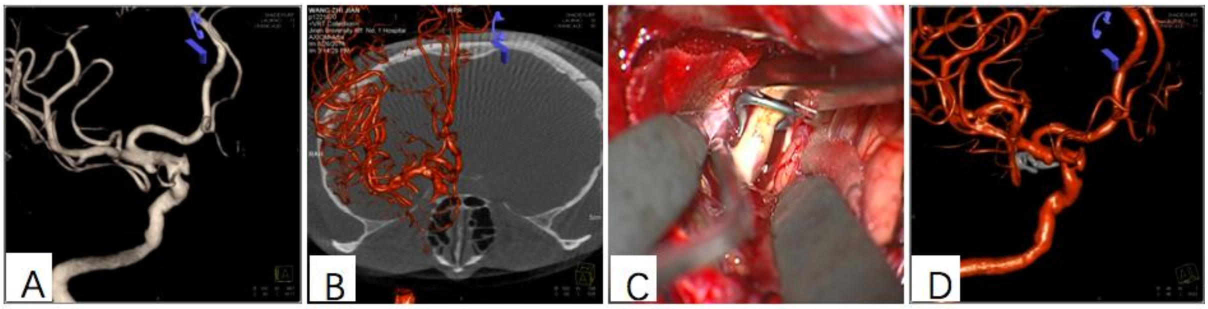

Figure 2 Characteristics of the aneurysm from case 2.
Figure A shows a carotid-ophthalmic aneurysm and a posterior communicating artery aneurysm; the ophthalmic artery originates from the aneurysm. Figure B shows that the ophthalmic artery aneurysm is located on the medial side of the anterior clinoid process, the ethmoid is close to the aneurysm, and the surgical field is narrow. Figure C, an intraoperative microscopic view, shows that the optic nerve is located superior to the aneurysm, and the aneurysm is poorly exposed. We performed aneurysm wrapping for this patient. Figure D shows the posterior communicating artery aneurysm disappeared and the relationship between the aneurysm clip and the parent artery is clearly displayed.

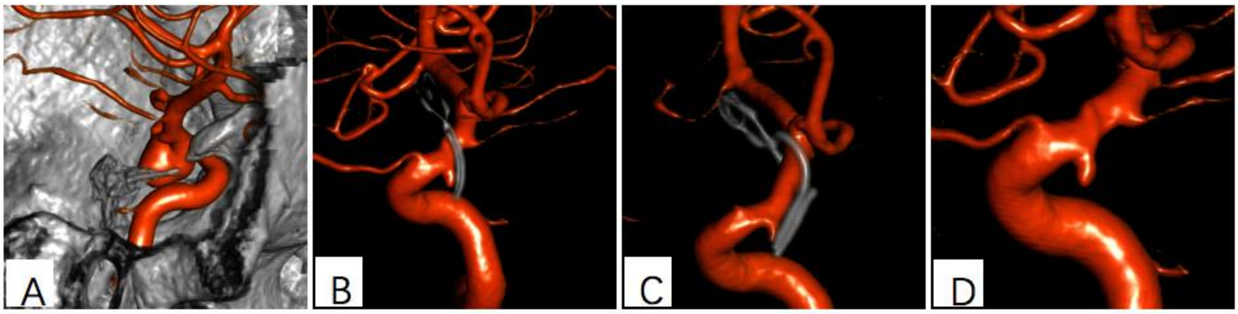

Figure 3 Characteristics of the aneurysm from case 3.
Figure A shows an aneurysm located on the medial side of the anterior and posterior clinoid processes. Figure B shows that there are aneurysm remnants after the primary clipping. Figure C shows the impression of the aneurysm clip on the ICA and the ICA stenosis. Figure D shows that there are few aneurysm remnants after adjusting the aneurysm clip and the ICA is not compressed.

Table 1 Characteristics of patients enrolled and dual-volume images of aneurysms

Case	**HHG**	**aneurysm size (mm)**	**Distance between ACP and aneurysm (mm)**	**Pointing to (artery)**	**Artery involved**	**Clip adjust (N/Y)**	**Postoperative GOS score**
1	3	6.0	5	P/L	PCA	N	5
2	3	4.1/3.2	3/5	A/M, P/L	ACA	N	5
3	3	6.6	6	P/L	ACA	N	5
4	3	5.2/2.0	0	A/M	PCA, ACA	N	5
5	1	12.7	0	P/L	N/R	Y	4
6	3	7.1	0	P/L	ACA, PCA	Y	5
7	2	3.3	3	A/M	PCA	N	5
8	2	9.1	0	A/M	N/R	Y	5
9	2	13.5	1	P/L	PCA	N	5
10	1	4.0/4.2	5/0	P/L, A/M	ACA	N	5

11	2	7.3	5	P/L	N/R	N	5
12	2	1.9/8.0	7/4	P/L, A/M	ACA, PCA	N	5
13	2	7.5	0	A/M	PCA	N	5
14	3	4.0	8	P/L	ACA	N	3
15	2	2.5	0	P/L	N/R	N	5
16	2	5.1	0	P/L	PCA	N	5
17	2	3.8	10	P/L	PCA	N	5
18	2	5.8	5	P/L	ACA, PCA	N	5
19	4	15.0	2	A/M	N/R	Y	3
20	3	5.0	6	P/L	ACA	Y	5

HHG, Hunt-Hess grades; ACP, anterior clinoid process; N, not; Y, yes; P/L, posterior/lateral to the internal carotid artery; A/M, anterior/medial side of internal carotid artery; ACA, anterior choroidal artery; PCA, posterior communicating artery; N/R, not reported.

4. DISCUSSION

Intracranial ICA aneurysm is the most common type of intracranial aneurysm. Due to the relatively deep location of the ICA, the aneurysm is likely to be blocked by the anterior clinoid process or the ICA during microscopic surgery [6]. Moreover, because the branches from the adjacent posterior communicating artery and anterior choroidal artery are among the vessels that supply blood to the basal ganglia, injury of these arteries may lead to basal ganglia infarction and resulting neurological disorders [7,8]. Therefore, it is very important to observe the relationships between the aneurysm and its adjacent structures from multiple perspectives before surgery in order to occlude the aneurysm completely and avoid damaging the neighboring blood vessels. If the aneurysm is located near the anterior clinoid process, the latter may affect exposure of the aneurysm neck and occlusion of the parent artery. Hence, the distance between the aneurysm and the anterior clinoid process and the relationship between the aneurysm and the anterior clinoid process should be evaluated before surgery [9,10]. Balloon-assisted occlusion of the internal carotid artery or removal of the clinoid process can be carried out to expose the aneurysm neck if necessary [11,12].

Intraoperative angiography and 3D dual-volume reconstruction after clipping of the aneurysm can help demonstrate the possible presence of residual aneurysms and possible damage to the adjacent blood vessels. Compared with routine DSA examination and 3D reconstruction, this procedure has significant advantages with regard to the observation of the aneurysm and its surrounding bone structures [13]. In addition, opening a bone window and removing the anterior clinoid process via the pterion approach can be simulated on the reconstructed image. Dual-volume reconstruction following aneurysm clipping can show the relationship between the aneurysm clip and the adjacent blood vessels, and guide the adjustment of the aneurysm clip. It is most helpful in patients with aneurysms located medial to the ICA and a poorly exposed aneurysm neck. The resolution of dual-volume reconstruction is better than that of CT 3D reconstruction for blood vessels less than 1 mm in diameter [13,14]. The CT angiography reconstruction of the adjacent skull base is likely affected by the bone and with this technique it is impossible to distinguish some small aneurysms near the bone structures, whereas dual-volume reconstruction is an excellent technique for solving this problem [15]. During microscopic surgery, we have to identify our targets along the surgical approach. To reduce the risk of intraoperative breakage of the aneurysm, repeated tractions of the parent artery and aneurysm should be avoided. However, some blind spots exist in the microscopic field of view due to this kind of blocking. Under the microscope, we only can observe the aneurysm and the outer layer of the blood vessel wall, which cannot accurately reflect the presence of residual aneurysms inside the lumen or the status of blood flow. Dual-volume reconstruction can help with observation of the aneurysm and the relationship between the aneurysm and adjacent structures, and clearly display the presence of aneurysm remnants and the status of blood flow [16]. Hence, it is an excellent complement to microscopic observation. However, demonstration of the proximal end of the patent artery with dual-volume reconstruction is not suitable for patients with temporary occlusion clips. Transluminal ballooning can occlude the proximal end of the parent artery to reduce aneurysm tension and bleeding. Because the DSA dual-volume imaging technique cannot reconstruct the soft tissue structures, such as the optic nerve, dual folds, etc., it cannot completely simulate the real situation observed using the microscope [17].

Among the 24 aneurysms in the present study, 23 were treated by aneurysm clipping and one was treated by aneurysm wrapping. Seven aneurysms (27.2%) were closely related to the anterior clinoid process and 8 aneurysms (33.3%) were located on the anterior/medial side of the ICA. The aneurysm clip was adjusted for 5 aneurysms (20.8%) during surgery. One aneurysm was not ideally exposed by 3D dual-volume reconstruction and it was found during surgery that the aneurysm was covered by the optic nerve [13,14]. Aneurysm clipping was performed after anterior clinoidectomy. Another aneurysm was located at the junction of the intracavernous ICA and intracranial ICA, and the ethmoid was closely located anterior to the aneurysm. In addition, it was found that the aneurysm was covered by the optic nerve during surgery and there was not enough space for clipping. Hence, we performed aneurysm wrapping for this aneurysm. The outcomes of aneurysm clipping were satisfactory, which shows that DSA 3D dual-volume reconstruction can clearly display the relationships between the aneurysm and its surrounding blood vessels and bone structures, and this technique has obvious advantages in the occlusion of an intracranial ICA aneurysm [17]. However, it cannot clearly show the relationship between the aneurysm and peripheral soft tissues, such as the optic nerve, dura, etc. Therefore, the high-resolution MR and DSA 3D reconstruction technique should be improved further to solve this problem.

5. CONCLUSIONS

In our study, intraoperative DSA dual-volume imaging is helpful for revealing the complicated intracranial ICA aneurysms and its surrounding structures. Additionally, it can evaluate the outcome of clipping. Balloon-assisted blocking of the ICA blood flow can improve the success rate and safety of surgery. However, more studies are needed to be confirmed these findings.

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