

Contralateral Approach Based on a Preoperative 3-Dimensional Virtual Osteotomy Technique for Anterior Circulation Aneurysms

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Objective: Our objective was to review 15 consecutive patients with anterior circulation aneurysms managed through a contralateral approach. Individualized surgical simulation using three-dimensional (3D) imaging was adopted to enable safe performance of clipping surgery. *Methods:* Five patients had multiple intracranial aneurysms, and 10 patients had a single aneurysm on the contralateral side of the craniotomy. Preoperatively, the unique architecture of aneurysms was fully understood in their 3-dimensionality reconstructed by Mimics software. The location of the cranial bone window and the patient's head position was individually optimized using a preoperative simulation system. *Results:* In this cohort, 17 contralateral aneurysms showed no wall calcifications. Projections of the aneurysms were superomedial (3/17, 17.6%), medial (8/17, 47.1%), posterior (3/17, 17.6%), and superior (3/17, 17.6%).

The visual similarity between the simulating scene and the operative view was excellent in 100% of the cases. Four patients were treated with a contralateral pterional approach, and the remaining 11 patients were treated with a contralateral supraorbital keyhole approach. All of them were well-clipped, except 1 blister-like aneurysm being wrapped. All 15 patients had good outcomes (mRS \leq 3) after a mean 13 months follow-up. There were no recurrences after surgical treatment. *Conclusions:* The contralateral approach for the selected anterior circulation aneurysms is feasible in experienced hands with acceptable morbidity. This approach should be the choice only under judicious case-to-case planning based on a preoperative 3D virtual osteotomy technique.

Key Words: Cerebral aneurysm—contralateral craniotomy—preoperative simulation—surgical clipping

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Introduction

Surgical results with intracranial anterior circulation aneurysms have improved with advances in microsurgical technique and anatomical research. Endovascular approaches have also improved, especially with the introduction of stent-assisted coiling and flow diverters. However, aneurysms with wide necks, large or giant size,

intraluminal thrombus, optic nerve compression, recurrence after prior endovascular therapy, and contraindication to antiplatelet therapy remain indications for surgery. An additional surgical indication is bilaterality: a contralateral aneurysm can often be clipped easily during the same craniotomy and spare the patient a second craniotomy or additional intervention. A contralateral approach

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remains a microsurgical option for selected anterior circulation aneurysms that project medially and superiorly.¹ However, the disadvantages of a contralateral approach (CA) include deep and narrow surgical corridors and inconsistent ability to achieve proximal control of the supraclinoid internal carotid artery (ICA). Therefore, preoperative evaluation is highly important. The location and size of the bone window and head positioning were carefully simulated and individualized using the virtual osteotomy technique based on 3-dimensional computed tomography angiography (3D-CTA) images fused with images of the skull and ICA before surgery.²

The present study describes the preoperative strategy to individualize contralateral approach using the 3D virtual osteotomy technique based on modern computational neuroscience. In this report, we analyzed 15 consecutive patients with anterior circulation aneurysms who were treated through a contralateral microsurgical approach. We describe the surgical technique and evaluate the results.

Patients and Methods

This study was approved by the Ethics Committee of the Third Affiliated Hospital of Sun Yat-Sen University. Fifteen patients harboring anterior circulation aneurysms who underwent microsurgical treatment via a contralateral craniotomy were identified from the prospectively maintained Vascular Neurosurgery database between 2015 and 2017.

Preoperative Surgical Simulation

Preoperative simulation to determine the surgical approach using a multisection helical 320 detector rows computed tomography (CT) scanner (Aquilion ONE; Toshiba Medical Systems, Nasu, Japan) which was used for CTA with injection of 50 mL of nonionic contrast medium (370 mg iodine/mL) with Mimics software (version 14.0; Materialise, Leuven, Belgium) in a workstation. The 3D images of the aneurysm, cerebral arteries, and skull were merged into 1 image. Various virtual craniotomies were used to simulate different surgical approaches on the 3D skull image. The surgical approaches, extent of cranial removal, and head positioning were scrutinized to optimize the visualization of the aneurysm with the surrounding structures. We emphasize the importance of the relationship of the aneurysm neck, proximal segment of the parent artery, tuberculum sellae, and anterior clinoid process (ACP) to determine the appropriate surgical approach.

We measured the maximal length, width, neck diameter, and aneurysm shape for all the patients. Additionally, we evaluated the aneurysm wall for the presence of irregularities, calcifications, and secondary pouches. The type of aneurysm was classified as saccular or fusiform. Moreover, we determined the direction of the aneurysm dome in relation to the parent vessel.

In patients with a subarachnoid hemorrhage (SAH), the grade of SAH was classified according to the modified

Fisher scale on CT scans. We assessed the patient's preoperative status by Hunt & Hess grading.

Surgical Technique

A standard pterional approach (PA) or supraorbital keyhole approach (SKA) was performed under general anesthesia. The head was positioned with less than normal head extension, enabling a direct view of the superior aspect of the ACP. If necessary, the cervical carotid artery was prepared and draped into the field in case proximal carotid exposure was needed for control. The proximal and distal parent artery was dissected. First, ipsilateral aneurysms in 4 patients with multiple aneurysms were treated by an ipsilateral craniotomy (2 ophthalmic artery aneurysms, 1 anterior communicating artery aneurysm, and 1 M1 aneurysm) by the senior author (Guo Y.).

Attention was later turned to the contralateral aneurysm. First, the ipsilateral A1-ACA segment was identified and followed to the anterior communicating artery complex. After opening the cistern, sufficient cerebrospinal fluid (CSF) was aspirated to make the brain slack, and we subsequently began to dissect and expose the aneurysmal complex. The interoptic triangle was opened widely, exposing the medial wall of the ICA. The contralateral aneurysms were identified. The aneurysm and/or the parent segment may have needed to be mobilized to visualize the neck. Medially, superomedially and superiorly projecting aneurysms were easily visualized and clipped without the anterior clinoidectomy and dural ring dissection that would have been required in an ipsilateral approach to these lesions. One proximal A2 segment aneurysm was clipped after exposure of the bilateral A1 segment and the proximal and distal A2 segment, and partial resection of the ipsilateral gyri rectus was performed. One case with blood blister-like PcoAA could not be clipped and replaced by wrapping treatment.

Indocyanine green videoangiography was routinely performed for all patients to confirm absence of aneurysm filling and flow in parent artery and branch arteries.

CT, 3D-CTA imaging was performed on the day after surgery to detect any abnormalities, including ischemic changes or hemorrhage, and to confirm complete clipping of the aneurysm.

All patients were followed up after discharge. Outpatient clinic data were analyzed retrospectively. Neurological outcomes were assessed using the modified Rankin score (mRS) at 3 months after surgery. Functional outcome was defined as good (mRS 0-3) or poor (mRS 4-6). A clinician not directly involved in the care of these patients performed all outcome assessments preoperatively, discharge, and at last available follow-up.

Results

The study population included 15 patients: 7 women (46.7%) and 8 men (53.3%) with a total of 25 IAs. Five patients (33.3%; 3 women and 2 men) had multiple IAs

(with a total of 15 IAs), 7 (7/15) of these were treated by contralateral approach, and 10 patients (66.7%; 4 women and six men) had a single aneurysm on the contralateral side of the craniotomy.

Of all patients, aneurysms were unruptured in 11, causing no preoperative visual deficits, except for a case of right eye blindness caused by poorly differentiated adenocarcinoma in the cranial-orbital region. Four patients (26.7%) had SAH. The median age of patients in this group was 54 years (range, 41-77 years). Characteristics of 15 patients and aneurysms are shown in Table 1.

Contralateral aneurysms showed no wall calcifications. Projections of the aneurysms were superomedial

(3/17, 17.6%), medial (8/17, 47.1%), posterior (3/17, 17.6%), and superior (3/17, 17.6%).

In this cohort, the visual similarity between the simulating scene and the operative view was excellent in 100% of the cases. Four patients (case 3, 4, 7, and 10) were treated with the contralateral PA, and the remaining 11 patients were treated with the contralateral SKA.

Partial removal of the tuberculum sellae was performed in 2 cases. Exposure of the cervical carotid artery was performed in 6 patients: 1 with a large, ruptured C6 aneurysm; 4 with unruptured C6 aneurysm, and 1 with a small, unruptured C7 aneurysm. Temporary carotid occlusion in the neck was not used in these patients during clip application.

Seventeen aneurysms (17/21) were treated by the contralateral approach, and all of them were well-clipped, except for 1 blister-like aneurysm that was wrapped (case 14). Aneurysm orientation, morphology, and the procedures applied during surgery are shown in Table 2.

Postoperatively, vision and visual field examinations were normal, except for a case of right eye blindness caused by poorly differentiated adenocarcinoma in the cranial-orbital region. Good outcomes (mRS ≤ 3) were observed in all 15 patients. The mean duration of follow-up was 13 months (Table 3). Two of the case examples are shown in Figures 1A-M and 2A-F.

Table 1. Characteristics of 15 patients and aneurysms approached via a contralateral approach

| | |
|---|------------|
| Total no. (%) of patients | 15 (100) |
| Sex distribution, no. (%) | |
| Female | 7 (46.7) |
| Male | 8 (53.3) |
| Age at diagnosis, y (range) | |
| Median | 54 |
| Range | 41-77 |
| Total no. (%) of aneurysms | 25 (100.0) |
| Single aneurysms | 10 (40.0) |
| Multiple aneurysms (bilateral aneurysms) | 15 (60.0) |
| Total no. (%) of clipped aneurysms | 21 (100.0) |
| Single aneurysms | 10 (48.0) |
| Multiple aneurysms (bilateral aneurysms) | 11 (52.0) |
| Total no. (%) of untreated unruptured aneurysms | 4 |
| C4 | 2 |
| C7 | 1 |
| M1 | 1 |
| No. (%) of patients with ruptured aneurysms according modified Fisher scale | 4(100.0) |
| Grade 4 | 2(50.0) |
| Grade 0 | 2(50.0) |
| No. (%) of patients with SAH according Hunt & Hess | 4(100.0) |
| Grade 2 | 1(25.0) |
| Grade 3 | 3(75.0) |
| Clipped aneurysm shape, no. (%) | |
| Saccular | 21 (100.0) |
| Clipped aneurysm neck size distribution, no. (%) | |
| Small (<7 mm) | 19 (90.0) |
| Medium (7-14 mm) | 2(10.0) |
| Associated aneurysms distribution, no. (%) | 21(100.0) |
| Opht(C6) | 14 (66.7) |
| PCoA(C7) | 4 (19.0) |
| M1 | 1 |
| ACoA | 1 |
| A2 | 1 |

Abbreviations: ACoA, anterior communicating artery; A2, 2 segment of anterior cerebral artery ;M1, 1 segment of middle cerebral artery; Opht, ophthalmic artery; PCoA, posterior communicating artery; SAH, subarachnoid hemorrhage.

Discussion

With improvements in endovascular techniques, fewer anterior circulation aneurysm are treated by surgical clipping. However, aneurysms with wide necks, large or giant size, intraluminal thrombus, optic nerve compression, recurrence after prior endovascular therapy, and contraindications for antiplatelet therapy remain surgical indications.³

The ICA-ophthalmic (opht,C6) segment aneurysms and PcoAA (C7) are often treated by the ipsilateral PA. When these aneurysms project to medial, the aneurysm necks are often blocked by the optic nerve, ICA and the ACP via the ipsilateral approach. Removal of the ACP, optic canal and opening the dural ring increase the risk of iatrogenic injury and operation time. It is reported that certain anterior circulation aneurysms, such as the C6/C7 segment aneurysm projecting to the medial or superior, can be treated by the contralateral approach.⁴⁻⁶

The feasibility of the contralateral approach depends on specific anatomic parameters related to the aneurysm itself and to the relationship of the ICA with the ACP.⁷ Therefore, the key to the safe implementation of the contralateral approach requires a precise understanding of the individual vascular anatomy with respect to the aneurysm factors, including neck width and shape, wall calcifications, dome, feeding and draining vessels, branching vessels, and neighboring structures, as well as factors relating to the approach: patient positioning, location and

Table 2. Aneurysm orientation, morphology, and the procedures applied during surgery

| Patient no. | surgical approach | Comorbidity | Presenting symptom | Hunt & Hess | Modified Fisher grade | No. of aneurysms | Rupt. Side | Location of the aneurysms | Aneurysm size dome*neck (mm) | Orientation & morphology | Procedure |
|-------------|-------------------|--|--|-------------|-----------------------|------------------|------------|---|--|--|---|
| 1 | SKA(R) | Hyperthyreosis | Dizziness,vomiting/2 weeks | 0 | 0 | 2 | no | C6(L)/AcomA [§] | 4*3/3*3 | Medial/antero-inferior-R [§] | SKA(R),Clip.of C6(L), Clip.of ACoA |
| 2 | SKA(L) | COPD/pulmonary heart disease/T2DM | Sudden headache/8 days | III | 0 | 1 | C6(R) | C6(R) | 15.2*12 | Superior | Cervical carotid (R) exposure,SKA(L),Clip.of C6 (R) |
| 3 | PA(L) | HBP | Dizziness, headache/1 month | 0 | 0 | 3 | no | C6(L) [§] /C4(L) [#] /C6(R) | 16*14/3.5*3.3 [#] /3*3 | superior [§] /medial [#] /posterior | Cervical carotid (L) exposure,PA(L),Ant.Clin.(L),Clip.of C6(L),Clip.of C6(R) |
| 4 | PA(R) | HBP | Sudden headache/6h | III | 4 | 4 | BBA | C6(R) [§] /C6(L)/C7(L)/C4(L) [#] | 6*3/4*3/5*4/2*2 [#] | Superior [§] /posterior/posterior/medial [#] | PA(R),Clip.of C6(R),Clip.of C6(L)and C7(L) |
| 5 | SKA(R) | HBP | Sudden headache, somnolence/2h | □ | 0 | 2 | C6(L) | C6(L)/C7(L) | 7*3/3*3 | Medial/superomedial | EVD(L),SKA(R),Clip.of C6(L) and C7(L) |
| 6 | SKA(L) | Embolization of C6 (L), 7 years ago in another hospital | Headache/1 month | 0 | 0 | 1 | no | C6(R) | 3*2 | Medial | SKA(L),Clip.of C6(R) |
| 7 | PA(R) | HBP | Sudden headache/5h | II | 4 | 4 | M1(R) | A2(L);M1(R) [§] ; M1(L) [#] ;C7(L) [#] | 7*4/5*4/3*2 [#] /2*1 [#] | Medial /anterolateral [§] /superior [#] /superior [#] | PA(R),Clip.of M1(R), Clip.of A2(L) |
| 8 | SKA(R) | Left trigeminal neuralgia | Left facial pain/5 years | 0 | 0 | 1 | no | C6(L) | 2*2 | Medial | SKA(R),Clip.of C6(L) |
| 9 | SKA(L) | No | Headache/2 days | 0 | 0 | 1 | no | C6(R) | 6*5 | Medial | Cervical carotid (R) exposure,SKA(L),Clip.of C6 (R),DSA |
| 10 | PA(R) | Low differentiated adenocarcinoma in right craniorbital region | Blindness, exophthalmos(od), headache/1 year | 0 | 0 | 1 | no | C6(L) | 3*2 | Medial | PA(R),Clip.of C6(L),Low differentiated adenocarcinoma in right craniorbital region |
| 11 | SKA(L) | No | Headache/1 month | 0 | 0 | 1 | no | C6(R) | 7*6 | Superomedial | Cervical carotid (R) exposure,SKA(L),removal of partial sellar tubercle,Clip.of C6(R) |
| 12 | SKA(R) | Multiple meningioma in the anterior cranial fossa | Epilepsy/1 week | 0 | 0 | 1 | no | C7(L) | 3*2 | Superior | SKA(R),resection of meningiomas,Clip.of C7(L) |

Table 2 (Continued)

| Patient no. | surgical approach | Comorbidity | Presenting symptom | Hunt & Hess grade | Modified Fisher grade | No. of aneurysms | Rupt. Side | Location of the aneurysms | Aneurysm size dome*neck (mm) | Orientation & morphology | Procedure |
|-------------|-------------------|-------------|--------------------|-------------------|-----------------------|------------------|------------|---------------------------|------------------------------|--------------------------|--|
| 13 | SKA(L) | HBP | Headache/3 months | 0 | 0 | 1 | no | C6(R) | 3*4 | Superior | SKA(L), Wrapping of C6 (R) |
| 14 | SKA(L) | No | Headache/2 months | 0 | 0 | 1 | no | C7(R) | 5.7*5.1 | Superomedial | Cervical carotid (R) exposure, SKA(L), removal of partial sellar tubercle, Clip of C6(R) |
| 15 | SKA(R) | No | Headache/1 year | 0 | 0 | 1 | no | C6(L) | 3*4.5 | Medial | Cervical carotid (L) exposure, SKA(R), Clip of C6 (L) |

Abbreviations: EVD, external ventricular drainage; HBP, high blood pressure; L, left; PA, pterional approach; R, right; SKA, supraorbital keyhole approach.
 C6, ICA-ophthalmic segment (opt); C7, ICA-posterior communicating artery segment.
 #No treatment.
 §Ipsilateral approach.

extent of craniotomy, clip size and configuration, geometry of the clip holder, and the risk of conflict with adjacent vessels or cranial nerves.⁸

The importance of precisely understanding the 3-dimensionality (3D) of aneurysms before clipping has been emphasized and studied by several groups.^{5,9-11} Pre-operative imaging is the only data source available to inform the development of a surgical strategy, and full utilization of this resource requires a comprehensive understanding of the spatial information. Integrating multimodal 3D images could help the neurosurgeon understand the individual vascular anatomy allowing clip preselection and positioning, as well as anticipating potential difficulties and complications, evaluating the necessity of drilling the ACP, and determining the feasibility of using a contralateral approach.^{12,13} In this study, we used Mimics software to build 3D images and perform preoperative simulation of different surgical approaches. The aneurysms projecting to the medial, superior, superomedial, or posterior can be treated by the contralateral approach. The visual similarity between the simulating scene and the operative view was excellent in 100% of the cases. Four aneurysms were clipped by the ipsilateral approach, and the 17 aneurysms were clipped through the contralateral approach (superomedial [3/17, 17.6%], medial [8/17, 47.1%], posterior [3/17, 17.6%], and superior [3/17, 17.6%]); and all of them were well-clipped, except for 1 blister-like aneurysm that was wrapped.

The contralateral approach can be applied even for a giant aneurysm of the C6 aneurysm.¹⁴ The maximum diameter of aneurysms in this group treated by the contralateral approach was 15.2 mm; however, a limitation of this study is that the cases are few, we cannot summarize the maximum diameter of the aneurysm treated by contralateral approach until now. We think the size of the aneurysm is only one of the factors to consider whether the contralateral approach can be performed, only when the neck of the aneurysm is small and when there is a space between the anterior wall of the aneurysm and the tuberculum sellae, the probability of anterior clinoidectomy and intraoperative rupture or rerupture of aneurysms can be reduced, so that we can safely clip the perclinoid aneurysms. As shown in case 2, if the ipsilateral approach is adopted, the aneurysm dome and its daughter sac projected to lateral are first encountered. Through the ipsilateral approach, it is more difficult to expose the aneurysm neck, brain retraction is increased, and the risk of aneurysm rupture during operative procedure is elevated. However, the contralateral approach can control the aneurysm neck first.

Although the preoperative simulation showed that proximal ICA control can be gained from intracranial segment, if the clinoid space is narrow, when necessary, resecting the ACP is still needed. Therefore, to be on the safe side, exposure of cervical segment to gain proximal ICA control from the ipsilateral side of the aneurysm before craniotomy should be performed first.¹⁵

Table 3. Pre- and postoperative conditions and clinical outcome

| Patient no. | Visual Field preop. | Visual Field Postop. | Preoperative hydrocephalus | Postoperative hydrocephalus | V-P shunt | Modified mRS score preop. | Modified mRS score last follow up | Follow Up (months) | | | | | |
|-------------|---------------------|----------------------|----------------------------|---|-----------|---------------------------|-----------------------------------|--------------------|-----|-----|---|---|---|
| 1 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 0 | 33 | | | | | |
| 2 | Nomal | Unchanged | Mild hydrocephalus | Mild hydrocephalus | N/A | 4 | 0 | 36 | | | | | |
| 3 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 23 | | | | | |
| 4 | Nomal | Unchanged | Yes | Yes | Yes | 3 | 3 | 19 | | | | | |
| 5 | Nomal | Unchanged | Yes | Yes | Yes | 2 | 1 | 17 | | | | | |
| 6 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 0 | 17 | | | | | |
| 7 | Nomal | Unchanged | N/A | N/A | N/A | 2 | 1 | 15 | | | | | |
| 8 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 14 | | | | | |
| 9 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 0 | 6 | | | | | |
| 10 | Blindness(od) | Blindness(od) | N/A | Yes | Yes | 3 | 3 | 8 | | | | | |
| 11 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 0 | 4 | | | | | |
| 12 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 4 | | | | | |
| 13 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 3 | | | | | |
| 14 | Nomal | Unchanged | N/A | N/A </tr <tr> <td>15</td> <td>Nomal</td> <td>Unchanged</td> <td>N/A</td> <td>N/A</td> <td>N/A</td> <td>1</td> <td>1</td> <td>3</td> </tr> | 15 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 3 |
| 15 | Nomal | Unchanged | N/A | N/A | N/A | 1 | 1 | 3 | | | | | |

Abbreviations: mRSs, modified Rankin Scale; N/A, not available; V-P shunt, ventriculoperitoneal shunt.

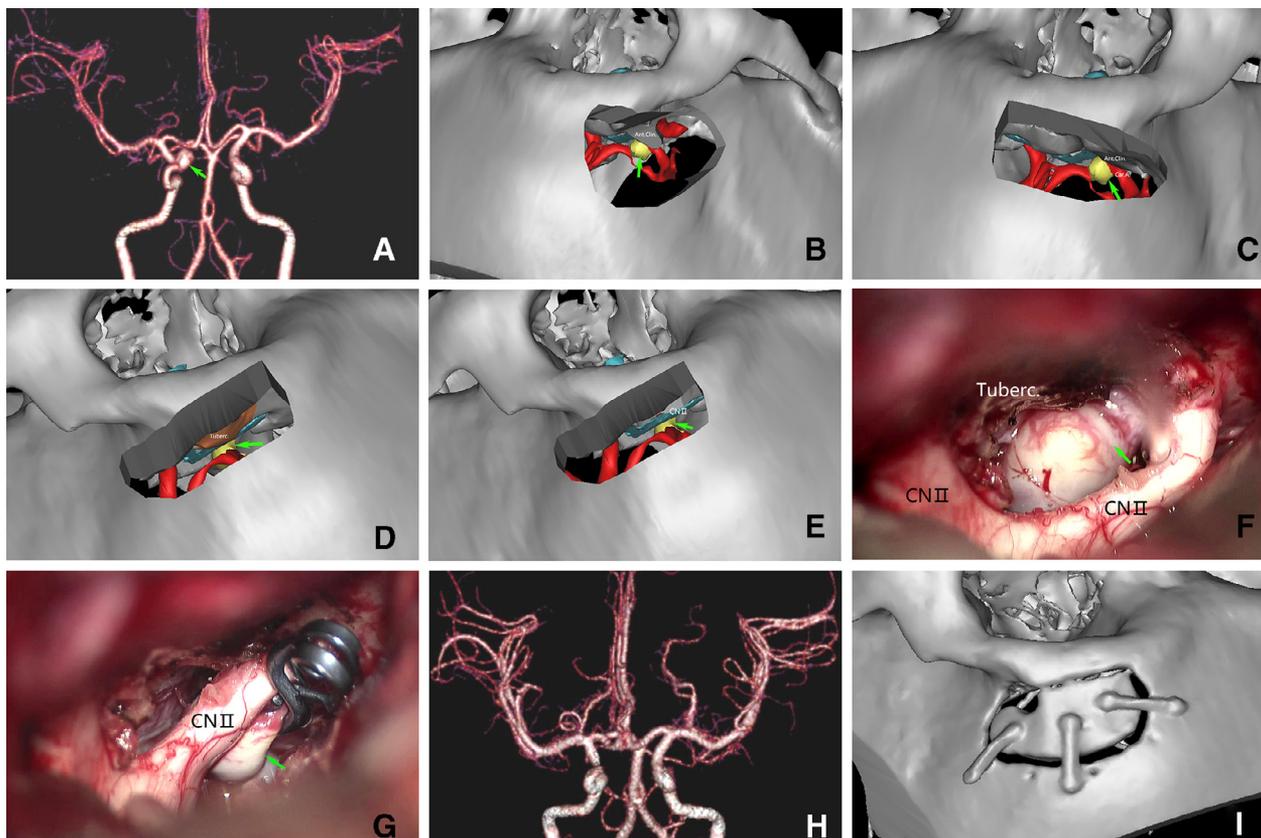


Figure 1. Case 11: A 43-year-old man underwent a CT to investigate episodes of headache. An aneurysm (green arrow, the same below) of the C6-right was revealed. The maximum diameter of the aneurysm was 7 mm and the dome was projected to medial (A). The patient expressed an explicit wish to have the aneurysm closed surgically. The CTA data were transferred to the Mimics software and 3D reconstructed for surgical planning. The preoperative simulation shows that if the ipsilateral PA (B) or the ipsilateral SKA (C) was used, the ACP obstructed the exposure of the aneurysm neck. However, if contralateral SKA was adopted, the aneurysm neck could be revealed after removal of partial sellar tubercle (D-E), without removing ACP. F: shows the intraoperative viewpoint with the dissected aneurysm and Fig. 1G shows the final position of the clip. H: shows the postoperative CTA that the aneurysm was completely occluded. I: shows the bone window of contralateral SKA. The patient had no neurological dysfunction after operation (mRS = 0). (Ant.Clin., anterior clinoid process; Car.A, internal carotid artery; Tuberc., tuberculum sellae; CN II, optic nerve). ACP, anterior clinoid process; CTA, computed tomography angiography; SKA, supraorbital key-hole approach. (Color version of figure is available online.)

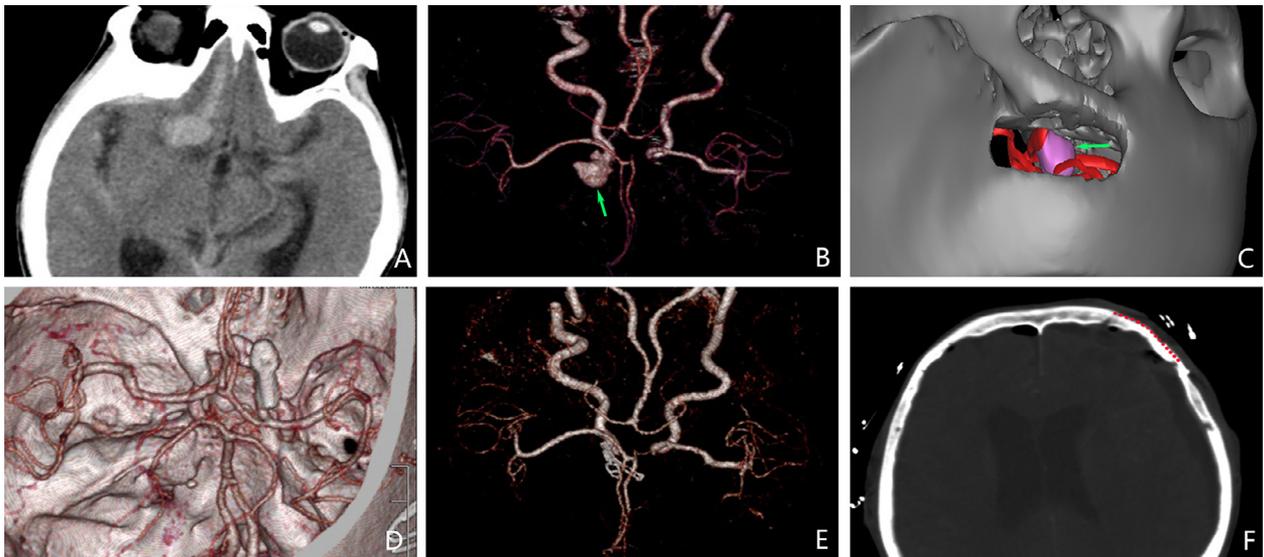


Figure 2. Case 2: A 60-year-old patient presented with acute headache for 8 days. On examination, he was fully oriented and neurologically intact. CT and CTA revealed a subarachnoid hemorrhage and a small amount of hemorrhage on the right frontal gyrus (A) and a saccular aneurysm (green arrow, the same below) of 15.2 mm diameter located at C6-right. The dome of the aneurysm appeared to carry 2 daughter sacs and projected superiorly (B). The CTA study was imported and was 3D reconstructed for surgical planning in Mimics software. The feasibility of contralateral approach was assessed preoperatively by 3D-CTA. C: shows the view toward the aneurysm from the surgical perspective through a simulated left SKA. The contralateral approach exposed the aneurysm neck and the distal part of the parent artery, and did not need to remove the contralateral ACP. However, the ipsilateral C1 segment should be exposed, in advance to temporarily block the proximal part of the parent artery. D and E: shows the postoperative CTA with the clip in place and the aneurysm was totally occluded. F: shows the bone window (red dashed line) of contralateral SKA. After the operation, he had no obvious sequelae and returned to normal life (mRS = 0). ACP, anterior clinoid process; CTA, computed tomography angiography; SKA, supraorbital keyhole approach. (Color version of figure is available online.)

Two cases (11 and 13) were accidentally discovered contralateral aneurysms during the examination of tumor lesions. With sufficient preoperative simulation, the contralateral aneurysms were successfully clipped, while the tumors were resected through the same bone window on the ipsilateral side of the tumor. Simultaneous operation of single bone window alleviated the patients' economic and psychological burden and reduced the damage of the operating procedure.¹⁶

Patients with bilateral aneurysms present a management challenge. These lesions may be treated in a staged manner or alternatively. For certain selected patients, a contralateral approach may be utilized to treat bilateral aneurysms with a single surgery.^{6,17} In general, the hemorrhagic side should be treated first. The feasibility of treatment of contralateral aneurysm with the same bone window was fully simulated preoperatively. Five cases of this group were multiple aneurysms. Guided by preoperative simulation, bilateral aneurysms were satisfactorily clipped through a bone window.

The domestic and foreign clinical experience showed that patients with Hunt-Hess I-III, aneurysm clipped via SKA is feasible and safe.^{1,18,19} In this group, 11 patients with 13 aneurysms were treated via SKA, of which 2 cases (case 2 and 5) were Hunt-Hess III. The modified Fisher grade of the patients treated with SKA was 0. However, patients with modified Fisher grade 3-4 are more affected by SAH, often using the PA (cases 4 and 7).

Someone may think that the virtual osteotomy would not be needed for aneurysms far away from the clinoid. However, especially for junior neurosurgeons, when combined with bilateral lesions, they can reassure that the feasibility of an approach for treating ipsilateral lesion and contralateral aneurysm through preoperative simulation.

Despite the clinical urgency associated with many ruptured aneurysms, the preoperative simulation that takes approximately 10-20 minutes has also been shown to be useful in planning for these cases when time allowed.

The surgical mortality and morbidity related to treating aneurysms in the anterior circulation is approximately 3%-5%. In the present study, 15 consecutive clipping surgeries of anterior circulation aneurysms were performed without mortality, but there were ventriculoperitoneal shunts in 3 cases.

A limitation of this study is that the cases are few, and the follow-up time is not sufficiently long. With the development of intravascular technology, the treatment of these aneurysms may become easier. However, a contralateral approach remains a microsurgical option for selected anterior circulation aneurysms. We consider that the use of a contralateral approach requires fine technical skills and should be the choice only under judicious case-to-case planning based on a preoperative 3-dimensional virtual osteotomy technique. This approach requires a meticulous preoperative analysis of the characteristics of the aneurysms to be clipped and of the anatomic constraints of the microsurgical operative corridor.

Conclusions

The contralateral approach for anterior circulation aneurysms in selected patients is feasible in experienced hands with acceptable morbidity. The contralateral approach requires a meticulous preoperative analysis of the characteristics of the aneurysms to be clipped and of the anatomic constraints of the microsurgical operative corridor. Contralateral approach based on careful surgical simulation with 3D images is a safe and less invasive means of treating anterior circulation aneurysm.

Declarations of Interest

None.

Supplementary Materials

Supplementary data to this article can be found online at doi:10.1016/j.jstrokecerebrovasdis.2018.12.040.

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