Fenestrated aneurysm clips in the surgical management of anterior communicating artery aneurysms: operative techniques and strategy

Clinical article

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Object. Aneurysms of the anterior communicating artery (ACoA) can be a considerable challenge to treat surgically based on variations in the anatomy and morphological features of the ACoA complex. The fenestrated aneurysm clip can be a simple and practical tool in the operative management of ACoA aneurysms. The goal in this study was to characterize the particular surgical situations in which the use of a fenestrated clip facilitates the clip ligation of ACoA aneurysms.

Methods. The authors present their operative strategy and techniques for the use of fenestrated clips in the treatment of ACoA aneurysms.

Results. One hundred ninety-nine patients underwent surgical clipping of an ACoA aneurysm at the authors' institution between the years 1991 and 2008. Of these patients, fenestrated aneurysm clips were used in 20 cases (10%). The following structures were enclosed in the clip aperture: ipsilateral A₂ artery, 12 patients (60%); ipsilateral A₁ artery, 4 patients (20%); ipsilateral A₁ artery plus recurrent artery of Heubner, 1 patient (5%); ACoA, 1 patient (5%); frontopolar artery, 1 patient (5%); and no structures, 1 patient (5%). Aneurysms approached from the left side more frequently required fenestrated clips than did right-sided aneurysms (80 vs 20%, $p = 0.0073$). In all cases, patency of the A₂ vessels was confirmed on postoperative angiography. In 2 patients, small remnant aneurysm necks were identified on postoperative angiography.

Conclusions. The use of fenestrated aneurysm clips can minimize tedious and potentially dangerous dissection of adherent branch vessels, while maintaining the integrity of structures placed within the clip aperture. The ACoA aneurysms pointing in a superior direction are more likely to require clip fenestration around the A₂ vessel, whereas those pointing in an inferior direction are more likely to require clip fenestration around the A₁ vessel. The parallel approximation of the fenestrated clip blades makes them especially useful in the treatment of large or giant aneurysms. (DOI: 10.3171/2009.2.FOCUS08314)

KEY WORDS • anterior communicating artery • aneurysm • fenestrated aneurysm clip • circle of Willis • outcome assessment

SURGICAL clip ligation of ACoA aneurysms can challenge even experienced cerebrovascular surgeons on account of the intricate and variable anatomy of the ACoA complex and its surrounding structures. Because an ever-growing number of these lesions are treated by endovascular coil embolization, aneurysms that require surgical management assume even greater overall complexity. Direct surgical obliteration of these lesions may therefore require a higher technical skill set and the use of several adjunct measures, including ex-

tended craniotomies, gyrus rectus resection, or revascularization techniques.⁹⁻¹¹ In certain anatomical situations, attempted aneurysm clipping with nonfenestrated devices may endanger the patency of the A₁ or A₂ arteries and increase the amount of dissection required for clip placement, thereby increasing the risk of intraoperative rupture.

Since their conception by Charles Drake in 1969, fenestrated aneurysm clips have become useful tools for vascular neurosurgeons encountering a variety of aneurysms.^{2,3} Fenestrated clips may reduce the requirement for dissection of surrounding vascular structures, thereby potentially preserving parent or branch vessel integrity. The apertures of fenestrated clips have been used to protect numerous structures, including arteries, nerves, ad-

Abbreviations used in this paper: ACoA = anterior communicating artery; AP = anteroposterior; FPA = frontopolar artery; ICA = internal carotid artery.

TABLE 1: Clinical characteristics of 20 patients undergoing surgical clipping of an ACoA aneurysm with fenestrated clips*

Case No.	Age (yrs), Sex	Fisher Grade	H&H Grade		GOS Score	Vasospasm	Complications
			Admission	Preop			
1	49, F	4	I	I	5	none	none
2	49, F	3	II	I	5	radiographic	none
3	46, F	4	II	I	5	none	none
4	31, F	3	III	I	4	clinical + radiographic + stroke	contralat leg weakness
5	41, M	3	II	II	5	radiographic	none
6	47, F	3	II	II	1	clinical + radiographic + stroke	intraop rupture, vasospasm, death
7	44, M	3	III	III	1	NA	MI, pneumonia, sepsis, death
8	34, M	2	III	I	5	none	none
9	49, F	3	II	0	5	none	intraop rupture
10	37, M	4	II	I	1	clinical + radiographic + stroke	vasospasm, stroke, seizures, death
11	69, M	4	III	III	4	radiographic	none
12	34, F	2	I	I	5	clinical + radiographic	none
13	59, F	3	III	IV	4	clinical + radiographic + stroke	intraop rupture, vasospasm, aphasia
14	44, F	2	I	I	5	none	none
15	26, F	4	III	III	5	none	none
16	58, F	NA	0	0	5	none	none
17	42, M	4	I	I	5	none	none
18	53, F	4	I	III	5	clinical + radiographic	none
19	59, F	NA	0	0	5	none	none
20	49, F	1	II	II	5	none	none

* GOS = Glasgow Outcome Scale; H&H = Hunt and Hess; MI = myocardial infarction; NA = not applicable.

ditional aneurysm clips, or a segment of the aneurysm neck.^{1,4,12} Our goal was to further characterize the particular surgical and anatomical situations in which fenestrated aneurysm clips may facilitate the surgical clipping of ACoA aneurysms. In this report, we describe our operative strategy and institutional experience involving the application of these devices in the surgical treatment of complex ACoA aneurysms.

Methods

Patient Population

During a 17-year period (1991–2008), 199 patients underwent surgical clipping of ACoA aneurysms by one surgeon (S.L.G.) at the University of Southern California Medical Center. Of these cases, 20 patients (10%) required the use of at least 1 fenestrated aneurysm clip. The mean age of these patients was 46 years (range 26–69 years). There were 14 women (70%) and 6 men (30%) in the group. Clinical and radiographic details pertaining to patient demographics and clinical presentation are highlighted in Table 1. Of the 20 patients, 18 (90%) presented with subarachnoid hemorrhage, whereas 2 (10%) underwent surgical clipping of an unruptured aneurysm.

Operative Technique

The approach side is frequently selected based on the location and direction of the aneurysm as well as the side

of the dominant A₁ feeding vessel, to obtain proximal vascular control. Presence of a frontal lobe clot may override decision making as to the laterality of the approach. A

FIG. 1. Schematic demonstrating the more parallel closing angle in fenestrated aneurysm clips (*left*) as compared with standard aneurysm clips (*right*). This facilitates the clipping of wide-necked aneurysms, especially nearest the proximal end of the clip blades. The *arrows* show the direction of closure of the aneurysm clip's blades.

Fenestrated clips in surgical management of ACoA aneurysms

FIG. 2. Case 19. A: Oblique angiogram demonstrating a superiorly pointing left ACoA aneurysm. B and C: Postoperative AP and lateral angiography studies demonstrating clip ligation of the aneurysm using a fenestrated clip. The fenestration is positioned around the left A₂ artery. D: Schematic of a superiorly pointing A₁/A₂ junction aneurysm with a straight fenestrated clip encasing the A₂ artery, which would ordinarily impede the clip's trajectory to the neck of the aneurysm.

lumbar drain is inserted preoperatively in selected cases of ruptured aneurysms, when a ventriculostomy catheter has not been previously placed. A standard pterional craniotomy is used in the majority of cases. In cases of large or giant superiorly pointing aneurysms, or if a significant degree of frontal lobe edema or hemorrhage is anticipated based on preoperative imaging, a modified supraorbital craniotomy may be used for improved exposure. The decision to remove the orbital rim can be implemented at any time during the procedure, if a restricted exposure is encountered.

Extradural drilling of the sphenoid wing is performed and the meningo-orbital artery is coagulated and ligated. The dura mater is tacked up, opened, and reflected anteriorly. The operating microscope is introduced, and microdissection of the sylvian fissure is performed. Once dissection of the fissure is initiated, 1 or 2 retractors are used to gently retract the frontal lobe. Cerebrospinal fluid drainage is usually undertaken at this time, and the carotid-ophthalmic cisternal membranes are widely opened. The ICA bifurcation and/or A₁ artery are identified and

followed anteromedially to the ACoA complex. Electroencephalographic burst suppression is obtained, followed by proximal control of one or both A₁ arteries in cases of ruptured aneurysms. Temporary clipping is seldom performed in small, unruptured aneurysms, although proximal vessels are identified and prepared in each case. For large or posteriorly pointing sacs, temporary occlusion of both A₁ vessels will slacken the sac and reduce its turgidity so that the dissection of the A₂ artery and smaller anterior communicating branches is facilitated.

As with any strategy used in ACoA surgery, complete dissection and evaluation of all branches is axiomatic. A considerable effort is made to identify and preserve small perforator vessels and the recurrent artery of Heubner. This is facilitated by wide dissection of the interhemispheric fissure and possible modest resection of the gyrus rectus when necessary. Dissection of the aneurysm dome and neck is performed, noting that a ruptured aneurysm is often adherent to one or more surrounding structures.

In the majority of cases, clip placement can proceed using a standard straight or curved aneurysm clip once

FIG. 3. *Left:* Schematic of an A_1/A_2 aneurysm ligated with an angled fenestrated clip encircling the A_1 artery and recurrent artery of Heubner. *Right:* Schematic of an inferiorly projecting A_1/A_2 aneurysm with a fenestrated clip placed around the A_1 artery.

the lesion's neck and surrounding vessels are dissected. In many instances, however, a direct trajectory to the aneurysm neck is impeded by parent or perforating vessels of the ACoA complex, requiring a more extensive degree of dissection, mobilization, and traction on the dome of the aneurysm to achieve clip placement. Furthermore, the closing pressure and angle of nonfenestrated clips may be a limiting factor in totally occluding wide-necked or giant aneurysms, as compared with fenestrated clips, which offer more parallel approximation of clip blades and a greater closing pressure (Fig. 1). Depending on the aneurysm's morphological features and the angle of the approach selected, any number of parent or perforating vessels may directly obstruct the trajectory to the aneurysm neck. For superiorly pointing ACoA lesions, the ipsilateral A_2 vessel frequently impedes clip placement across the aneurysm neck. In such cases, the use of a fenestrated clip may allow the surgeon to limit tedious and potentially dangerous dissection of severely adherent A_2 branches off the dome of the vessel (Fig. 2). In addition, superiorly directed aneurysms may require additional resection of the gyrus rectus prior to clipping to identify all components of the complex.

For posteriorly pointing aneurysms, extensive dissection of the neck and dome from surrounding A_1 perforators and the A_1 – A_2 complex is frequently required. The ipsilateral A_1 artery and multiple perforating arteries may impede neck dissection and direct clip placement. In such cases, the aperture of a fenestrated clip placed around the A_1 artery and/or recurrent artery of Heubner often facilitates clip ligation and limits excessive dissection (Fig. 3). Angled fenestrated clips may be especially helpful in these situations. Given the size of branch vessels in the region of the ACoA aneurysm, small (2-mm) clip apertures are usually sufficient. Larger-aperture clips can be cumbersome in restricted exposures to the ACoA region.

Following clip placement, the neck and dome of the aneurysm and surrounding vessels of the ACoA complex are inspected. Patency of the parent artery and distal branches is confirmed under direct inspection, and frequently with the use of a Doppler microprobe, fluorescein angiography, intraoperative angiography, or an endoscope. Intraoperative angiography is not routinely used except in cases of large or giant aneurysms, although intravenous fluorescein angiography has been used frequently over the last 2 years. The subarachnoid space is irrigated and hemostasis is achieved. The dura mater is reapproximated in watertight fashion, followed by replating of the bone flap with titanium microplates. The wound is closed in standard fashion.

Characteristics of ACoA Aneurysms Requiring Fenestrated Clips

Of the 20 patients with surgically treated ACoA aneurysms that required the use of a fenestrated clip, 15 had ACoA aneurysms originating from the left A_1 /ACoA junction, whereas 4 had lesions originating from the right A_1 /ACoA junction, and 1 patient had an aneurysm projecting from the midline of the ACoA with no apparent origin from either side. A fenestrated clip was used with a left-sided approach in 16 patients (80%), whereas 4 patients (20%) required fenestrated clip placement with a right-sided approach ($p = 0.0073$, chi-square test). The mean maximal aneurysm diameter was 10 mm (range 3–25 mm). Aneurysms were noted to point in the following directions: superior (7 lesions), inferior (4), posterior (3), medial (4), and anterior (1).

The following structures were incorporated into the clip fenestration in each case (Tables 2 and 3): ipsilateral A_2 artery, 12 patients (60%); ipsilateral A_1 artery, 4 patients (20%); ipsilateral A_1 artery plus recurrent artery of

Fenestrated clips in surgical management of ACoA aneurysms

TABLE 2: Operative details in 20 patients undergoing craniotomy for ACoA aneurysm ligation with fenestrated clips*

Case No.	Approach Side	Lesion Size (mm)	Direction	Temp Clip	Ischemia Time	Fenestrated Structure	Clip Type	Postop Angiography
1	lt	14		yes	10	A2 artery	straight fenestrated clip	A2 intact
2	rt			no	NA	A2 artery	straight fenestrated clip	A2 intact
3	lt			no	NA	A2 artery	straight fenestrated clip	A2 intact
4	lt		pst	yes	14	A1 artery	angled fenestrated clip	A2 intact
5	lt		inf	yes	28	A1 artery	straight clip across dome; fenestrated clip across neck	A2 intact
6	rt		pst/inf	yes	37	A1 artery + recurrent artery of Heubner	NA	A2 intact
7	lt	6	medial	yes	27	A2 artery	NA	A2 intact
8	lt		sup	yes	29	A2 artery	angled fenestrated clip	A2 intact
9	lt		medial	yes	25	A2 artery	straight fenestrated clip	A2 intact
10	lt†	6	sup	yes	16	A2 artery	angled fenestrated clip	NA
11	lt	10		yes	75	A2 artery	straight fenestrated clip	A2 intact
12	rt			no	NA	FPA	angled fenestrated clip	NA
13	lt		sup/pst	yes	21	A2 artery	straight fenestrated clip	A2 intact
14	lt			yes	5	A2 artery	straight fenestrated clip	A2 intact
15	lt	9	sup	yes	10	A1 artery	straight clip across dome; fenestrated clip across neck	A2 intact
16	rt	8	sup/ant	yes	20	A2 artery	2 angled fenestrated clips	A2 intact
17	lt	5	inf/medial	yes	13	A1 artery	angled fenestrated clip	A2 intact
18	lt	3	sup/medial	yes	16	ACoA	straight fenestrated clip	A2 intact
19	lt	9	sup	no	NA	A2 artery	straight fenestrated clip	A2 intact
20	lt	25	inf	yes	31	none	2 straight fenestrated clips	A2 intact

* Ant = anterior; inf = inferior; pst = posterior; sup = superior; temp clip = temporary clipping.

† Aneurysm originated from the midline, yet was approached via a left craniotomy.

Heubner, 1 patient (5%); ACoA, 1 patient (5%); and FPA, 1 patient (5%). In 1 additional patient, the dome of a giant aneurysm required perforation and thrombectomy, followed by clipping using 2 straight fenestrated clips across the neck and puncture site, with no adjacent branch structures inside the clip aperture (Fig. 4). Overall, straight fenestrated clips were used more frequently than angled fenestrated clips (67 vs 33%, respectively). Multiple aneurysm clips were used in 4 cases. In 2 of these cases, a combination of straight clip placement across the aneurysm dome was combined with fenestrated clip placement across the aneurysm neck. In 1 case, 2 angled fenestrated clips were used across the neck of the aneurysm. Intraoperative rupture occurred in 3 cases (15%).

Routine postoperative angiography was obtained in 18 of 20 patients. In all 18 of these patients, patency of the A₂ arteries was demonstrated. A small residual neck remnant was observed in 2 patients (11%), whereas in the other 16 patients (89%) no residual aneurysm or neck was identified.

Discussion

Aneurysms of the ACoA region can be a consider-

able challenge to treat surgically, based on the variety in the morphological features of these aneurysms and the surrounding ACoA complex. The presence of small, critical perforating vessels originating from and traversing the region make precise vessel dissection and clip placement imperative. A variety of surgical adjuncts are available to the surgeon to improve the operative exposure and the ability to identify critical components of the ACoA complex prior to aneurysm dissection and clipping. These measures may include extended craniotomies, brain relaxation with CSF drainage, resection of the gyrus rectus, and dissection of the interhemispheric fissure. Although each of these strategies may improve the exposure of the ACoA region and reduce the amount of brain retraction required, dissection of the aneurysm neck and dome still poses a tedious and challenging task prior to safe clipping of the aneurysm, especially in cases of previous aneurysm rupture. When possible, placement of a straight or angled nonfenestrated clip across the aneurysm neck under direct visual observation remains the safest and simplest method of surgical aneurysm ligation. However, due to variations in the direction of ACoA aneurysms and the microvasculature of the region, straight clip placement may be impeded by structures traversing the operative trajectory.

TABLE 3. Summary of structures preserved within fenestrated clip aperture in 20 operative cases

Structure	No. of Patients (%)
A ₂ artery	12 (60)
A ₁ artery	4 (20)
A ₁ + recurrent artery of Heubner	1 (5)
ACoA	1 (5)
FPA	1 (5)
none (blades across aneurysm neck & perforation site)	1 (5)

The use of a fenestrated aneurysm clip can be a safe and practical approach to minimizing the requirement for dissection and retraction of these vessels and the dome of the aneurysm. The surgical clipping of ACoA aneurysms pointing superiorly is often facilitated by the use of a straight fenestrated clip placed with its aperture around the ipsilateral A₂ artery. For posteriorly directed aneurysms, angled fenestrated clip placement is often used around the ipsilateral A₁ artery. A variety of additional branch vessels may be incorporated into the clip aperture, including the recurrent artery of Heubner, orbitofrontal artery, FPA, and additional microperforating vessels of the ACoA complex. The need to maintain patency of the circle of Willis, or because of important perforating vessels that arise from the ACoA, necessitates aneurysm clip blade placement completely parallel to the communicating vessel. For wide-necked aneurysms, blade placement in any direction other than completely parallel frequently results in kinking of the ACoA. The use of a straight fenestrated clip, with potential placement of one of the A₂ branches within the fenestration, usually allows better preservation of flow through the ACoA.

For wide-necked or giant aneurysms, a series of fenestrated straight or angled aneurysm clips can be used in parallel to recreate the wall of the parent vessel and provide increased combined closing pressures, as originally described by Drake and detailed in Lownie et al.⁷ Another key characteristic of fenestrated aneurysm clips is the more evenly distributed closing pressure exerted at the proximal and distal ends of the clip blades, as compared with that of nonfenestrated clips.⁸ Furthermore, the approximation of fenestrated clip blades occurs in a more parallel orientation than in straight clips, making them especially useful for positioning across the necks of large or giant aneurysms. For this reason, they can also be used near puncture sites in aneurysm domes or in conjunction with an aneurysmectomy, when an even distribution across the aneurysm neck is desirable.

Our review of these cases suggests that the most appropriate situations for fenestrated clip use may occur in the context of aneurysms approached from the surgeon's nondominant side, and those with superiorly or posteriorly pointing dome trajectories. Given the context of a residency training program, it may be that for less experienced surgeons, the use of a fenestrated aneurysm clip may allow placement of the device with the dominant hand. Another explanation is that a disproportionate number of ACoA aneurysms originate at the left A₁/A₂ junction as compared with the right. In this series, the most common structure enclosed in the aperture of the fenestration (in ~60% of cases) was the ipsilateral A₂ artery. In a series described by Fujita et al.,⁵ the ipsilateral A₂ artery was also the structure most frequently incorporated into the clip fenestration (60% of cases). The A₁ artery was the next most frequent structure requiring preservation with a fenestrated clip.

Historical Development of the Fenestrated Aneurysm Clip

Surgical clip application has been the mainstay treat-

Fig. 4. Case 20. A: Preoperative AP angiogram showing a large inferiorly pointing left ACoA aneurysm. B and C: Postoperative AP angiography showing complete clip ligation of the aneurysm. Two fenestrated clips were used following an embolectomy and aneurysmectomy to obtain a stronger and more parallel closing pressure.

Fenestrated clips in surgical management of ACoA aneurysms

ment of intracranial cerebral aneurysms since the first clipping of an ICA aneurysm by Walter Dandy in 1937 (detailed in Louw et al.).⁶ The first surgical clip designed to incorporate a vital structure in an opening near the handle while securing an aneurysm within its blades did not appear until > 3 decades later. The “Drake-Kees” clip, as it was initially referred to, was first used on September 8, 1969, to treat a basilar artery aneurysm. Years later, Drake referred to this fenestrated clip design as the “modified Mayfield clip.”¹¹

The fenestrated aneurysm clip design was later improved and mass produced by Sugita, who first learned of the clip and its application from Drake. Sugita provided many variations to the original design, with a spectrum of blade curvatures and lengths becoming available to surgeons.^{6,12} Sugita et al. described the 24 types of fenestrated aneurysm clips in use in 1982, based on clip shape (straight, oblique-angled, right-angled, and bayonet-shaped), blade length (5–12 mm), and fenestration aperture (3.5–6 mm). The blade-deviated fenestrated clip was later designed by Fujita and colleagues to accommodate aneurysms of the ICA, which may project medially or posteriorly off the parent carotid vessel. This clip type was later described as being useful in the ligation of ACoA aneurysms with a neck origin on the posterolateral aspect of the parent artery, and projecting in a superior or anterior-superior direction. The clips designed by Fujita have a blade deviation from the handle with an angle of 35 or 40°, and fenestrations of 3.5 or 5 mm. Fujita et al.’s series⁵ reported on 15 patients in whom ACoA aneurysms were clipped with blade-deviated type aneurysm clips. The authors reported successful clipping in all 15 cases. As in our series, in the majority of these patients the ipsilateral A₂ was placed within the clip fenestration.

Conclusions

The fenestrated aneurysm clip has become an integral and practical tool in the surgical clipping of complex ACoA aneurysms. Because an ever-growing number of these lesions are treated by coil embolization, more complex aneurysm cases are being referred for surgical clipping. The use of a fenestrated clip may allow the surgeon to limit dissection of adherent branch vessels, while maintaining the integrity of structures placed in the fenestration. Aneurysms pointing in a superior direction are more likely to require fenestration of the A₂ vessel with

aneurysm clipping, whereas aneurysms pointing in an inferior direction are more likely to require fenestration of the A₁ vessel. Surgical and radiographic outcomes demonstrate excellent preservation of parent vessels when these devices are used by an experienced surgeon.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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