Falxuplication, a Novel Method for Wrap-Clipping a Fusiform Aneurysm: Technical Note

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BACKGROUND: Various techniques have been used for wrap-clipping a ruptured, fusiform intracranial aneurysm; however, there is no available literature on use of the falx cerebri for wrap-clipping. We present a review of the literature, with an illustrative case, of a ruptured fusiform pericallosal artery aneurysm firmly attached to the lower edge of the falx cerebri and not amenable to endovascular intervention.

METHODS: Although the firm attachment between the inferior falx and the fusiform aneurysm was maintained, a section of the lower thinner part of the falx cerebri firmly attached to the aneurysm was dissected and wrapped around the fusiform aneurysm, and then stabilized with a fenestrated clip. We chose a segment slightly longer than the length of the fusiform aneurysm to avoid pre- and post-wrap-clipping stenosis.

RESULTS: Postprocedure, except for a small area of numbness on the left distal anterolateral left leg, the patient was neurologically intact and remained neurologically intact at a 12-month follow-up.

CONCLUSIONS: An inferior thin segment of the falx cerebri can be used for wrap-clipping of ruptured fusiform anterior cerebral artery aneurysms. Furthermore, the inferior falx can be wrapped around the attached fusiform anterior cerebral artery aneurysm without compromising flow, offering a safe solution in these unusually complex cases.

INTRODUCTION

The overall prevalence of intracranial aneurysms is approximately 2%–3%,¹³ with peak incidence during the sixth decade of life.¹ Different reports estimate the overall risk of aneurysmal rupture at 2–30/100,000 individuals per year.²⁻⁴⁻⁶ As classified by morphology, intracranial aneurysms can be saccular, fusiform, or dissecting. Saccular aneurysms are the most common, accounting for 90% of cases and for most of the morbidity and mortality associated with aneurysmal subarachnoid hemorrhage (SAH).⁷ Fusiform aneurysms, the focus of this article, are the second most common type. They can be defined as a circumferential dilation of a segment of an intracranial artery lacking a defined orifice of flow, unlike saccular aneurysms.⁷ Because the inflow and outflow are longitudinally separate in fusiform aneurysms, resulting in no clearly defined anatomic neck, surgical and endovascular interventions are challenging.⁷ Without an anatomic neck akin to saccular aneurysms, fusiform aneurysms are not easily amenable to clipping or coiling. The reported prevalence is between 3% and 13% of all intracranial aneurysms⁸ and has increased in recent years.⁹ Atherosclerotic fusiform aneurysms have a 5.2% annual mortality risk owing to rupture or ischemic stroke, compared with 0.51% for nonatherosclerotic fusiform aneurysms.¹⁰ Fusiform aneurysm risk progression is also greater in atherosclerotic patients; the annual risk is 12% for atherosclerotic fusiform aneurysms versus 1.6% for nonatherosclerotic ones.¹¹ The same study demonstrated that atherosclerotic fusiform aneurysms are more likely to be located in the posterior circulation and of larger diameter, with a mean size of 11.6 mm versus 7.5 mm for nonatherosclerotic ones.¹¹ It has also been suggested that arterial dissection can lead to the formation of fusiform aneurysms.¹¹

Key words
- Falx cerebri
- Falxuplication
- Fusiform aneurysm
- Wrap-clipping

Abbreviations and Acronyms
ACA: Anterior cerebral artery
CT: Computed tomography
SAH: Subarachnoid hemorrhage

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Wrap-clipping for fusiform aneurysms has not been widely studied, but some cases have been reported in the literature. Reported materials for wrap-clipping have historically been non-autologous. In a case series of 22 patients with fusiform aneurysms, 7 were treated with wrap-clipping using either Bemsheet or periosteum.9 There was 1 reported mortality and 1 case of contralateral intracranial hemorrhage. The remaining patients had fair outcomes or no follow-up. Another series of 48 patients with dolichoectatic or fusiform aneurysms reported wrap-clipping with Gore-Tex in 18 patients (45%).12 There were no strokes or parent vessel stenoses in the patients who received wrap-clipping, but 2 patients (11%) experienced recurrent aneurysms, for which they underwent repeat wrap-clipping without recurrence for 2 subsequent years.12 Another series of 40 patients with dolichoectatic and fusiform aneurysms in the anterior circulation reported wrap-clipping of 3 cases with muslin gauze.13 Although the outcomes of these individual patients were not specified, patients with anterior circulation aneurysms appeared to have better outcomes than those with aneurysms in the posterior circulation.

Several cases of nontraumatic, distal anterior cerebral artery (ACA) intracranial aneurysms adherent to the falx cerebri have been reported in the literature. One such case involved a saccular aneurysm in which the dome was adherent to the falx but amenable to clipping.14 Another larger case series of 117 patients with distal ACA aneurysms also described surgical clipping via an interhemispheric approach, with consequent sectioning of the falx; however, the specific number of adherent aneurysms, or any cases of wrap-clipping, were not reported.15 Although dura mater has been used as an autologous wrap material for wrap-clipping of cerebral aneurysms, there are no reports in the literature of using the falx cerebri as a wrapping material for distal fusiform ACA aneurysms attached to the falx, or any cases of wrap-clipping using the falx cerebri as an autologous wrap material for aneurysms at other locations. Here we report a novel method for treating a pericallosal artery aneurysm.

**CLINICAL PRESENTATION**

The patient, GCS 15 and Hunt & Hess 1, presented with severe headache classical for subarachnoid hemorrhage. She had a small area of light numbness for light touch in the anteromedial distal third of her left leg. A preoperative computed tomography (CT) scan showed hyperdensity suspicious for SAH in the interhemispheric tissue (Figure 1). CT angiography and cerebral

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**Figure 1.** Preoperative noncontrast computed tomography scan of the head, axial view, showing suspicious subarachnoid hemorrhage.

**Figure 2.** Preoperative digital subtraction angiography image showing a saccular aneurysm at the right pericallosal and callosomarginal artery bifurcation and a fusiform aneurysm at the pericallosal artery distal to the callosomarginal takeoff. (A) Anteroposterior (AP) view. (B) Lateral view.
catheter angiography showed a fusiform pericallosal artery aneurysm immediately distal to the callosomarginal takeoff, and a saccular aneurysm at the pericallosal-callosomarginal junction (Figures 2 and 3). Endovascular intervention had a high risk of sacrificing the arteries.

The patient underwent craniotomy for interhemispheric approach to treat both aneurysms. There was mild SAH along the fusiform aneurysm, but no subarachnoid blood around the saccular aneurysm. The dome of the saccular aneurysms was severely attached to the lower edge of the falx. The entire medial aspect of the fusiform aneurysm was attached to the lower edge of the falx cerebri. Dissection would have put the patient at high risk for aneurysm rerupture and thus was contraindicated.

An 8 × 8 mm segment of the lower falx cerebri, with its inferior edge firmly attached to the medial edge of the fusiform ruptured aneurysm, was sectioned. The falcine graft was then brought inferior to the callosomarginal artery and was wrapped around the fusiform pericallosal aneurysm (Figure 4). A fenestrated clip, allowing both the callosomarginal and the wrapped pericallosal arteries to pass through the fenestration, stabilized the wrapping inferior to the pericallosal artery (Video 1). The saccular aneurysm at the bifurcation of the pericallosal and callosomarginal arteries was also clipped with a fenestrated clip. Intraoperative indocyanine green and micro Doppler ultrasound showed good flow through both arteries, and a postoperative catheter angiogram showed satisfactory results (Figures 5 and 6). The
patient experienced several episodes of vasospasm during her hospital stay and reported an unchanged small area of mildly decreased sensation for light touch on her distal anteromedial left leg. Except for this mild sensory deficit, she left the hospital neurologically intact. A postoperative cerebral catheter angiogram performed at 3 days after surgery demonstrated patency of the pericallosal and callosomarginal arteries without recurrence of either aneurysm (Figure 7).

Except for the small area of decreased sensation for light touch on her left lower leg, the patient continued to be neurologically intact at 6-month and 1-year follow-ups. A cerebral catheter angiogram at a 1-year follow-up showed no recurrence of the aneurysm, stable appearance of the arterial calibers, and stable position of the aneurysm clips with preservation of flow in the pericallosal and callosomarginal arteries (Figures 8–11).

DISCUSSION

Our patient presented with a ruptured fusiform pericallosal artery aneurysm firmly attached to the inferior edge of the falx cerebri, wherein the falx was used as an autologous material to facilitate wrap-clipping of the aneurysm. The falx cerebri attaches anteriorly to the crista galli of the ethmoid bone and posteriorly to the superior surface of the tentorium cerebelli.16,17 Its anterior segment is relatively thin but becomes broader as it extends posteriorly.16,17 The pericallosal artery is thought to be at particular risk for aneurysm formation following head trauma, owing to shear stress on the arterial wall by the lower edge of the falx.18

Autologous wrap materials that have been discussed in the literature include pericranium, dura mater, muscle, and fascia. Autologous materials are easily obtained and can be used in procedures that are time-sensitive.19 Muscle, dura, and fascia adhere fairly well to the vessel wall but subsequently reabsorb in situ, with little granulation tissue formation or fibrosis.20,21 This suggests poor long-term support of the aneurysm wall. On the other hand, nonautologous materials, such as Bemsheet in particular, show superior adhesion and proliferation of collagen fibers surrounding the vessel, suggesting greater protection against rupture or rerupture of the aneurysm.20,21 Other nonautologous materials include muslin, gelatin sponge, gauze, hemashield, Teflon, silastic sheet, fibers, fibrin glue, plastics, silicone, resins, vinyl polymers, and cyanoacrylate adhesives.21

The fibrosis induced by a nonautologous wrap is thought to protect against late, but not early, rebleeding.21 However, nonautologous materials are also associated with many
adverse effects, including foreign body granuloma,22-24 fibrous scar,25 optochiasmatic arachnoiditis with progressive bilateral vision loss,26-28 cranial nerve palsy,29 toxic neuropathy,30,31 infections with cerebritis and abscess or fluid accumulation23,32,33 intraluminal thrombosis with arterial occlusion,32,34,35 and parent vessel narrowing.36 Moreover, an uncontrolled inflammatory response can cause substantial neurologic damage, even in the presence of an unruptured aneurysm.23,26-29,32,35,37 Therefore, the risks of using non-autologous wrap material must be carefully considered against the risks of autologous wrap materials for treating aneurysms. For this patient, with the aneurysm’s medial aspect severely adherent to the falx cerebri, using the falx cerebri as wrap material was both time-efficient and practical.

For complex intracranial aneurysms, flow-diverting stents are a new alternative to endovascular coiling.38 Several strategies are available for intervention in aneurysms not amenable to direct clipping, especially fusiform aneurysms. Extracranial-intracranial and intracranial-intracranial cerebral artery bypasses allow for flow reversal, leading to proximal occlusion with or without trapping of the parent vessel while limiting postoperative symptomatic sequelae.39,40 When the parent artery cannot be sacrificed, reinforcement by wrapping is an alternative. This reinforcement prevents fragmentation of the internal elastic lamina and degeneration of the tunica media, decreasing the likelihood of aneurysm recurrence.41 Cellulose cotton sheets are commonly used, but granuloma and toxic neuritis have been reported in reaction to coarsely woven gauze.37,42-44 Additional artificial materials include Gore-Tex, silastic sheet, Teflon, and Dacron.45-47 Muscle, fascia, pericranium, or dura mater can be used as autologous wrap materials.19,48-50

Figure 9. Twelve-month digital subtraction angiography image showing stable clipping and good flow in the pericallosal and callosomarginal arteries. (A) Anteroposterior view. (B) Lateral view.

Figure 10. Lateral views of preoperative (A), postoperative (B), and 12-month (C) angiography showing no aneurysmal recurrence and good flow in both the pericallosal and callosomarginal arteries.
One case series by Kim et al. examined longitudinal outcomes following wrap-clipping with cellulose cotton fabric in 24 patients, 10 of whom had fusiform aneurysms. The authors reported that 87.5% had either healed or stable aneurysms at a 10- to 75-month follow-up. Another 9-patient series reported by Figueiredo et al. with 33% fusiform aneurysms at a 10- to 75-month follow-up. Another 54-patient series reported by Yagmurlu et al. with 33% fusiform aneurysms at a 10- to 75-month follow-up. Finally, Cudlip et al. explored wrap-clipping ruptured aneurysms and reported no rebleeding at 2-year mean follow-up.


Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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