Techniques and long-term outcomes of cotton-clipping and cotton-augmentation strategies for management of cerebral aneurysms

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OBJECTIVE To address the challenges of microsurgically treating broad-based, frail, and otherwise complex aneurysms that are not amenable to direct clipping, alternative techniques have been developed. One such technique is to use cotton to augment clipping (“cotton-clipping” technique), which is also used to manage intraoperative aneurysm neck rupture, and another is to reinforce unclippable segments or remnants of aneurysm necks with cotton (“cotton-augmentation” technique). This study reviews the natural history of patients with aneurysms treated with cotton-clipping and cotton-augmentation techniques.

METHODS The authors queried a database consisting of all patients with aneurysms treated at Barrow Neurological Institute in Phoenix, Arizona, between January 1, 2004, and December 31, 2014, to identify cases in which cotton-clipping or cotton-augmentation strategies had been used. Management was categorized as the cotton-clipping technique if cotton was used within the blades of the aneurysm clip and as the cotton-augmentation technique if cotton was used to reinforce aneurysms or portions of the aneurysm that were unclippable due to the presence of perforators, atherosclerosis, or residual aneurysms. Data were reviewed to assess patient outcomes and annual rates of aneurysm recurrence or hemorrhage after the initial procedures were performed.

RESULTS The authors identified 60 aneurysms treated with these techniques in 57 patients (18 patients with ruptured aneurysms and 39 patients with unruptured aneurysms) whose mean age was 53.1 years (median 55 years; range 24–72 years). Twenty-three aneurysms (11 cases of subarachnoid hemorrhage) were treated using cotton-clipping and 37 with cotton-augmentation techniques (7 cases of subarachnoid hemorrhage). In total, 18 patients presented with subarachnoid hemorrhage. The mean Glasgow Outcome Scale (GOS) score at the time of discharge was 4.4. At a mean follow-up of 60.9 ± 35.6 months (median 70 months; range 10–126 months), the mean GOS score at last follow-up was 4.8. The total number of patient follow-up years was 289.4. During the follow-up period, none of the cotton-clipped aneurysms increased in size, changed in configuration, or rebled. None of the patients experienced early rebleeding. The annual hemorrhage rate for aneurysms treated with cotton-augmentation was 0.52% and the recurrence rate was 1.03% per year. For all patients in the study, the overall risk of hemorrhage was 0.35% per year and the annual recurrence rate was 0.69%.

CONCLUSIONS Cotton-clipping is an effective and durable treatment strategy for intraoperative aneurysm rupture and for management of broad-based aneurysms. Cotton-augmentation can be safely used to manage unclippable or partially clipped intracranial aneurysms and affords protection from early aneurysm re-rupture and a relatively low rate of late rehemorrhage.

<http://thejns.org/doi/abs/10.3171/2015.7.JNS151165>

KEY WORDS cotton-clipping technique; cotton-augmentation technique; microsurgery; microsurgical clipping; cerebral aneurysm; ruptured aneurysm; unruptured aneurysm; subarachnoid hemorrhage; vascular disorders

ABBREVIATIONS ACoA = anterior communicating artery; CTA = CT angiography; GOS = Glasgow Outcome Scale.

SUBMITTED May 19, 2015. **ACCEPTED** July 15, 2015.

INCLUDE WHEN CITING Published online January 15, 2016; DOI: 10.3171/2015.7.JNS151165.

MICROSURGICAL management of broad-based, frail, or blister-like aneurysms may be particularly challenging due to their propensity to rupture intraoperatively, as well as the lack of an identifiable neck.^{14,15,35} Fusiform, dysplastic, and otherwise complex aneurysms may not be amenable to direct clipping and may require alternative management strategies.^{1,3,11,15–17,26,33,34,65} We have previously reported our experience with wrapping and clip-wrapping these types of aneurysms with cotton.^{15,35} However, our wrapping strategies have evolved over the past decade, and we now most frequently use Gore-Tex membrane (W. L. Gore & Associates, Inc.) when circumferentially wrapping unclippable aneurysms. We use cotton to augment clipping of segments of aneurysms that cannot be wrapped circumferentially due to the presence of perforators or aneurysms that cannot be clipped primarily.

We have previously used the “cotton-clipping” technique to manage intraoperative ruptures or tears in the aneurysm neck or parent vessel,^{2,42,60} as well as to bolster clipping in cases in which slippage of the clip is a risk.^{33,34} Furthermore, we have frequently used the “cotton-augmentation” technique to reinforce unclippable segments of an aneurysm or small remnants of aneurysm necks, the so-called dog-ears, between the parent vessel and the base of the clip.¹⁴ However, few reports are available on the long-term safety and angiographic durability of cotton-clipping strategies. We now report a contemporary series on the long-term clinical and radiographic follow-up of patients with aneurysms treated with cotton-clipping and cotton-augmentation techniques.

Methods

A database consisting of all patients with aneurysms treated at Barrow Neurological Institute between January 1, 2004, and December 31, 2014, was queried to identify all cases in which cotton-clipping or cotton-augmentation strategies were used. This retrospective review study was approved by the institutional review board of St. Joseph's Hospital and Medical Center, Phoenix, Arizona. Because of the retrospective nature of the review, the study was exempted from informed consent requirements.

Management was categorized as the cotton-clipping technique if cotton was used within the blades of the aneurysm clip (Videos 1 and 2) and as the cotton-augmentation technique if cotton was used to reinforce aneurysms or parts of aneurysms (so-called dog-ears) that were unclippable due to perforators, atherosclerosis, or unclipped aneurysm areas between the clip blades (Fig. 1, Video 3).

VIDEO 1. Video clip shows the cotton-clipping technique of a small, fragile, blister-like ACoA aneurysm. Because the ACoA is fenestrated, there is no concern about circumferential placement of cotton around the aneurysm and parent vessel. Copyright Barrow Neurological Institute. Published with permission. Click here to view.

VIDEO 2. Video clip shows a small, fragile, broad-based aneurysm that is clipped with the cotton-clipping technique to increase the surface area prior to clipping, as well as to avoid clip slippage and aneurysm neck or parent vessel tear. Copyright Barrow Neurological Institute. Published with permission. Click here to view.

VIDEO 3. Video clip demonstrates simple cotton-augmentation of

a basilar tip aneurysm to reinforce an unclipped, dog-ear residuum that was left to protect perforators that are especially important in this area. Copyright Barrow Neurological Institute. Published with permission. Click here to view.

We reviewed patient sex and age; side, size, and projection of the aneurysm; symptoms at presentation; treatment modalities; complications; and outcomes for each patient. The patients' clinical examinations and imaging studies, operative and angiographic reports, and inpatient and outpatient records were reviewed. Clinical outcome was based on chart review, clinic follow-up, and telephone interviews. Patients underwent conventional catheter angiography, CT angiography (CTA), or MR angiography to evaluate changes in the size or configuration of the aneurysms. Outcomes were measured using the Glasgow Outcome Scale (GOS). Annual rates of aneurysm recurrence or hemorrhage were determined by dividing the number of clinical events (aneurysm formation or hemorrhage) by the number of patient-years of observation for the population or particular subgroup.

Results

We identified 18 patients with ruptured aneurysms and 39 patients with unruptured aneurysms who had clinical and angiographic follow-up. Overall, 60 aneurysms in 57 patients (15 male, 42 female) were treated using cotton-clipping or cotton-augmentation strategies. Five patients had two aneurysms each and 7 had three or more aneurysms each. Of the 60 aneurysms treated, 23 were managed with cotton-clipping techniques (11 of these presented with subarachnoid hemorrhage) (Videos 1 and 2) and 37 with cotton-augmentation (7 of these presented with subarachnoid hemorrhage) (Table 1, Video 3). There were 20 small fragile, blister-like, or broad-based aneurysms; 17 saccular aneurysms; 9 atherosclerotic or calcified aneurysms; 8 giant or complex dysmorphic aneurysms; and 6 dissecting or fusiform aneurysms (Fig. 1). Most aneurysms were in the anterior circulation (Table 1, 57 aneurysms), and the orbitozygomatic and pterional approaches were most commonly used for management of these aneurysms (Table 2). The mean age of patients was 53.1 years (median 55 years; range 24–72 years). The mean length of hospital stay for patients with unruptured aneurysms was 8.5 days (median 4 days; range 1–28 days), and the mean length of hospital stay for patients who presented with ruptured aneurysms was 14.8 days (median 12 days; range 10–37 days). Among patients with ruptured aneurysms, 14 (77.8%) required external ventricular drain placement and 7 underwent permanent shunt placement. One patient with an unruptured aneurysm required a ventriculoperitoneal shunt. Complications developed in 7 patients, including 6 who were treated for pneumonia or respiratory failure and 1 who developed a subdural hematoma that required evacuation postoperatively. There were no deaths or worsening of neurological status postoperatively. The mean GOS score at the time of discharge was 4.4 and the mean GOS score at the time of last follow-up was 4.8. Patient outcomes by treatment group are shown in Table 3. The mean follow-up was 60.9 ± 35.6 months (median 70 months; range 10–126 months). Patient follow-up years totaled 289.4. One patient treated

FIG. 1. Illustrations demonstrate various operative scenarios where cotton-clipping (A, B, F) or cotton-augmentation (C, D, E) can be used. Cross sections indicate the position of the clip and cotton. **A:** In case of a tear in the parent vessel or aneurysm neck, cotton can be used to cover and control the bleeding while applying suction and tamponading; the clip is applied to the cotton and the tear site. **B:** Cotton may be used to clip blister aneurysms. This increases the surface area and helps hold the clip, preventing parent vessel stenosis. **C:** Cotton-clipping and cotton-augmentation can be useful in cases of atherosclerotic, calcified vessels and aneurysm necks. Cotton may be used to prevent clip slippage and to augment unclippable aspects of the aneurysm neck. **D:** Cotton can also be used to augment unclippable wall changes in case of fusiform, dolichoectatic vessels that involve the entire vessel wall circumferentially. **E:** Cotton-augmentation can also be applied to unclippable dog-ear residua that must be left to protect perforators. **F:** Cotton-clipping can be applied to broad-based aneurysms to prevent clip slippage and parent vessel stenosis. Copyright Barrow Neurological Institute. Published with permission.

with cotton-augmentation sustained a rehemorrhage and 2 showed enlargement of their aneurysms on angiographic follow-up. All patients underwent subsequent successful management as outlined below. Thus, for all patients with aneurysms that were managed with either cotton-clipping

or cotton-augmentation techniques, the overall risk of hemorrhage was 0.35% per year and the annual recurrence rate was 0.69% for the entire study population. Additional details on the 2 subpopulations (cotton-clipping and cotton-augmentation) are provided below.

TABLE 1. Aneurysm location

Aneurysm Location	No. of Patients (%)		
	Aneurysms	Cotton-Clipped Aneurysms	Cotton-Augmented Aneurysms
Internal carotid artery	7 (11.7)	5 (21.7)	2 (5.4)
Posterior communicating artery	9 (15.0)	4 (17.4)	5 (13.5)
Ophthalmic artery	7 (11.7)	1 (4.3)	6 (16.2)
Middle cerebral artery	14 (23.3)	5 (21.7)	9 (24.3)
ACoA	11 (18.3)	4 (17.4)	7 (18.9)
Pericallosal artery (A ₂ /A ₃ segment)	6 (10.0)	2 (8.7)	4 (10.8)
Basilar artery	2 (3.3)	1 (4.3)	1 (2.7)
Posterior inferior cerebellar artery	2 (3.3)	1 (4.3)	1 (2.7)
Posterior cerebral artery (P ₁ /P ₂ segment)	1 (1.7)	0 (0.0)	1 (2.7)
Superior cerebellar artery	1 (1.7)	0 (0.0)	1 (2.7)
Total	60 (100)	23 (99.8)*	37 (99.9)*

* Total of percentages is < 100% due to rounding.

Cotton-Clipped Aneurysms

The average follow-up for patients treated with cotton-clipping was 4.1 years. Focusing only on cotton-clipped aneurysms, the corresponding observation time is 96.1 patient-years. During the follow-up period, no aneurysm that was managed with a cotton-clipping technique increased in size or changed in configuration. There were no recurrent hemorrhages in this subgroup.

Cotton-Augmented Aneurysms

There were no deaths or worsening of neurological status in patients with aneurysms who were treated with cotton-augmentation techniques. None of these patients experienced early rehemorrhage or recurrence. Two patients who were treated with partial clipping and cotton-augmentation techniques had recurrences. One patient with a cotton-augmented, small, broad-based aneurysm sustained a rehemorrhage.

The patient who experienced rebleeding had initially presented with a ruptured, small, friable, broad-based anterior communicating artery (ACoA) aneurysm that was clipped and augmented with cotton. She then had a rehemorrhage 8 years after the initial aneurysm rupture. This patient initially presented with diffuse subarachnoid hemorrhage; however, at the time of the second hemorrhage, the patient had a localized frontal lobe hematoma. A recurrent aneurysm just adjacent to the previous clip site was detected on angiographic evaluation (Fig. 2). The aneurysm

was re-explored and again successfully clipped with cotton-augmentation of the ACoA. She remained without any neurological deficits at the time of her last follow-up, 10 years after the initial hemorrhage and 2 years after the second. On follow-up, digital subtraction angiography showed no change in the aneurysm's size or configuration 2 years after the second clipping.

The first patient with a recurrent cotton-augmented aneurysm initially presented with a complex right ophthalmic artery aneurysm and visual loss. The patient underwent an orbitozygomatic craniotomy and aneurysm clipping with 2 aneurysm clips and cotton reinforcement. Two years later, on catheter angiographic follow-up evaluation, the aneurysm was found to have increased in size and the patient underwent stent-assisted coil embolization. Again, 2 years after the endovascular procedure, the aneurysm was found to have changed in size angiographically and a pipeline embolization device was placed. One year after placement of the pipeline embolization device, she became pregnant and underwent successful delivery by cesarean section. Two years after her most recent treatment and 8 years after her initial clipping, she remains neurologically intact and the aneurysm remains completely obliterated on angiographic follow-up.

The second patient whose aneurysm recurred after clipping and cotton-augmentation was a woman who was incidentally found to have an unruptured, broad-based ACoA aneurysm with perforators originating from the base of the aneurysm. She underwent a right-sided orbitozygomatic craniotomy for partial clipping and cotton reinforcement to protect the perforators. The small residual aneurysm was followed with serial imaging, which showed an increase in size of the aneurysm 6 years after her initial surgery. She underwent microsurgical clipping of this lesion. During the surgery, the aneurysm recurred at a segment close to the previously clipped segment on the dorsal aspect of the aneurysm where there was no cotton. The recurrent segment was clipped with a second aneurysm clip. The patient remains neurologically intact and the aneurysm remains completely obliterated at 12-month angiographic follow-up.

TABLE 2. Surgical approach

Surgical Approach	No. of Cases
Orbitozygomatic	27
Pterional	18
Interhemispheric	6
Far lateral	4
Other	2
Total	57

FIG. 2. Axial CT and angiographic images show the sequence of events in a patient with recurrent hemorrhage. The patient presented initially with diffuse subarachnoid hemorrhage as seen on a CT scan (**A**). Using CT angiographic evaluation (**B**), a friable, small, broad-based ACoA aneurysm was seen as the source of the hemorrhage (arrow) and was clipped. Eight years after the initial aneurysm rupture, the patient presented with rehemorrhage and CT showed a localized frontal lobe hematoma (**C**). An aneurysm recurrence just adjacent to the previous clip was noted on CT scan (**D**, arrow). This aneurysm was successfully reclipped (**E**) and cotton was placed around the ACoA.

For only the cotton-augmentation procedures, the average follow-up was 5.6 years and the corresponding observation time was 193.3 years. Given the 3 events (1 rebleeding aneurysm and 2 recurrences), the risk of rehemorrhage for partially clipped and cotton-augmented aneurysms was 0.52% per year and the recurrence rate for these aneurysms was 1.03% per year (Table 3).

Discussion

Reinforcing Aneurysm Walls

The need for follow-up data to evaluate the safety and efficacy of various treatments in the management of intracranial aneurysms has become increasingly important.^{66,68} Given this concern, our study was designed to determine the natural course of cotton-clipped and partially clipped cotton-augmented aneurysms. Histological examination of recurrent aneurysms has shown that arterial wall thinning

and disruption of both the muscle layer and the internal elastic lamina may lead to local frailty of the arterial wall adjacent to the clipped aneurysm and may be the cause of the formation or recurrence of an aneurysm.^{19,20,24,31,50} Reinforcement of the residual neck and abnormal arterial wall is thought to lower the incidence of aneurysm recurrence.^{19,20,31,54} Several previous reports indicate that aneurysms can recur from residual aneurysm fragments, and even from apparently well-clipped aneurysms,^{14,32,47,68,69} and early reports stress the value of microsurgical reinforcement of incompletely obliterated aneurysm walls.^{16–18,57,67,71} The associations between various reinforcement materials and different rates of recurrence and postoperative bleeding have also been reported.^{12,13,15,18,26,27,40,51,52,54,55,59,61} In histological as well as clinical studies, cotton has been found to be the most effective reinforcement material.^{19,31,59} However, several reports have described complications associated with wrapping modalities, such as cranial neuropathy

TABLE 3. Results for 57 patients treated with cotton-clipping and cotton-augmentation strategies

Measures	Cotton-Clipped Aneurysms (n = 23)	Cotton-Augmented Aneurysms (n = 37)	Total Aneurysms (n = 60)
Mean follow-up (years)	4.1	5.6	5.1
Follow-up (patient-years)	96.1	193.3	289.4
Annual recurrence rate (%)	0	1.03	0.69
Annual hemorrhage rate (%)	0	0.52	0.35

and parent vessel stenosis.^{4–10,12,22,25,29,30,36–38,41,43,45,49,56,58,72} Therefore, we use cotton cautiously for circumferential wrapping of intracranial vessels. Cotton-evoked chronic inflammation, fibrosis, and granuloma formation of the adventitia may even be desired in select cases, such as in the treatment of fusiform aneurysmal dilations and aneurysm segments that cannot be completely clipped. We use small wisps of cotton and usually avoid circumferential wrapping of major vessels or placing cotton in contact with adjacent cranial nerves. In our follow-up of patients treated with cotton-clipping or cotton-augmentation, we have not encountered any complications such as vessel stenosis or cranial neuropathy.

Utility and Techniques of Cotton-Clipping and Cotton-Augmentation

The risk of regrowth of completely clipped aneurysms has been found to be much lower than the risk of de novo aneurysm formation (0.26% vs 0.89% annually).⁶⁸ The cumulative incidence of recurrent subarachnoid hemorrhage after clipping is approximately 3% within the initial 10 years after treatment, which emphasizes the reliability of clipping.^{62,68,70} However, not all aneurysms can be clipped completely. Unclippable or partially clippable aneurysms may present in various configurations. The most common variant that we have encountered is the small, fragile aneurysm without an adequate reconstructable neck. These broad-based aneurysms can be augmented with small wisps of cotton around the aneurysm base if complete clipping is not feasible (Fig. 1). Furthermore, when clipping this type of aneurysm, the challenge is to incorporate the dome of the aneurysm into the clip without compromising the lumen of the parent vessel. The wide base of the aneurysm and the small size of the dome make direct clip placement complicated and the clip may slide off, causing tears in the vessel wall or the aneurysm neck. In these cases, a piece of cotton is placed on the aneurysm or wrapped around the site of the aneurysm on the parent vessel (Videos 1 and 2); then the aneurysm is clipped over the cotton (Fig. 3). We have also used this cotton-clipping technique to treat a variety of saccular aneurysms.

Intraoperative rupture cannot be completely avoided in aneurysm surgery, especially in patients undergoing repair of ruptured aneurysms,^{21,60} and it has been shown that the occurrence of this complication does not diminish even as the experience of the neurosurgeon performing the surgery increases.⁴⁴ Several reports have described important measures taken to control intraoperative aneurysmal rupture, including proximal and distal control for temporary clipping prior to aneurysm dissection, tamponade, suction, performing surgery with or without hypotension, and cerebral protection with hypothermia or pharmacological agents.^{28,44,46,63,64} In the event of an intraoperative rupture, free cotton applied to a bleeding site will tamponade the hemorrhage and provide a larger surface area where suction can be applied to facilitate visualization and clip placement. The cotton-clip construct acts as a durable bolster, which is located far enough distally on the neck to maintain patency of the parent vessel lumen (Fig. 1). We previously described the cotton-clipping technique;^{2,42,60}

FIG. 3. Preoperative axial CT (A), axial CTA (B), and sagittal CT (C) images obtained in a patient with a ruptured, very small, broad-based, blister-like ACoA aneurysm. An intraoperative microsurge image shows a small, broad-based, and very fragile aneurysm (D) of a fenestrated ACoA segment. The small size of the dome makes direct clip placement very intricate and increases the risk of the clip sliding off the aneurysm wall and causing tears in the parent vessel wall or the aneurysm base. Therefore, cotton is wrapped around the site of the aneurysm (Video 1) and the aneurysm is successfully clipped over the cotton (E, arrow). Cotton is used in this case because the fenestrated ACoA segment is too small and tight to accommodate a Gore-Tex wrap. The risk of parent vessel stenosis due to circumferential cotton wrap is acceptable in this case because of a fenestrated redundant ACoA complex. Postoperative CTA (F, axial; G, sagittal) shows complete obliteration of the small aneurysm (arrows) without any compromise of the flow in the A₂ segments (G).

however, the current study is the first long-term series verifying its durability. There were no recurrences or complications, such as parent vessel stenosis, using the cotton-clip technique in 23 patients with long-term follow-up in our series. Fusiform aneurysms are usually best treated with clip-wrapping techniques.^{3,15} However, fusiform and

FIG. 4. Preoperative coronal (A) and sagittal (B) CTA images, digital subtraction angiogram (C), and 3D (D and E) angiographic images show a large ACoA aneurysm. The aneurysm dome is clip-reconstructed with 2 aneurysm clips using a tandem-clipping technique (F–I). There is an unclipped remnant at the base of the aneurysm (F–I, arrows) to protect a small perforating branch (F and G, arrowheads) best seen on the 3D reconstructions.

dissecting aneurysms, especially in the posterior circulation, are frequently difficult to manage with clip-wrapping techniques due to the significant likelihood of perforator involvement as well as the depth of the corridor of exposure (Video 2).¹⁵ These aneurysms can also be augmented with wisps of cotton placed around the diseased segment when circumferential wrapping with Gore-Tex is not possible (Video 3). Furthermore, clip-reconstruction and cotton-augmentation of residual aneurysms can be performed when perforators are incorporated into the aneurysmal segment or for aneurysms with heavy calcifications that prevent complete clipping (Fig. 4).

Rates of Recurrence and Rebleeding in Residual Aneurysms

Late re-rupture after treatment of ruptured intracranial aneurysms with either coil embolization or surgical clipping is rare.³² However, early re-rupture within the 1st year of treatment occurs more frequently and has major consequences.³² In the Cerebral Aneurysm Rerupture After Treatment (CARAT) study, the overall risk of re-rupture in the 1st year after treatment was found to be 1.8%.³² Similarly, the International Subarachnoid Aneurysm Treatment (ISAT) trial found a 1.7% risk of re-rupture in the 1st year.⁵³ Several studies have suggested that subtotal occlusion of an aneurysm either with a surgical clip or with coils is associated with a significantly higher risk of subsequent hemorrhage compared with complete occlusion.^{14,32} Overall, the incidence of residual aneurysms after clipping is estimated to range between 4% and 18%.^{14,32,39,48,68,69} Although some residual aneurysms may undergo spontaneous thrombosis, others may enlarge and cause recurring hemorrhage.^{14,23,68,70} The reported risk of hemorrhage from an aneurysm residuum varies and, depending on the location and the size of the remnant, is between 3.5% and 28%.^{14,23,32,39} However, even complete aneurysm occlusion does not guarantee prevention of re-rupture, and the risk of re-rupture for completely occluded aneurysms may be as high as 1.1% during the 1st year.³² The overall annual recurrence and hemorrhage rates of cotton-augmented, incompletely clipped aneurysms in the current series (0.52% and 1.03%, respectively) are much lower than our previously reported risk of recurrence from an aneurysm residuum of 2.9% per year, as well as risk of hemorrhage from an aneurysm remnant of 1.5% per year.¹⁴

Furthermore, it must be stressed that in the current series the only recurrent subarachnoid hemorrhage was encountered in a patient with a small broad-based aneurysm. We recognized previously that these aneurysms may constitute a completely separate subtype with a higher risk of recurrent hemorrhage.^{14,35} In the current series with 20 such broad-based aneurysms and mean follow-up of approximately 5 years, the patients had no rebleeding episodes or parent vessel stenoses when the cotton-clipping technique was used and only one late rebleed (5%) when clipping and cotton-augmentation were used. Our prior experience with clip ligation of these broad-based aneurysms without the use of cotton showed a much higher annual recurrence rate (19%).¹⁴ Although our study indicates that cotton can be used safely and without complications, it remains to be determined whether cotton-augmentation truly changes the natural history of aneurysm remnants. Nevertheless, given that incomplete aneurysm occlusion is a strong predictor of risk of re-rupture, with most re-ruptures occurring during the 1st year after treatment and especially during the first days after aneurysm obliteration,^{8,32} our study suggests that cotton-augmentation may provide a degree of protection reducing the risk of early re-rupture from aneurysm remnants.

Limitations

The retrospective nature of this study limits the strength of our conclusions. The median follow-up period for our

patients was 70 months, which is still inadequate to determine the true long-term benefits of this technique. Several studies have shown that the risk of re-rupture may remain for several decades after treatment.^{69,70} The use of cotton is a bailout strategy for difficult-to-treat aneurysms and no prior study has looked at the long-term outcome of these patients. Direct comparisons between the outcomes of patients treated with this technique and historical controls would be very difficult given that these techniques are applied to a very select and challenging subset of lesions.

Despite the well-known inherent shortcomings of retrospective studies, we believe that our experience suggests several conclusions.

Conclusions

Cotton-clipping for the treatment of aneurysms is a safe and durable technique without acute or delayed postoperative complications. Cotton-clipping is especially effective for managing intraoperative rupture of an aneurysm neck and for managing broad-based aneurysms without an adequate reconstructable neck. Cotton-augmentation can be safely used to manage unclippable or partially clippable intracranial aneurysms and provides promising protection from early aneurysm re-rupture. It remains to be determined whether cotton-augmentation provides protection from growth and late subarachnoid hemorrhage of an unclipped aneurysm remnant. The overall rates of regrowth and re-rupture were relatively low in this series.

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Disclosures

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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Conception and design: Safavi-Abbasi. Acquisition of data:

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Supplemental Information

Videos

Video 1. <https://vimeo.com/140797220>.

Video 2. <https://vimeo.com/140797221>.

Video 3. <https://vimeo.com/140797219>.

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