Surgical Clipping of Previously Ruptured, Coiled Aneurysms: Outcome Assessment in 53 Patients

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Abstract

Background: Occasionally, previously coiled aneurysms will require secondary treatment with surgical clipping, representing a more complicated aneurysm to treat than the naïve aneurysm. Patients of this group who initially presented with a ruptured aneurysm may pose an even riskier group to treat than those with unruptured previously coiled aneurysms, given their potentially higher risk for re-rupture.

Objective: To assess the clinical outcomes of patients who undergo microsurgical clipping of ruptured previously coiled cerebral aneurysms. In addition, we present a thorough review of the literature.

Methods: A total of 53 patients were studied from a single institution who initially presented with a subarachnoid hemorrhage (SAH) and underwent surgical clipping of a previously coiled aneurysm between December 1997 and December 2014. Clinical features, hospital course, as well as pre-operative and most recent functional status (Glasgow outcome scale (GOS) score) were reviewed retrospectively.

Results: The mean time interval from coiling to clipping was 2.6 years and mean follow-up was 5.5 years (Range .1 – 14.7 years). Five patients (9.8%) presented with re-bleed prior to clipping. The majority of patients (79.3%, 42/53) experienced good neurologic outcomes. Most showed “no change” (81%, n=43/53) or “improvement” (13%, n=7/53) in functional status following microsurgical clipping. One patient (2%) deteriorated clinically and there were 2 (4%) mortalities.

Conclusions: Microsurgical clipping of previously ruptured, coiled aneurysms is a promising treatment method with favorable clinical outcomes.

Introduction

Following the introduction of the Guglielmi detachable coil (GDC; Boston Scientific/Target Therapeutics, Fremont, CA) in 1990, endovascular coiling of intracranial aneurysms has become the most widely used modality for cerebral aneurysm treatment in just a short span of time.^{1,2} Compared to microsurgical clipping (the once solely offered treatment), endovascular coiling provided a new, minimally invasive alternative associated with lower initial morbidity and mortality rates and shorter hospital stay.²⁻⁷ However, endovascular coiling has been shown to have greater risk for aneurysm recurrence, aneurysm remnant, and rebleeding.^{4-6,8-16} Based on earlier rates, is estimated that up to 20% of coiled aneurysms recur and necessitate additional treatment, although recently more sophisticated technology including stent-assisted coiling and pipeline stents have come out.^{4,6,7,17-19} Certain known risk factors associated with aneurysm recurrence after coiling include aneurysm size > 8mm, wide neck, low aspect ratio (the maximum dimension of the dome/the width of the neck of the aneurysm), posterior circulation aneurysms, smoking, patient age < 52 years, and ruptured aneurysms.^{12,20,21}

As the number of patients presenting with recurrence of previously coiled aneurysms has increased over the years, so has the demand for an evidence-based strategy for treating these complex lesions. In particular, clinicians seek strategies for identifying whether certain indications favor microsurgical clipping over repeat endovascular coiling.^{19,22,23} However, with only a limited amount of available data directly comparing the two treatments for recurrent previously coiled aneurysms, neither have been shown to be superior to one another.^{19,22,23}

Re-embolization is often considered first when contemplating treatment for a recurrent or residual previously coiled aneurysm because this procedure is thought to result in lower perioperative morbidity and mortality rates as well as lower peri-procedural complications.^{4,10,22,24-30} Nevertheless, aneurysm re-embolization comes with its own risks of coil compaction, shifting, malformation, extrusion and protrusion, as well as aneurysm residual, regrowth and rupture, peri- and post-operatively. For instance, Dorfer et al. (2012) reported that a single re-embolization of previously coiled aneurysms demonstrating regrowth was successful in only 14.3% of cases, and this same group of patients had a 9.3% perioperative morbidity.¹⁰ In addition, Johnston et al. (2008) found that overall risk of aneurysm rerupture was greater after re-coiling a previously coiled aneurysm as compared to clipping a previously coiled aneurysm.⁴

Alternatively, when open surgery is selected to treat a previously coiled aneurysm, certain issues need to be considered. Various abnormalities arising from the coil mass may make it more difficult to attain full occlusion of the aneurysm. If the neck is not available due to minimal recurrence, incomplete compaction, or coil extrusion, surgical clipping of the aneurysm becomes extremely difficult. This effect may significantly compound the risk for re-rupture, especially intraoperative rupture, in patients who initially presented with a ruptured aneurysm as these aneurysms are already at an increased risk for rupture.³¹ In light of this and conflicting results from different studies favoring open and endovascular treatments (Slob et al. 2004; Kang et al. 2006; Dorfer et al. 2012), a need exists for more information on clinical outcomes for this particular subgroup of patients.^{10,26,32}

In this study, we assessed the outcomes of a consecutive series of patients with a previously coiled aneurysm who presented with SAH and underwent clipping after a return to medical attention with aneurysm recurrence or residual.

Methods

Study Design

This retrospective case series study was performed in compliance with Health Insurance Portability and Accountability Act regulations and was given approval by the Institutional Review Board of the academic medical institution, including waiving consent for accessing medical charts. The prospective database of the senior author (M.T.L.) was queried for patients who underwent microsurgical clipping of a cerebral aneurysm after a previous coiling at single tertiary medical center in the United States. Medical and operative records, preoperative and postoperative images, angiographic data (including location, size, and type of aneurysm), and the hospital course were reviewed retrospectively.

Patient Population

Between December 1997 and December 2014, a total of 73 patients with a previously coiled aneurysm were surgically treated by the senior author (M.T.L.). After excluding patients who were not treated solely with microsurgical clipping (wrapping n=5; bypass n = 8; trapping n=1) or did not initially present with subarachnoid hemorrhage (SAH) prior to coiling (n=6), 53 patients were included in the study (**Figure 1**).

Patient demographics, aneurysm location, residual or recurrent aneurysms, size, if intraoperative coil extraction occurred, coil compaction, and hospital course including surgical and medical complications as well as functional status (Glasgow Outcome Scale (GOS) score) prior to surgery, and at the time of most recent follow-up were recorded. Outcomes were defined as ‘improved’ in patients who experienced an increase in GOS score from presentation to time of most recent follow-up, “no change” in patients the same GOS score, and “worsened” in patients whose GOS score decreased. Aneurysm sizes were categorized into three different size ranges based on the maximum dome size: (1) small (<10mm), (2) large (10-25mm), and (3) giant (>25mm), a classification system used in previous cerebral aneurysm studies.³³⁻³⁵ Residual aneurysms were defined as those with blood flow within the aneurysmal sac following endovascular treatment confirmed by angiography and recurrence as aneurysms with confirmed aneurysm obliteration that then showed a return of blood flow within the aneurysmal sac at a later date. Recurrence included renewed patency of flow due to either coil compaction or aneurysm growth, both of which were recorded by comparing aneurysm size from previous imaging. GOS scores prior to surgery and at follow-up were assigned by practitioners not directly involved in patient care.

Results

Fifty-three patients with 53 previously coiled intracerebral aneurysms met criteria for inclusion in the study. The median age of patients was 50 years (Range 4-74 years), 86.8% (n=46) of whom were female. The proportion of residual versus recurrent aneurysms was nearly equal in our series (28 vs. 25, respectively). Five patients (9.4%) experienced re-bleed from the time of endovascular bleeding to surgical clipping. The mean time interval from coiling-to-clipping was

2.6 years (Range .1 - 17 years) (**Table 1**). The mean time of post-operative follow-up was 5.5 years (Range .1 – 14.7 years).

There were 34 aneurysms located in the anterior circulation (64.2%), with the most common locations being the anterior communicating artery (n=17, 32.1%), posterior communicating artery (n=11, 20.8%), middle cerebral artery (n=7, 13.2%), and pericallosal artery (n=5, 9.4%). Other locations included the basilar artery (n=3, 5.7%), ophthalmic artery (n=2, 3.8%), posterior inferior cerebellar artery (n=2, 3.8%), posterior cerebral artery (n=2, 3.8%), superior cerebellar artery (n=2, 3.8%), anterior choroidal artery (n=1, 1.9%), internal carotid artery (n=2, 3.8%).

Aneurysms averaged 9.2 mm (Range 3 to 26 mm) in size; the most frequent size category being <10 mm (65.4%), then 10-25 mm (32.7%), and >25 mm (1.9%). One patient did not have aneurysm size available during data collection. Despite all the patients initially presenting with SAH prior to coiling, the median patient GOS score prior to clipping presentation was still 5 (n=38, 71.7%). All but 3 aneurysms were completely occluded with clipping, which were shown to have residual flow on follow-up. The patient and aneurysm characteristics of this group are listed in **Table 2**. At the time of most recent follow-up, no aneurysms had required further treatment. Ten aneurysms (18.9%) required extraction of the coils for successful clipping. Of the 25 recurrent aneurysms, 14 (56%) were the result of coil compaction while the remainder was caused by aneurysm growth. These patients were noted for having the easier clip placement through available access underneath the coil mass at the neck.

The majority of patients (79.3%, 42/53) experienced good neurologic outcomes,

showing “no change” (81.1%, n = 43/53) or “improvement” (13.2%, n = 7/53) in neurologic status following surgical treatment, as measured by GOS scores (**Figure 2**). The pre-operative GOS scores for patients who improved were the following: 4 (57.1%) had a GOS of 2, 1 (14.2%) had a GOS of 3, and 2 (28.6%) had a GOS of 4. Additionally, 4 (57.1%) of these patients were taken back immediately following coiling. Follow-up ranged from 2 - 14.7 years (mean=6.9 years) in this group. Deterioration was observed in 3 patients: “worse” (1.9%, n=1/53) and “death” (3.8%, n=2/53) (**Table 3**). Of the 14 patients who presented with compacted coils, 13 (92.9%) had “no change” and 1 (7.1%) had “improvement” as their outcome.

Twelve patients (22.6%) did suffer perioperative complications following treatment (**Table 4**). Four (7.5%) developed new sensory deficits, 2 (3.8%) post-operative wound infections, 1 transient dysphagia (n=1, 1.9%), 1 a scalp hematoma (n=1, 1.9%), 1 significant temporal muscle atrophy (n=1, 1.9%), and 1 vasospasm (n=1, 1.9%). Two patients (n=3.8%) developed post-operative hydrocephalus and required ventriculoperitoneal shunting.

Of the two patients who died in this series, neither were related to intraoperative complications. Both presented with a SAH and were in a vegetative state prior to treatment. Endovascular coiling was attempted but complete obliteration could not be achieved, at which point they were referred for surgical clipping. One of these patients experienced rebleed preoperatively and was emergently taken back for surgery. The other was taken to surgery after attempted coiling without rebleeding, but her post-operative course was also complicated by vasospasm. Neither patients experienced meaningful neurological recovery and care was withdrawn. The third

patient in this series who worsened in neurologic status monocular vision loss following clip placement.

Case Illustration

A 55-year old female with a Hunt and Hess Grade 3, Fisher Grade 4 presented with a recurrent previously coiled giant anterior communicating aneurysm (ACom). Given her previous failure of endovascular coiling due to recurrence and the large size of the aneurysm, she was taken back for microsurgical clipping. After locating the optic carotid triangle through a transylvanian approach, bilateral A1 anterior cerebral arteries (ACA) were identified and temporary clipped (**Figure 3A**). The giant, posteriorly-directed ACom aneurysm was clipped with a temporary 45-degree angle, long-bladed fenestrated clip, occluding blood flow through the giant aneurysm at the neck (**Figure 3B**). A thrombectomy was performed during surgery to soften the aneurysm while leaving the coils in place using an ultrasonic aspirator (**Figure 3C**). Then a permanent straight fenestrated clip was placed adjacent to the superior edge of the temporary clip (**Figure 3D**), followed by final a closing clip to close the fenestration. The temporary clips were subsequently removed, successfully returning patency to the bilateral A1 ACAs and ACom (**Figure 3E**).

Discussion

To date, this single-center, single-surgeon case series is one of the largest published studies looking at clinical outcomes of patients who underwent microsurgical clipping of previously coiled aneurysms. The results of the present study show that microsurgery is an acceptable management choice for previously coiled aneurysms that initially presented with rupture prior to

coiling. This group represents a heterogeneous group of patients with complex aneurysms that failed previous treatment of endovascular coiling due to either recurrence or residual patency and were then selected for surgical clipping.

The majority of our patients (94%) had no change or improvement from their preoperative functional status, and complete occlusion via surgical clipping was achieved in 94.3% (50/53) of patients. In the group of patients who did improve, this was likely related to the normal recovery process following the immediate neurologic impairments caused by an acute intracranial hemorrhage, as 4 patients from this group were taken directly back from coiling to the operating room after initially presenting with SAH. In the acute setting, transient neurological impairment can be caused by a number of factors, including hydrocephalus, perihematomal ischemia, perihematomal edema, and seizures.³⁶ In the other, less acute patients, it is also possible long term recovery from the initial SAH allowed for a regaining in functional status. Research has indicated healing properties exist within the brain following a stroke, occurring through the reorganization of neural synapses, the sprouting of new connections, and the migration of neural cells into the periinfarct cortex.^{37,38} Given these recovery processes following a stroke may continue for an extended period of time after the stroke, the follow-up spanning multiple years (Range 2 – 14.7 years) in this group further supports this as a possibility.³⁸

Our findings are in keeping with previous studies reporting on the results of microsurgical clipping of previously coiled aneurysms with 81.8% (18/22) citing good outcomes or ‘improvement or no change in neurological status’ following microsurgical clipping in 80% or

more of their patients. Among these 25 studies spanning 772 patients, the combined mortality rate was 4.1% with 24 deaths out of the 581 reported outcomes (**Table 5**).^{6,10,18,19,22,24,25,39-56}

Previous studies on the management of previously coiled aneurysms

In previous reports, the majority of patients who underwent microsurgical clipping of a previously coiled aneurysm had “no change” or an “improved” outcome.^{6,10,18,19,22,24,25,39-56}

Currently, the largest prospective series of subjects who underwent clipping of previously coiled aneurysms is the International Subarchnoid Aneurysm Trial (n=191), but it does not provide outcomes for this particular subset-group.⁶ As such, Dorfer et al. (2012), Romani et al. (2011), and Owen et al. (2015) remain the largest retrospective studies that report patient outcomes for this population (n=105 and n=81 and n=73, respectively).^{10,19,51} All three report high rates of good outcomes (90% and 88% and 89%, respectively), and conclude clipping previously coiled aneurysms is a safe method of treatment. However, Daou et al. (2012) does not allow for appreciation of change neurological status following treatment, as pre-operative neurologic status was not recorded. Owen et al.’s (2015) series does not include strictly clipping, but also trapping and bypass in its results, as does Romani et al. (2011). None of the studies analyzed patients specifically with initial SAH presentation prior to coiling; a riskier group known to be more prone to re-rupture, including intraoperative rupture.^{4,6,31,59} Additionally, both Romani et al. (2011) and Daou et al. (2012) provide patient series treated from multiple surgeons and or from multiple institutions, as opposed to our single-center, single-surgeon (M.T.L) series.

Although, this may be beneficial by having reduced surgeon expertise bias, it simultaneously introduces risk for other confounding factors such as selection bias.

Present study

Clipping previously ruptured, coiled aneurysms proves to be a safe and reliable treatment. Although previously ruptured aneurysms may be more prone to re-rupture, our results show that they do not appear to have a noticeable effect on outcomes in our series.^{4,6,59} Overall patients responded well to the treatment, with all but 3 patients showing an improvement or no change in neurologic status. Therefore, the critical conclusion from the present study would be that this particular subpopulation of previously coiled aneurysms, may have a favorable long-term outcome with aggressive open surgical clipping. Yet this population is not immune from post-operative complications. New sensory deficits and wound infection (7.5%), hydrocephalus (3.8%), and death (3.8%) most commonly occurred. Careful consideration into the cost-benefit of treatment versus the risk of future rupture should be taken.

The Technical Challenges of Clipping Ruptured Previously Coiled Aneurysms

When tackled microsurgically, previously coiled aneurysms take on a distinct character unique from other aneurysms. With platinum coils located in the lumen, the aneurysm can be stiff, non-compressible, and have an irregular hemodynamic profile. Often, they are more resistant to manipulation, which can be especially challenging to treat in narrowly accessed anatomical corridors.^{2,48,60} The presence of SAH further compounds these challenges, reducing visibility of adjacent cisterns and vital structures. In some cases, coils extend out of the aneurysm and into the parent vessel, and in these instances, clip blades may slide down to the tip of these coils, encroaching on the lumen of the parent vessel and compromising its blood flow. If extruding coils are present, it is typically recommended to leave them in place as much as possible unless extraction is necessary for aneurysm occlusion.^{24,39,41,42,49,61} Partial extraction including

performing a simple opening of the aneurysmal sac, is advocated over complete removal of the coils. This may require the use of temporary clips, which can also add to surgical risk. Ten (19%) of the aneurysms in this study required manipulation of coils prior to successful clipping. Alternatively, 14 (26%) of the aneurysms in this study were noted to have tightly compacted coils and were all easily clipped without manipulation, indicating that a careful analysis of preoperative coil morphology can be beneficial for preoperative planning and risk assessment.

Limitations and Future Directions

A major limitation of this study is its retrospective design, creating the possibility for inaccurate data collection and selection bias. Second, the data analyzed are those of a single surgeon who performs a high volume of aneurysm surgeries, and this potentially undermines the reproducibility of our results in centers with less open aneurysm surgery experience. Third, patient outcomes were measured using the crude GOS, possibly masking more subtle differences in patient outcomes. The fact that only 3 of 53 patients in this case series had a “worse” outcome made any statistical analysis between patient outcomes not feasible. Ideally, large prospective clinical trials comparing surgical and endovascular treatments for previously coiled aneurysms will be performed in the future.

Conclusion

Microsurgery is an acceptable management choice for previously coiled aneurysms that originally presented with rupture. The majority of patients show improvement or no change in clinical outcomes post microsurgical clipping of previously coiled aneurysms.

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Figures

Figure 1. Patient Selection for Study Inclusion.

Figure 2. Patient GOS Score Prior-to and Post-Microsurgical Clipping.

Figure 3. Case illustration of microsurgical clipping a previously coiled, anterior communicating artery aneurysm. In this figure panel, the anatomy, cerebrovasculature, and the anterior communicating artery aneurysm can be visualized in **Figure 3A**. **Figure 3B** illustrates placement of the temporary clip, followed by puncture of the aneurysmal wall and thrombectomy in **Figure 3C**. In **Figure 3D**, the straight fenestrated clip is placed superiorly to the temporary clip; remnant coils within the aneurysm are apparent in this image. The final clipping configuration prior to closing is shown in **Figure 3E**.

Demographic Information	Total Subjects (n=53)
	Number (%)
Age	51.9 (SE 14.9)
Sex (Female Male)	46 (86.8) 7 (13.2)
Mean Time Interval from Coiling to Clipping (months)	31.3
Residual Aneurysm Recurrent Aneurysm	28 (52.8) 25 (47.2)
Anterior Posterior Circulation	34 (64.2) 19 (35.8)
Side (Left, Right, Midline)	15 (28.3) 18 (34) 20 (37.7)
Size (mm)	9.2 (SE .68)
< 10 mm	34 (65.4)
10-25 mm	17 (32.7)
>25 mm	1 (1.9)

Table. 1 Patient Summary

Patient ID	Age (years)	Gender	Location	Size (mm)	Coil Compaction	Coil Extrusion	Complication	GOS	Follow-Up (years)
Patient 3	65	Female	MCA	15	No	No	Vasospasm	1	NA
Patient 32	37	Female	Pericallosal	7	Yes	No	None	5	0.1
Patient 69	69	Female	Pericallosal	9	No	No	None	5	0.2

Table 2. Patient and Aneurysm Characteristics with Incomplete Obliteration Following Clipping.,

Time	Glasgow Outcome Scale	
Presentation	Score	Number (%)
	1	0
	2	7 (13.2)
	3	1 (1.9)
	4	7 (13.2)
	5	38 (71.7)
Discharge	1	2 (3.8)
	2	2 (3.8)
	3	1 (1.9)
	4	6 (11.3)
	5	42 (79.3)
Outcome Change	Δ	Number (%)
	Death	2 (3.8)
	Worse	1 (1.9)
	No Change	43 (81.1)
	Improve	7 (13.2)

Table 3. Glasgow Outcome Scale Score at Presentation, Discharge, and Glasgow Outcome Scale Change.

Post-Operative Complications	Total Subjects = 12
	Number (%)
New Sensory Deficits	4 (7.5)
Wound Infection	2 (3.8)
Hydrocephalus and VP-Shunt Placement	2 (3.8)
Transient Dysphagia	1 (1.9)
Scalp Hematoma	1 (1.9)
Temporal Muscle Atrophy	1 (1.9)
Death	2 (3.8)
Vasospasm	1 (1.9)

Table 3. Post-Operative Complications

Year Published	Author	Years Studied	Previously Coiled Aneurysms Clipped	Coiling Retreatment Rate	Presented with SAH	Mean Time Between Coiling-to-Clipping	Reported Outcomes	Mortality	Intra-Operative Complications
1995	Gurian et al. ²²	1986-1994	8		6 out 8	4.1 months	88% No Change or Improved Outcome	n=0	None
1996	Civit et al. ³⁹	1990-1994	8	7.30%	8 out of 8		63% No Change or Improved Outcome	n=1	None
1999	Horowitz et al. ²⁵	1993-1998	5	4%			100% No Change or Improved Outcome	n=0	
2000	Thornton et al. ⁴⁰	1994-1999	11	5.30%	2 out of 11	4.1 months	100 % No Change or Improved Outcome	n=0	Aneurysm rupture x1
2001	Boet et al. ⁴¹	1994-1999	7	8.60%	7 out 7		71.4% Good Outcome	n=1	Rupture of residual aneurysm in one patient
2002	Conrad et al. ⁴²	1997-2000	4	25.40%	4 out of 4		75% Excellent Outcome	n=1	
2003	Zhang et al. ⁴³	1995-2002	38		24 of 38	6 months (median)	87% Excellent or Good Outcomes	n=3	None
2003	Deinsberger et al. ⁴⁴	1998-2001	7		7 out 7	5.3 months	57% Good Outcome	n=1	Aneurysm sheared off at neck x1, Aneurysm sheared off at base x1
2004	Veznedaroglu et al. ⁵⁷	8 year period	18	4.40%	1 out 18		100% No Change or Improved Outcomes	n=0	Aneurysm sheared off at neck x1, Aneurysm sheared off at base x1
2006	Minh et al. ¹⁸	2003-2005	7	13.00%	6 out 7		86% No Change or Improved Outcomes	n=0	Central anteromedial arteries injured, Recurrent artery of Heubner injured
2006	Raftopoulos et al. ⁴⁵	1996-2006	17		11 out of 17	17.8 months (to detection)	100% No Change or Improved Outcomes	n=0	
2007	Konig et al. ⁴⁶	2002-2005	10		6 out of 10	14 months (median time to detection)	100% No Change or improved Outcomes	n=0	

2007	Tirakotai et al. ⁴⁷	1998-2005	8		4 out 8	11.01 months	88% Excellent or Good Outcome	n=1	None
2008	Lejeune et al. ⁴⁸	1997-2007	21	0.80%	20 out of 21	10.9 months	90% No Change or Improved Outcomes	n=0	
2008	Klein et al. ⁴⁹	1996-2005	13		13 out of 13	19.6 months	92% No Change or Improved Outcomes	n=1	
2009	Molyneux et al. (ISAT) ⁵⁸		191			5.7. months			
2010	Chung et al. ⁵⁰	2001-2008	29	4.70%	28 out of 29	3.62 months	93.1% Good Outcome	n=1	None
2011	Romani et al. ⁵¹	1995-2009	81		61 out of 81	12 months	88% No Change or Improved Outcome	n=6	Intraoperative Rupture x13
2012	Dorfer et al. ¹⁰	1992-2009	44		14 out 44	9.9 months		n=0	Intraoperative Rupture x1
2013	Nakamura et al. ⁵²	2006-2011	15		14 out of 15	19.1 months	87% No Change or Improved	n=1	
2014	Rubino et al. ⁵³	2009-2012	20	6.10%	3 out of 20			n=0	Intraoperative Rupture x1
2015	Izumo et al. ⁵⁴	2003-2013	7	7.70%	6 out 7	28.8 months	100% No Change Improved Outcomes	n=0	None
2015	Owen et al. ¹⁹	1997-2014	73	2.70%	64 of 73		92% No Change or Improved Outcome	n=3	None
2016	Daou et al. ⁵⁵	2002-2014	105 (6 of 111 wrapped)		88 out of 111	23 months	90% Good Outcome	n=3	None
2017	Wang et al. ⁵⁶	2004-2014	19		18 out of 19	26 months	84% Good Outcome	n=1	None

Table 4. Case Series Literature Review of Previously Coiled Aneurysms Clipped