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Clipping or Coiling of Cerebral Aneurysms

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Cerebral aneurysms remain a formidable challenge for neurosurgeons and interventional neuroradiologists. It is estimated that approximately 5% to 15% of all stroke cases are secondary to ruptured saccular aneurysms; therefore, it also remains an important health issue in the United States [1]. Although cerebral aneurysms can present with other symptoms related to their mass effect, such as cranial nerve palsies, their most significant sequela is related to the hemorrhage secondary to their rupture. After this hemorrhage, despite recent improvements in the diagnosis and treatment of cerebral aneurysms, the resultant aneurysmal subarachnoid hemorrhage (SAH) retains a mortality rate of 20% to 40% [2–4]. In those patients who survive, up to 50% are left severely disabled [2–4]. Rehemorrhage is associated with a worse prognosis, with 50% to 85% of patients dying [1,5,6]. The poor outcome is largely related to the effects of the hemorrhage; therefore, the prevention of rehemorrhage in ruptured aneurysms and initial hemorrhage in unruptured aneurysms is the primary strategy for lowering the mortality rate. The goal of preventing the hemorrhage or rehemorrhage can only be achieved by successfully excluding the aneurysm from the circulation.

Two treatment modalities are now available to exclude the aneurysm from the circulation: microsurgical clipping and endovascular coiling. Microsurgical treatment is more invasive and requires a craniotomy, open dissection of the aneurysm, and clipping of the aneurysm. Endovascular coiling is done through a groin puncture, negating the need for a craniotomy, and the aneurysm is excluded from within with microcoils. The surgical treatment of cerebral aneurysms is the traditional method and remains the "gold standard" in some centers, whereas endovascular coiling is a more recent technique that has been approved by the US Food and Drug Administration (FDA) since the middle of the 1990s. The availability of the two modalities has generated a large amount of controversy and debate with regard to the best treatment of aneurysms. The superiority of either of the treatment options has not been defined, but data are now available with regard to the safety and efficacy of each modality and can be used to decide what is best for individual patients. This decision needs to be made with knowledge of the safety and efficacy data and combined with other important variables, such as the patient's expected longevity, aneurysm factors (eg, size, aneurysm configuration, aneurysm location), and the operator's experience. In addition, it is equally important to consider whether the aneurysm is unruptured or ruptured. This complex decision requires entertaining all the variables, ensuring that patients receive the most appropriate care. This article first addresses the safety and efficacy data and most of the variables that need to be considered and then discusses the management of patients with unruptured and ruptured cerebral aneurysms with respect to clipping or coiling the aneurysm.

Safety of microsurgical clipping versus endovascular coiling

When comparing the safety of the two treatment options, although coiling is not without risk, it seems to be safer than clipping for an individual treatment session. In analyzing the safety data, it is best to evaluate the results of unruptured aneurysms so as to remove the confounding

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associated with the injury related to the SAH. The mortality rate from clipping an unruptured intracranial aneurysm (UIA) is between 1% and 3.8%, and the morbidity rate is between 4% and 12%. A meta-analyses of 733 patients by King and colleagues [7] reported a mortality rate of 1% and a morbidity rate of 4%, and one by Raaymakers and colleagues [8], which included 2460 patients, reported a mortality rate of 2.6% and a morbidity rate of 10.9%, with both decreasing in recent years for anterior circulation aneurysms. The most comprehensive study looking at the risks of surgical treatment was the International Study of Unruptured Intracranial Aneurysms (ISUIA) [9]. In the prospective group of 961 patients who had no history of SAH, the investigators reported a mortality rate of 2.3% at 30 days and 3.8% at 1 year and a morbidity rate of 12% at 1 year [9]. This study also looked at more subtle morbidities, such as neuropsychologic outcomes. Recently, a population-based study evaluating the impact of surgical clipping on survival in unruptured and ruptured cerebral aneurysms reported a 5.5% 30-day and 8.5% 1-year mortality rate in patients with unruptured aneurysms [10]. In addition, those patients who were treated were noted to have a higher than expected death rate compared with the general population, which extended throughout the study period [10].

With respect to coiling, the reported mortality rate after coiling a UIA is between 0.5% and 2% and the morbidity rate is 4% to 5%. A meta-analysis by Brilstra and colleagues [11] that included 1383 patients in 48 studies reported a 3.7% permanent complication rate. Johnston and colleagues [12] compared a cohort of patients with UIAs undergoing surgery and reported a mortality rate of 2.3% versus 0.4% and a morbidity rate of 18.5% versus 10.6%. Johnston and colleagues [13] also reported on 2069 patients treated for UIAs in California between 1990 and 1998 and reported a mortality rate of 3.5% for clipping versus 0.5% for coiling. A recent large meta-analysis of 1379 patients by Lanterna and colleagues reported a mortality rate of 0.6% and a 7% permanent morbidity rate after coiling UIAs [14]. Therefore, the data support the notion that endovascular coiling is safer than microsurgical clipping in patients with a UIA.

The safety of endovascular coiling compared with clipping was further augmented by the results of the International Subarachnoid Aneurysm Trial (ISAT) [15]. This prospective, randomized, controlled trial of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms demonstrated an absolute risk reduction of 8.7% at 1 year [15]. The results of this trial have generated further controversy [16–18], but it is fair to say that coiling does seem to be safer than microsurgical clipping in ruptured cerebral aneurysms as it is in UIAs.

Efficacy of microsurgical clipping versus endovascular coiling

The appeal of endovascular occlusion of cerebral aneurysms is that it is a less invasive technique and has been shown to be safer than clipping. When managing a patient with a cerebral aneurysm, however, the major goal of treatment in those patients deemed to require treatment is the prevention of hemorrhage or rehemorrhage in unruptured and ruptured aneurysms, respectively, by successfully excluding the aneurysm from the circulation. When comparing endovascular treatment with surgical obliteration of aneurysms, it is believed that the efficacy of endovascular aneurysm occlusion is far less optimal. Aneurysm occlusion using endovascular techniques and surgery is quite different, and this difference may have significant implications for residual aneurysms. In the clipped aneurysm residual, the walls are closely apposed and the remaining aneurysm is completely excluded from the circulation. By contrast, using endovascular techniques, the coils keep the remnant's walls apart. In addition, although experimental models of coiled aneurysms demonstrate that the aneurysm neck becomes entirely occluded by organized thrombus and that the free luminal surface is covered by endothelium, endothelialization is not observed in coiled aneurysms obtained at autopsy or surgery [19]. These various factors mean that any intraaneurysmal thrombus or coil is exposed to circulating blood, which may allow compaction of the coils or flow around the coil's periphery into the aneurysm sac.

This "efficacy" has been an important factor in favor of microsurgical clipping, because clipping seems to be superior to coiling in achieving those goals over the short and long term. Most series report a 92% to 96% exclusion rate of the aneurysm from the circulation with microsurgical clipping [20–22], as confirmed by postoperative angiography. In addition, this efficacy is sustained with a 0.5% recurrence per year in completely clipped aneurysms [20]. Most importantly, microsurgical clipping also significantly changes the natural history of the disease. In ruptured aneurysms, David and colleagues [20] reported a 0% incidence of rebleeding in 147 aneurysms that were completely clipped over a mean follow-up period of 4.4 years. Twelve (8.2%) of the 147 aneurysms had a residual neck, and they were divided into two groups: dog ear residua and broad-based residua. Patients with the dog ear type had a risk of 1.9% per year of recurrent hemorrhage, and patients with the broad-based type had no recurrent hemorrhage, although they had significant regrowth. Combined, these residuals had a recurrent bleeding rate of 1.5% per year [20] in the 8.2% of aneurysms with residual necks after clipping. The effectiveness of changing the natural history has also been found in UIAs. Tsutsumi and coworkers [23] reported a 0.09% per year hemorrhage risk in a cohort of 114 patients who had completely clipped UIAs.

With respect to endovascular coiling, most series report 40% to 55% complete exclusion, 35.4% to 52% near-complete exclusion, and 3.5% to 8% incomplete exclusion of the aneurysms from the circulation [24,25]. In addition, the long-term durability of endovascular coiling seems significantly concerning, with rates of recanalization reported to range from 20.9% to 28% [25,26]. This recanalization was found to be largely associated with larger aneurysms and those with a poor dome-to-neck (d/n) ratio [25], however. Despite the fact that microsurgical clipping provides a far superior anatomic cure compared with endovascular coiling, coiling has been shown to be effective in changing the natural history of unruptured and ruptured aneurysms. Therefore, complete anatomic cure is not required to change the natural history of a cerebral aneurysm. In the report by Kuether and colleagues [24] on 74 patients with 77 aneurysms that included ruptured and unruptured aneurysms, the authors had no reported hemorrhages over a follow-up period of 1.9 years in those aneurysms that demonstrated complete exclusion. In those with near-complete occlusion, a hemorrhage rate of 1.4% per year was found in the 1.9-year follow-up [24]. The report by Murayama and colleagues [25] on an 11-year experience in 818 patients with 916 aneurysms demonstrated a hemorrhage rate of 1.6% that decreased to 0.5% in the last 5 years. The recent meta-analyses on the treatment of UIAs by Lanterna and colleagues [14] in 1379 patients with an average follow-up time of 0.5 to 3.8 years demonstrated a total of 13 nonprocedural bleeding events occurring in 703 eligible patients. The overall annual bleeding rate was 0.9% per year, and, importantly, only partially occluded UIAs of 10 mm or more bled. Specifically, the bleeding rate of the UIAs larger than 10 mm was 3.5% per year [14]. Therefore, although endovascular treatment does change the natural history of a cerebral aneurysm, it is not superior to clipping and is particularly concerning for larger aneurysms and those that are not completely occluded.

This concern was also demonstrated by a report by Eskridge and Song [27] that evaluated endovascular occlusion in 150 basilar tip aneurysms as part of an FDA multicenter clinical trial that demonstrated a bleeding rate for treated unruptured aneurysms of up to 4.1%. Further addressing the issue of size in the endovascular treatment of aneurysms is a study by Malisch and colleagues [28] that demonstrated a 4% incidence of post–Guglielmi detachable coil embolization hemorrhages in patients with large aneurysms and a 33% incidence in giant aneurysms. Therefore, using current endovascular techniques, although endovascular occlusion is effective, it does seem that it is a less effective mode of therapy than surgical treatment, particularly in large aneurysms and those with an unfavorable d/n ratio.

Patient factors: patient's life expectancy (age, comorbidities, family history, and World Federation of Neurological Societies grade)

It has well been described that advancing age is associated with a worse outcome in ruptured and unruptured aneurysms [9,29]. This was particularly well illustrated in the ISUIA, which demonstrated a combined morbidity and mortality rate of 6.5% for patients less than 45 years old, 14.4% for patients 45 to 65 years old, and 32% for patients greater than 64 years old in those patients undergoing surgical clipping [9]. Similar finding have been reported with endovascular coiling, but the effects seem to be less significant with endovascular coiling in older patients [29,30]. In managing a patient with a cerebral aneurysm, however, age is only one of the factors that need to be considered. This is one area of medicine today that truly requires an individual evaluation when determining care.

This is particularly important in that two modes of therapy are now available, each with its own advantages and disadvantages, that can be used to facilitate appropriate care for the individual patient. For example, it may be more appropriate for an elderly patient or a patient with severe comorbidities with a limited life expectancy to receive no specific treatment or a treatment that is safe than one that provides decades of cure. Similarly, a young patient may forego a safer treatment for one that is more permanent.

Therefore, when evaluating the patient with a cerebral aneurysm, the patient's life expectancy should be estimated. The patient's life expectancy is related to age, associated comorbidities, and family history of illnesses and longevity. Based on these variables, the author divides his patients into those with long, intermediate, and short life expectancies. A long life expectancy would be exemplified by a patient who is expected to live longer than 16 years, an intermediate life expectancy by a patient who is expected to live 5 to 15 years, and a short life expectancy by a patient who is expected to live less than 5 years. The patient's estimated life expectancy is particularly important when dealing with unruptured aneurysms, because the estimated length of life translates into the patient's length of risk from the aneurysm in an untreated (natural history) or treated (no current aneurysm treatment is 100% effective) form.

In patients with ruptured aneurysms, the patient's neurologic condition after the initial hemorrhage is directly associated with survival, and therefore longevity. Multiple grading schemes have been proposed, of which two are the most widely used: the Hunt and Hess scale [31] and the World Federation of Neurological Societies (WFNS) scale [32,33]. Despite this, outcome prediction remains inexact, but these grading scales do provide a guide with regard to survival. WFNS I grade patients are expected to make an excellent recovery; WFNS II and III grade patients are expected to make a good recovery; and in WFNS IV and V grade patients, an unfavorable outcome is expected in greater than 50% of the patients [34]. Therefore, in ruptured aneurysms, in addition to evaluating the premorbid life expectancy, the WFNS or Hunt and Hess grade must be taken into account when deciding on treatment.

Aneurysm factors

Aneurysm size

Aneurysm size is an important factor to consider because it relates to the safety and efficacy of treatment in microsurgical clipping and endovascular coiling. Increased size has unequivocally been shown to have an increased risk with microsurgical treatment [8]. Wirth and colleagues [35] have demonstrated a linear relation with regard to size and outcome, with a complication rate of 3% for aneurysms less than 5 mm, 7% for 6- to 15-mm aneurysms, and 14% for aneurysms of 16 to 24 mm. Soloman and colleagues [36] showed similar results with microsurgical clipping, with an excellent or good outcome in 100% of aneurysms less than 10 mm, 95% in aneurysms 11 to 25 mm, and 79% in aneurysms greater than 25 mm.

The safety of endovascular treatment is also affected by size on both sides of the size spectrum, with extremely large and extremely small aneurysms having increased complications. Extremely small aneurysms are associated with an increased risk of intraprocedural rupture and a worse outcome. Giant aneurysms usually have a less favorable d/n ratio, are often associated with a higher incidence of a branch vessel origin of the aneurysm neck, and often have intra-aneurysmal thrombus. These factors are associated with parent, branch, or distal vessel occlusion and an associated stroke. Gruber and colleagues [37] demonstrated this and reported a 13.3% procedure-related morbidity rate and a 6.7% procedure-related mortality rate in aneurysms greater than 25 mm with coiling, which is similar to the results with open surgery.

With regard to the efficacy of treatment, surgical clipping is less affected than coiling by increasing size of the aneurysm. Increased aneurysm size is associated with residua, and to a small degree with clipping, and large calcified aneurysms may be treated with parent vessel occlusion with an associated cerebral bypass in select cases with effective results. In contrast, endovascular coiling is associated with significant aneurysm recanalizing and rebleeding with increasing size of the aneurysm [14,37], with rates of postprocedural hemorrhage of 3.5% per year in UIAs larger than 10 mm in size [14].

Aneurysm configuration

Aneurysm configuration is another important factor to consider in the surgical and endovascular treatment of aneurysms. In surgery, the major factors are the size of the neck and the relation of the aneurysm to the major neighboring artery(ies). In patients with wide-necked aneurysms and/or having the aneurysm involve the major neighboring artery(ies), the surgical complexity is increased and experience is required to ensure complete exclusion of the aneurysm with preservation of the parent vessel and its associated branches. With experience, the operator can achieve greater than 90% occlusion of a wide-necked aneurysm safely. Small-necked aneurysms are simple to treat for a neurovascular surgeon.

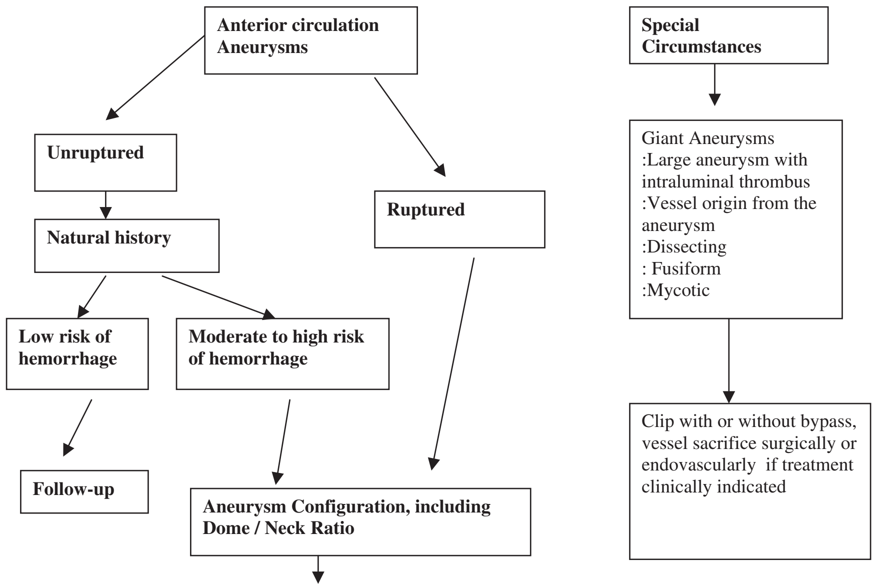
Aneurysm configuration is even more important in the endovascular treatment of aneurysms, because the occlusion rate of aneurysms by endosaccular packing with coils is influenced by a variety of factors related to the morphologic features of the aneurysm. These include the d/n ratio, size of the neck and dome, shape, and relation to the major neighboring artery(ies). Dense packing of the coils within the aneurysmal sac can be achieved with less risk of migration of the coil into the parent artery when the treated aneurysm has a small dome size, a small neck, and a large d/n ratio, which are conditions that enhance the complete occlusion of the aneurysm with fewer complications [38,39]. In patients with favorable configurations, a high success rate (80%–85%) of complete occlusion can be achieved in such aneurysms [38–40]. In less favorable configurations, the rate of complete occlusion decreases dramatically and is associated with significantly increased complications and decreased efficacy of treatment. The most important factor relating to aneurysm configuration is the d/n ratio, and this is divided into three groups: large, intermediate, and small d/n ratios describing the most favorable to least favorable configuration. Newer techniques have been developed, however, such as stent-assisted coiling, that may change the paradigm of the treatment of wide-necked aneurysms [41,42].

Aneurysm location

In deciding between clipping and coiling an aneurysm, location is of prime importance, because the safety and efficacy of the two treatment modalities are affected by the location of the aneurysm [8,11]. Posterior circulation aneurysms have always been associated with a higher complication rate with microsurgical treatment when compared with anterior circulation aneurysms of similar size [8]. Most published series report mortality that ranges from 3% to 30% and morbidity that ranges from 7% to 40% with surgical clipping [43–46]. In contrast, with endovascular coiling, complications with posterior circulation aneurysms are not significantly different from those with anterior circulation aneurysms [11,47]. More significantly, however, is that complications seem to occur significantly less frequently with coiling than with clipping in the treatment of posterior circulation aneurysms. Tateshima and coworkers [48] reported procedure-related morbidity and mortality rates of 4.1% and 1.4%, respectively, with endovascular treatment of posterior circulation aneurysms. Eskridge and Song [27] reported on 150 basilar tip aneurysms and had a periprocedural mortality rate of 2.7% and morbidity rates of 5% of ruptured aneurysms and 9% of unruptured aneurysms. Therefore, evidence has shown that endovascular treatment of posterior circulation aneurysms is safer than clipping, and most patients with posterior circulation aneurysms undergo endovascular therapy (Fig. 1). This has been questioned, however, because it has been reported that in expert hands with experience, no increase in risk has been noted in nongiant posterior circulation aneurysms with microsurgical clipping [36].

Unlike posterior circulation aneurysms, middle cerebral artery aneurysms favor surgical treatment. Middle cerebral artery aneurysms often have the aneurysm originating from one or both of the branching vessels and often have an associated unfavorable d/n ratio. This configuration may often result in the aneurysm being unable to be coiled or may allow for migration of the coil into the parent vessel or a branch, resulting in a stroke. Regli and coworkers [49] reported on the endovascular treatment of unruptured middle cerebral artery aneurysms. In that series, 11 (34%) of 34 cases had attempted embolization, 21 (66%) of 34 needed upfront clipping, and 2 (6%) of 34 were successfully embolized, with the remainder undergoing clipping after failed embolization [49]. Therefore, despite major technical advances in imaging and endovascular treatment of cerebral aneurysms, surgical clipping is still the most safe and efficient treatment for most middle cerebral artery aneurysms.

Another location that requires mention is anterior communicating artery aneurysms. These often require dissection around hypothalamic perforators; therefore, with surgical treatment, the question of cognitive dysfunction after treatment has been raised. In a recent study, Chan and colleagues [50] reported impaired verbal memory and executive function with clipping compared with coiling. Finally, in the treatment of paraclinoid aneurysms, microsurgical clipping often requires decompression of the optic nerve to expose the proximal neck; therefore, blindness is always a concern. In contrast to popular belief, however, no difference in complications has been documented in paraclinoid aneurysms, particularly



Patient Factors	**D/N Ratio**	**D/N Ratio**	**D/N Ratio**
	Large	**Medium**	**Small**
Estimated Life Expectancy ; WFNS SAH Scale			
Long; WFNS I	Coil	Clip	Clip
Intermediate; WFNS II and III	Coil	Either- UIA; Clip in SAH	Clip
Short; WFNS IV and V	Coil	Coil	Coil if Possible

Fig. 1. Algorithm as a guideline in treating anterior circulation aneurysms.

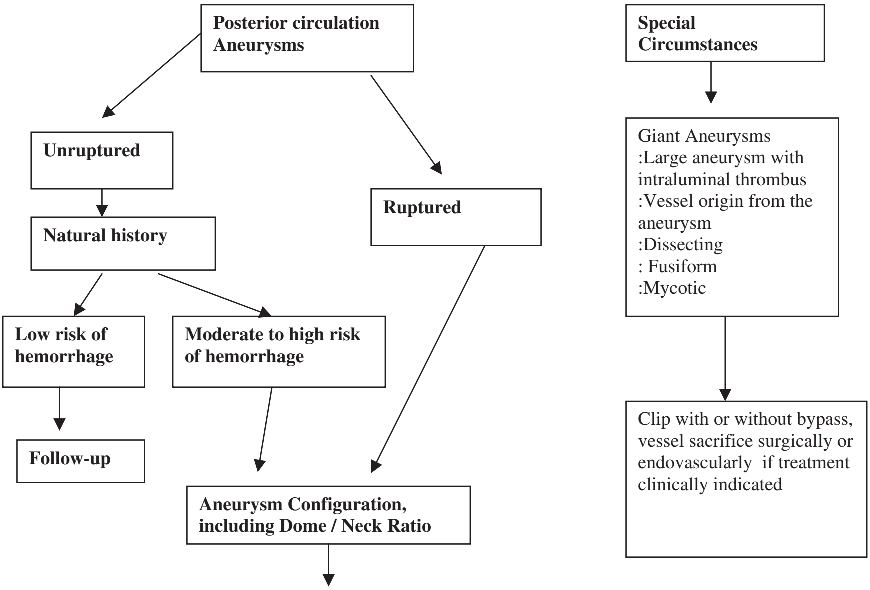
with regard to visual loss with coiling versus clipping [51].

Operator experience

The management of cerebral aneurysms is becoming more specialized, and experience affects outcome, as has been demonstrated in other procedure-related reports in the literature. Unequivocally, improved outcome is found based on the number of cases undertaken and the experience of the surgeon in treating cerebral aneurysms. Solomon and colleagues [52] have demonstrated a 53% decrease in mortality if greater than 10 operations are performed per year. Chyatte and Porterfield [53] demonstrated similar results during the evaluation of outcomes in 449 aneurysm surgical procedures in 366 patients performed by 10 surgeons and found a strong prediction for better functional outcome related to the number of aneurysms treated by a surgeon. Similar findings have been documented with endovascular coiling of aneurysms [54]; therefore, more and more aneurysms are being treated by neurovascular neurosurgeons and interventional neuroradiologists with an interest in cerebral aneurysms.

Management of unruptured aneurysms

SAH after rupture of a cerebral aneurysm is a devastating condition. In UIAs, prevention of this rupture by surgical or endovascular treatment is believed to be the most effective strategy for lowering the morbidity and mortality rates (see Fig. 1; Fig. 2). All current treatments carry some risks; therefore, in formulating recommendations for treatment of a patient with a UIA, multiple factors have to be considered. The first and probably the most important decision is to evaluate if the patient should be treated at all, because treatment-related complications usually occur at



Patient Factors	D/N Ratio Large	D/N Ratio Medium	D/N Ratio Small
Estimated Life Expectancy ; WFNS SAH Scale			
Long; WFNS I	Coil	Coil-UIA; Either in SAH	Clip
Intermediate; WFNS II and III	Coil	Coil	Coil- UIA; Either in SAH depending on aneurysm configuration
Short; WFNS IV and V	Coil	Coil	Coil if possible

Fig. 2. Algorithm as a guideline in treating posterior circulation aneurysms.

or around the time of the procedure. The indication to treat a UIA is if the risk of the aneurysm outweighs the risk of the treatment. The risk that the aneurysm poses is the natural history of a UIA. Although understanding the natural history of UIAs is critical in the management of patients with a UIA, it is poorly understood, and the risk of rupture has been estimated to be between 1% and 2% per year in multiple studies for aneurysms of average size [55–59]. This continued debate has recently been highlighted by the landmark report from the ISUIA [9], which has suggested a yearly rate of hemorrhage of 0.05%, and recent articles by Asari and Ohmoto [60], Juvela and coworkers [61], Tsutsumi and colleagues [21], and Winn and coworkers [62], which have supported the earlier yearly rate of 1% to 2%.

In treating UIAs, the author divides the risk of hemorrhage into low, moderate, and high risk. Low risk is an estimated natural history of 0.05% per year or less, moderate risk is an estimated natural history of 0.06% to 2% per year, and high risk is an estimated natural history of greater than 2% per year. Therefore, in those patients with a single UIA less than 5 mm in size, most surgeons do not treat the aneurysm, and the author places those aneurysms in the low-risk category and observes for growth of the aneurysm. An exception to this generalization is that patients with multiple aneurysms, posterior circulation aneurysms, a history of a prior SAH, or a strong family history may have an increased risk of hemorrhage, and the surgeon may consider treating an aneurysm of 4 to 5 mm in size in those situations. Aneurysms ranging from 6 to 24 mm in size are placed in a moderate risk of hemorrhage category. Aneurysms that are larger in size, such as giant aneurysms (>25 mm), have a particularly grave prognosis with a rupture rate of 6% in the first year and 45% within 7.5 years and are placed in the high-risk hemorrhage category [58]. Patients who have a moderate to high risk of hemorrhage should always be considered candidates for treatment.

In those patients who are deemed candidates for treatment, the aneurysm configuration and, in particular, the d/n ratio should be evaluated next. Because almost all intracranial aneurysms can be treated surgically, the plausibility and effectiveness of the endovascular option should be addressed, and the aneurysm configuration provides these data as described previously. Patients are then grouped into those with a large, intermediate, and small d/n ratio describing the most favorable to least favorable configuration, respectively.

All this information is taken into consideration after evaluating the patient's estimated life expectancy. Patients are considered to have a long, intermediate, or short life expectancy. As described earlier, the only time to treat an aneurysm is if risk of rupture over the patient's expected lifespan is greater than the risk of treatment. For example, an elderly and frail patient may not warrant treatment at all even if the patient has a moderate to high risk of hemorrhage, because the risk of the procedure would be higher in an old patient and the length of risk from the aneurysm may be short. In those patients in whom the risk of the aneurysm is worse than the treatment, a treatment option should be discussed with the patient. In those patients, the aneurysm configuration and the patient's estimated life expectancy are calculated with knowledge of the advantages and disadvantages of the two different treatment modalities. As discussed earlier, the advantage of clipping is that it is a relatively safe procedure that is effective in changing the natural history of a UIA in the short and long term. The disadvantage of clipping is that the risk of treatment is higher than that of coiling. The advantage of coiling is that it is less invasive and safer than clipping, but the major limitation is its lack of durability in changing the natural history compared with clipping in those aneurysms that have a less than ideal configuration and in large aneurysms.

Therefore, in anterior circulation aneurysms in patients with a large d/n ratio, endovascular coiling should always be considered as the first line of treatment in those patients with long, intermediate, and short estimated life expectancies, because this treatment provides the patient with relatively effective treatment that is safer than clipping. Some authors may argue that those patients with an estimated long life expectancy should undergo clipping because it has been proven to more durable than coiling. This is a reasonable option for the experienced neurovascular surgeon and the patient. At the other extreme, patients with a long estimated life expectancy or small d/n ratio should undergo clipping, except those patients who have an extremely short life expectancy and in whom coiling is possible based on aneurysm configuration. In patients with a medium d/n ratio and a long estimated life expectancy, clipping would be most appropriate to provide a more durable treatment. In patients with an intermediate lifetime risk, either treatment would be appropriate, and in patients with a short estimated lifetime risk, coiling would be more appropriate.

With regard to posterior circulation aneurysms, in the hands of most surgeons, a higher complication rate is associated with microsurgical treatment when compared with anterior circulation aneurysms of a similar size and is higher than with endovascular coiling. Therefore, in those patients with large and medium d/n ratios, the patient should undergo endovascular coiling regardless of the estimated life expectancy, because endovascular coiling provides a safer treatment that is relatively effective. In those patients with a small or unfavorable d/n ratio, coiling should still be considered in those individuals with a short or intermediate estimated life expectancy because it is still probably safer than microsurgical clipping. In some posterior circulation aneurysms with less favorable configurations, where the aneurysm sac involves one of the posterior cerebral branches, clipping may be the only alternative. Microsurgical clipping should also be performed in those patients with an unfavorable or small d/n ratio with a long estimated life expectancy by an experienced neurovascular neurosurgeon so as to provide the patient with reasonably safe and effective long-term treatment.

Management of ruptured cerebral aneurysms

In ruptured aneurysms, the primary cause of death or disability is related to the effect of the initial hemorrhage, subsequent rebleeding, and associated complications of hemorrhage, such as vasospasm and hydrocephalus. Therefore, in addressing the treatment of a ruptured aneurysm, preventing rebleeding is crucial to prevent further injury to an already compromised brain. Rehemorrhage is associated with an even worse prognosis, with 50% to 85% of patients dying [1,5,6].

The natural history data on ruptured aneurysms suggest that between 20% and 30% of these ruptured aneurysms may rebleed within 30 days [5]. This rebleeding is greatest on day 1 (4%) and then occurs at a constant rate of 1% to 2% per day over the next 4 weeks [63]. After the 4-week period, the rebleeding rate settles down to approximately 3% per year, which is higher than for unruptured aneurysms of a similar size [5]. Therefore, in treating patients with ruptured aneurysms, the primary goal is early, complete, permanent, and safe aneurysm occlusion unless other factors, such as brain death, poor premorbid medical condition, or poor clinical grade, deem this inappropriate.

In those patients who are deemed candidates for treatment, as with UIA, the aneurysm configuration and, in particular, the d/n ratio should be evaluated next. Again, patients are then placed into large, intermediate, and small d/n ratio categories describing the most favorable to least favorable configuration for endovascular therapy. In ruptured aneurysms, in addition to evaluating the patient's life expectancy based on the premorbid status, the patient's clinical condition after the hemorrhage must be considered because this is directly associated with early survival, and therefore longevity. The author arbitrarily places patients into three groups: those expected to survive with no or minimal deficits (WFNS I), those expected to survive with mild to moderate deficits (WFNS II and III), and those possibly not surviving and most likely to have deficits (WFNS IV and V).

As discussed earlier, although endovascular coiling is effective in changing the natural history of ruptured aneurysms, it does seem to be less effective than surgical treatment, particularly in large aneurysms and those with an unfavorable n/d ratio. In ruptured aneurysms, the effectiveness of treatment is particularly vital, because rebleeding is associated with a worse prognosis. Therefore, in treating a patient with a ruptured aneurysm in the anterior circulation, clipping is advocated in those patients with medium or small d/n ratios, except in those patients with a short life expectancy and/or a poor clinical grade after the initial hemorrhage. Endovascular coiling is reserved for those patients with a large d/n ratio in whom complete occlusion can be obtained. In posterior circulation aneurysms, coiling is still the first choice; microsurgical treatment is advocated for those patients with an unfavorable d/n ratio, a long life expectancy, and a good clinical grade and is an option in those with a medium d/n ratio.

Special circumstances

Although most aneurysms can be treated with standard microsurgical clipping or endovascular therapy, some aneurysms require special mention. Giant calcified aneurysms, large aneurysms with intraluminal thrombus, aneurysms in which the vessel is originating from the aneurysm, dissecting aneurysms, and fusiform and mycotic aneurysms need to be evaluated differently. These aneurysms require clipping with or without bypass or vessel sacrifice surgically or endovascularly if treatment is clinically indicated.

Summary

The management of a patient with a cerebral aneurysm is complex, and two accepted treatment modalities are now available. The superiority of either of the treatment options has not been defined, but data are now available with regard to the safety and efficacy of each modality and can be used to decide what is best for individual patients when combined with other important variables, such as the patient's expected longevity, specific aneurysm factors (eg, size, d/n ratio, location), and operator's experience. This complex decision entertaining all the variables should ensure that patients receive the most appropriate care. New developments in the endovascular management of cerebral aneurysms are likely to alter this algorithm.

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