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Endovascular Versus Surgical Management of Intracranial Pseudoaneurysms: A Comparative Review

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Abstract:

Intracranial pseudoaneurysms (IPAs) are uncommon cerebral lesions that are quite difficult to treat because they have high rates of rupture and deaths. This narrative review provides a comparison between the surgical and endovascular modalities of treatment of IPAs, paying attention to efficacy, durability, application, and safety. There was traditionally the gold standard of a definitive cure and that is open surgery; even clipping, trapping with bypass, and that old standard of wrapping. The methods, however, are physiologically challenging and they have high morbidity. Less invasive alternatives endovascularly include coiling, parent artery occlusion, and flow diversion which has the benefit of leaving the parent artery intact in greater than 90% of cases. Surgical trapping and bypass are the most definitive treatment, have high occlusion rates and low recurrence, and necessitate parent sacrifice. Endovascular reconstructive techniques are instant remedial and protect the parent vessel, but the long-term resilience is variable. Flow diversion is promising with rates of complete occlusion but increases risks of delayed thrombosis, and rupture. Higher morbidity and mortality are linked to surgical management because of craniotomy and repair of vessels, and endovascular complications are mostly thromboembolic and ischemic stroke. The variables taken into consideration to select a model of treatment include: the patient (age, comorbidities, neurological status), the aneurysm (location, size, morphology) and institutional (expertise, resources). IPAs are rare; most of the available evidence is retrospective in nature and prone to selection bias, as well as heterogeneity in recording. It should be multidisciplinary and tailored to the patient and would use an endovascular intervention with surgery only in more complex cases or those refractories to endovascular management. It is important to

develop quality improvement programs and coordinate partnerships between endovascular experts and neurosurgeons in order to maximize patient outcomes.

Key words: Intracranial Pseudoaneurysms, Surgical Management, Endovascular Techniques, Hemorrhagic Complications, Clip Ligation, Flow-Diverting Stents.

Introduction:

Intracranial Pseudoaneurysms (PSAs) are characterized as a rare condition patients present with, when there has been disarray of the vessel wall (1). It represents 1 per cent of all intracranial aneurysm and causes major difficulty in its medical management and high mortality rate (2). Intracranial PSAs are dangerous presentations due to complications caused by rupture of the vessel and consequent hemorrhage (epidural, subdural, arachnoid, intracerebral) and even cerebral thromboembolism (3,4). Formation of PSAs is largely dependent on etiology. Based on the main cause, there will be resultant disruption of the artery. However, the blood is entrapped within the adventitial layer or within tunica media as well unlike true aneurysms, which anatomically involve all three layers (5,6). The most frequent factor in patients presenting with PSAs is direct or indirect trauma to the skull. Unlike extracranial vessels, thin and rigid vessels that are located inside of the skull are readily prone to damage that lead to formation of PSA. Bacteria, fungi and other infectious agents that predominate very severe cases typically seen in younger populations. Another identifiable etiology of the disease is iatrogenic injuries. The latter has been reported in the case of transsphenoidal resection of a pituitary adenoma (1,7). The majority of PSAs are asymptomatic. Unbeknownst to the patient however, intracranial blood flow becomes increasingly turbulent (6). This can later progress to a symptomatic stage where headaches, seizures, epistaxis, cranial nerve deficits and intracranial bleeding can result. Epistaxis is a frequent red flag here, as it's typical in damage to the internal carotid artery. Moreover, rupture leading to bleeding can even be fatal in the bulk of cases (1,7). It is clear that PSAs impose multiple distinctions from its classification, etiology to even symptoms. Deep diving into the peculiarities of each of these are out of the scope of this review. It is now clear how vital it is that PSAs are diagnosed accurately and as early as possible in order to reduce the risk of fatal bleeding. In this comparative review, we look at two feasible methods of managing an intracranial PSA: surgical and endovascular techniques.

Before the introduction of endovascular techniques, microsurgery was the method of choice. This includes clipping, vessel reconstruction, ligation, resection and trapping with or without bypasses (1,4). The most common technique, clip ligation involves forfeiting the parent artery. Another shortcoming when using clipping to treat PSAs lies in its features. PSAs are extremely fragile in nature as blood is trapped in a spindle shape without involving all vascular layers. They also possess a false neck making it unfavorable to carry out this procedure without risks. The next surgical options are wrapping and trapping. Both of these procedures maintain patency of the parent vessel unlike in clipping. Trapping involves bypass procedures making it even more challenging and increases risk of damage to the skull base. Ligation is another technique some specialists opt for; however, it has a significant risk of leading to post-op ischemia. End organ resection is also another procedure rarely done (1,2,8). Surgical therapy has got several alternatives, and it is conventional. Yet, surgeons face 2 major issues when it comes to

surgical management of PSAs: the need to control the emergent bleed swiftly along with maintenance of vascular patency to prevent further ischemic complications (9).To fix these issues, endovascular techniques were introduced in the 1990s (10).Options available for treatment in this case are coiling, occlusion of the parent artery and flow-diversifying stents. The main edge endovascular methods had over their surgical counterparts was that it was less invasive. The most frequently used option in narrow PSAs is coiling. Although this assists in access to these tortuous locations that cannot be clipped, it is subject to risk of perforation and recurrence. Distal PSAs normally require occlusion of the parent artery. However, one of the issues that remain a serious concern among the patients that have had this procedure is ischemic complications. Flow-diverting stents is a newer option that involves stimulating thrombus formation within the parent artery and promoting remodeling (1,3, 11). It is evident that while endovascular techniques theoretically seem superior to their conventional surgical counterpart, in practice, they each have their own benefits and limitations. Throughout this review, we will compare between these techniques and further understand the nuances between their complementary nature.

Methodology

The present study is a narrative review in which the authors are trying to compare the results of the endovascular methods and operative treatment methods of intracranial pseudoaneurysms. PubMed, Google scholar and research present were used as literature search tools and 20 articles were identified to be included in this review (1,2,3). The articles with a publication date of 2020-2025 were searched. The keywords and combinations applied are as follows: Endovascular treatment, Surgical Management, Intracranial pseudoaneurysm and Competitive Outcomes. Selection of articles was carried out on predetermined criteria. Articles published in English, ones in which human subjects were involved, and full text were obtained (4). A retrospective cohort study, case reports and literature reviews were also regarded to be included since they presented useful clinical information regarding various management methods. Conversely, animal studies, non-English papers, abstracts and editorials were filtered out of consideration because they did not directly pertain to the research question. The selection of studies was dependent on the reliance of the research goal. Original research articles of better quality, and studies with bigger samples which give reliable conclusions, were given priority (4,5). The results of the chosen studies were integrated not in any formal meta-analysis but using narrative. This was attributed to the fact that the availability of study design, sample sizes, outcomes measures, and interventions among others could not enable quantitative pooling of data. Rather, the comparison and description of the studies was conducted in a qualitative way to find the trends and variations of endovascular and surgical methods of managing these types of patients (6,7).

DISCUSSION

Intracranial aneurysms are a rarity represented in roughly 1 out of the hundred intracranial aneurysms and their clinical importance is exceedingly over proportional pointing towards high rupture rates and

massive mortality rates (4,8). Intracranial pseudoaneurysms (IPA) are a difficult condition when it comes to the management of cerebrovascular lesions (12). Research in surgical and endovascular management presents heterogeneity in treatment modality and evidence on outcome (it contains retrospective case series and a little on the randomized control trial, making it difficult to come up with evidence-based treatment methods). According to a review of the literature, the areas that are significant in its management include efficacy, durability, application and safety.

Overview of treatment methods

Traditionally, the gold standard for definitive cure of intracranial pseudoaneurysms was open surgery-clipping, parent artery trapping with bypass and surgical wrapping were techniques used with each specific indications and limitations. But they are physiologically demanding, carry substantial morbidity and demand technical expertise in microvascular reconstruction (13,14).

Microsurgical Management

Expert opinion is varied on reconstructive surgical approach to IPAs, with clipping of aneurysmal neck being threatening and challenging due to the friable nature of the pseudoaneurysm wall and the absence of true vessel wall (1). While surgical wrapping is used to reinforce the weakened wall and preserve connection to the parent artery, it is less invasive, but this is only a temporary stabilization approach as it carries significant risk of re-bleeding and pseudoaneurysm regrowth (15). Parent artery trapping with bypass is the most definitive surgical approach and treatment modality to eliminate IPAs by placing clips proximally and distally to the aneurysm on the parent vessel (1,5). It is highly dependent on the status of collateral supply with low-flow bypasses recommended for superficial temporal artery and middle cerebral artery compared to high-flow bypasses recommended for ICA pseudoaneurysms using radial artery or saphenous vein grafts (1). This procedure requires careful preoperative planning and surgical expertise to ensure adequate revascularization.

Endovascular Embolisation Management

In the case of intracranial pseudoaneurysms, endovasculature intervention represents an alternative to microsurgery because it provides possibilities of deconstructive and reconstructive needs in different clinical settings. These include reconstructive coiling procedures- simple coiling, stent-assisted coiling (16), stent-within-a stent and flow -diversion and Parent artery occlusion with or without aneurysm. Coiling techniques also provide an immediate treatment mode to wide-necked pseudoaneurysms preserving parent artery but, complications exist with its use like being highly linked to recanalisation and neointima compared to flow diversion (17) except covered stents which has been shown to limit both of these complications with exception of dissection and vasospasm by its stiffness of delivery system that makes it difficult to use in aneurysm with ICA or branches thereof (1). Flow Parent vessel occlusion is the endovascular definitive treatment in IPAs with collateral supply of proven flow, which however does not spare the parent artery (16). The most recent endovascular treatment, the flow diversion or flow-diverting strategy as applied to the IPA has shown promising high complete occlusion results with retention of parent artery and low complication rates (1,12,15). It entails a reshaping of

flows and gradual promotion of thrombosis with an increasing occlusion of pseudoaneurysms taking place over several weeks to months. This delay thrombosis process is part of its restriction since there are chances of possible rebleeding during this period due to delay in filling the aneurysm as well as postoperative intracranial hematomas that are among complications of dual antiplatelet therapy (16,17)

Outcomes comparison

Focusing on the review of outcomes of both microsurgery and endovascular management in a comparative manner one will find a complex interrelationship and trade-offs between efficacy and long-term durability and preservation of the parent artery. The main complications of intracranial pseudoaneurysms are re-rupture and thus rebleeding of the vascular lesion. Thus, surgical trapping by creating a bypass is the most conclusive treatment option, considering the possible effectiveness and sustainability of permanent curing, along with the high rates of occlusion not less than 100 percent, and low risk of recurrence (1). In comparison to endovascular reconstruction methods, which show inconsistency in regard to the long-term durability that depends on the respective techniques that are applied. Coiling-based techniques offer immediate treatment as needed for acute settings but raise concern with recanalisation rates and neointima formation (18,20) especially when compared to the rates for true aneurysms, they reveal higher rates, in part due to the friable nature of pseudoaneurysms walls (21). Parent vessel occlusion offers similar result as surgical trapping but is applicable in a minority of cases with redundant circulation. While flow diversion strategies show promising results with complete occlusion rates at 12 month following ups but poses risks of ruptured lesions due to absence of immediate thrombosis of the pseudoaneurysm or exclusion, and thus complete occlusion that takes weeks to occur. Parent Artery Preservation represents the most critical difference between treatment modalities (1,15). Endovascular reconstructive approaches have a significant advantage in achieving parent artery preservation in >90% of cases, limiting the complexities and risks associated with bypass procedures as evidenced by the landmark single-center comparative study by Shi et al, comparing patients parent artery preservation in endovascular cohort 91.7% versus 20% in microsurgery cohort (8). Further, precise localization of the PA as well as assessment of the vasculature was demonstrated in endovascular approaches (6). Compared to surgical approaches which require the sacrifice of the parent vessel and thereby requirement of bypass procedures result in higher associated risks. This advantage of endovascular therapy with its ability to preserve the anatomy of the parent vessel makes it a stronger preference as it avoids bypass procedures and failures that could result in neurological deficits (4,24).

Complications and risks

One of the fundamental aspects that demonstrate the discrepancy between a non-invasive approach to procedure or an invasive-like procedure with endovascular versus surgical management is the profile of complications. On the one hand, in terms of surgical management, due to the invasion of craniotomy along with vascular reconstruction and the intricacies of the latter, it is predisposed to increases in mortality and morbidity (24). The possible complications include ischemic stroke caused by temporary obstruction of the vessel or clipping in the wrong positions of certain cranial nerves or palsies caused

by manipulation in the cramped skull base (6,15). Postoperative infections and related problems prolong the recovery and admission at the surgical management.

Less invasive endovascular complications on the other hand do have minimal periprocedural morbidity and mortality (0-10%) yet it also has its own risks based on thromboembolic events and ischemic strokes due to clot formation on devices or distal emboli constating the major concern and complication of treatment(4).Flow -diverters and covered stents face this dangerously unavoidable consequence of occluding small perforating arteries or large side branches occluded by the device itself due to large metallic surface area and the dual antiplatelet therapy(25). Involved arteries comprise occlusion of ophthalmic artery up to 15 percent of cases and cavernous ICA pseudoaneurysms (19). In addition, complications related to devices have strong effects even though the complications are not as prevalent. The described complications like the migration of the devices, malposition (26), or even failure and the combination with DAPT provide peculiar complications in acute settings and in the patients who have different emergent clinical needs including those who need the subsequent surgeries and patient related factors (15).

Patient and aneurysm factors influencing choice

The optimal treatment strategy depends on multiple factors including technical expertise and available hospital resources that dictates the careful consideration of patient and aneurysm-specific factors, with the overall clinical condition being priority. The patient-related influences in the treatment choice include age, comorbidities and neurological condition (15). Less invasive procedures like endovascular techniques are better tolerated and thus reserved for elderly patients, patients with significant comorbidities, prior use of antiplatelets or anticoagulants however endovascular treatment for the elderly becomes challenging with the presence of tortuous arteries (15,27). Younger patients can be treated with definitive measures, such as microsurgery, because of ease of access and lifetime occlusion rates, which has been performed on ruptured anterior circulation bifurcation aneurysms (28). Aneurysmal Factors influencing choice of treatment modality include pseudoaneurysm location size, and morphology. In deep inaccessible places, such as the cavernous portion of the internal carotid artery or cavernous sinus, IPAs are normally treated using endovascular procedures (15).While endovascular coiling is suitable for saccular IPA with smaller narrow neck, large fusiform IPA with associated hematoma or dissecting IPA is better suited for flow diverter or surgical management to allow removal of the clot and simultaneous treatment of the lesion. However infectious pseudoaneurysms utilize both endovascular therapy as a temporary or bridging procedure and definitive management with surgical approaches, which allow for its tissue sampling and debridement (2,6). Institutional factors also influence treatment selection. The choice of minimal invasive endovascular techniques over microsurgery is dependent on depending on availability of experienced surgeons and hospital resources and economic impact. This is especially true for developing countries which already run on low availability of resources in both expertise and resources (29,30).

Limitations of current evidence

Intracranial pseudoaneurysms are uncommon and therefore present major drawbacks to developing evidence and, subsequently, standardization of treatment. Limitations in comparison of both endovascular and surgical management can be attributed to the study design, development of selection bias, and heterogeneity. In terms of study designs available, conducting randomized control trials is unfeasible, largely due to their rarity; thus, majority of evidence stems from retrospective case studies and institutional experiences which leads to significant risk of selection bias(12) . For instance, endovascular studies may include clinical cases with surgically challenging locations such as cavernous sinus that is known as difficult surgery targets versus surgical therapy studies that include patients with large hematomas and poorer clinical grades or failed endovascular treatments. This introduces significant heterogeneity in reporting and limits meta-analysis that is needed for comparisons between studies, as variability in outcome definitions, follow-up protocols, and thus standardization of treatment becomes challenging (26,27,28)

Clinical implications

The treatment of intracranial pseudoaneurysms involves multidisciplinary multifactorial study with a personalized process and anti-selections of therapy depending on the thorough evaluation of the peculiarities of a patient and aneurysm. Initially, endovascular treatment is recommended as first-line strategy for majority of IPA given its lower morbidity, lesser recovery time and most importantly preservation of parent artery. Surgery is not obsolete but plays a primary role as therapy recommended in management of complex cases such as large hematoma cases and as salvage therapy for failed endovascular treatments. Both treatment modalities may benefit from Quality improvement initiatives by establishing multicenter registries as well as encouraging specialized training and maintenance of expertise to combat the limitations imposed by the rarity of these lesions and provide higher quality of evidence for clinical practice guidance (30).

Conclusion:

The reversal of an intracranial pseudoaneurysm is not always seen as the best way of treating each situation. Less invasive insertion methods are also used by placing coils, filling, glue embolization, or flow diverters. These methods have gained popularity over the previous year's given that they have reduced recovery times two to threefold. They especially apply to aneurysms when emergency treatment of hemorrhage is needed and in locations where open surgery is not applicable. Nevertheless, surgical intervention is not totally gone. Irregularly shaped, immaturely large and failing to respond well to the earlier interventions, surgery tends to be a more feasible response. In these abnormal situations clipping or bypassing will result in protracted recuperation times. Healthcare providers should take into account all the details since the characteristics of the patients differ significantly, such as the appearance of the aneurysm, its location, or the general health of the patient. At the time when there is collaboration between endovascular experts and neurosurgeons the chance that the endeavor will be successful increases. Nevertheless, surgery is also important in treatment of patients regardless of the emergence of endovascular technology. The determinant is finding the best strategy or a combination of the two approaches upon which to maximize patient recovery.

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