Minimally Invasive Neurosurgery for Vascular Lesions

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KEYWORDS

- Keyhole craniotomy • Aneurysm surgery • AVM
- Arteriovenous fistula • Cavernoma

Intracranial vascular lesions are known to affect 2% to 4% of the population, predisposing those affected to a lifetime risk of hemorrhagic stroke, ischemia, focal neurologic deficits, or epileptic seizures. These lesions constitute a heterogeneous group, with different lesion types characterized by distinct biologic mechanisms of pathogenesis and progression. In this article, the minimally invasive management of intracranial aneurysms, arteriovenous malformations (AVMs) including arteriovenous fistulas (AVFs), and cavernous malformations are discussed.

ANEURYSMS

The annual incidence of subarachnoid hemorrhage (SAH) from a ruptured intracranial aneurysm in the United States is approximately 1 case per 10,000 persons, yielding approximately 27,000 new cases of SAH each year.[1,2] Autopsy studies indicate a prevalence of intracranial aneurysms of between 1% and 5% in the adult population,[3] which translates to 10 million to 12 million persons in the United States.[1] SAH is more common in women than in men (2:1),[4] and its incidence increases with age, occurring most commonly between 40 and 60 years of age (mean age $\geq$50 years).[5,6] An estimated 5% to 15% of cases of stroke are related to ruptured intracranial aneurysms.[7]

The most common presentation of intracranial aneurysm is rupture leading to SAH. Given the increased availability of noninvasive imaging techniques, aneurysms are increasingly detected before rupture. An unruptured aneurysm may be asymptomatic and thus be found incidentally, or it may be diagnosed on the basis of symptoms.[8] Unruptured aneurysms may cause symptoms by exerting mass effect, leading to cranial nerve palsies (eg, the rapid onset of a third nerve palsy caused by the enlargement of an aneurysm of the posterior communicating artery[1]) or brainstem compression.[9] Aneurysms presenting with SAH tend to bleed again. Two percent to four percent of aneurysms hemorrhage again within the first 24 hours after the initial episode, and approximately 15% to 20% bleed a second time within the first 2 weeks.[10,11] Aneurysmal SAH has a 30-day mortality rate of 45%; an estimated 30% of survivors will have moderate to severe disabilities.[12] Aneurysm repair performed after an SAH is generally associated with higher mortality and morbidity rates than elective clipping in unruptured aneurysms.[13] Because of the high risk of rebleeding within the first week, increased treatment risks during the vasospasm period between the 4th and 14th day, and limited medical treatment options for vasospasm in patients with unsecured aneurysms, early treatment (surgical or endovascular) within the first 72 hours following SAH is generally recommended.[13–15] The risk for bleeding in nonruptured aneurysms depends on aneurysms' size and configuration, localization, and endogenous factors.[16–18] Presently, surgical or endovascular treatment of unruptured aneurysm is recommended in patients having suffered from an SAH caused by another aneurysm and patients bearing symptomatic and/or larger aneurysms (>12 mm). In young patients with positive endogenous factors and/or irregular aneurysm shape, treatment is recommended also in smaller aneurysms.

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Surgical Treatment

The goal of surgical treatment is to completely exclude the aneurysm from the circulation, without impairment of the cerebral perfusion. This treatment may be enabled by elective clipping or wrapping of the aneurysm or trapping of the affected area of the carrying vessel. The latter may need to be combined with a bypass to maintain sufficient cerebral perfusion. Surgical treatment may also be combined with endovascular techniques, such as stenting and coiling, and may be necessary after technically inadequate endovascular treatment.

Minimally invasive aspects of aneurysm surgery include methods for limiting the exposure of brain tissue using keyhole craniotomies for definitive treatment of ruptured and unruptured aneurysms, reduction of number of required procedures and craniotomies in patients with multiple aneurysms, and reduction of hospitalization time and reconvalescence.

Minimally invasive approaches suitable for aneurysm surgery are the eyebrow, pterional, subtemporal, retrosigmoid, and interhemispheric minicraniotomies (see the article by Garrett and colleagues elsewhere in this issue for further exploration of this topic).

Critical steps involved with the surgical approach to an intracranial aneurysm are sufficient visualization of the associated proximal and distal vessels, early control of the feeding vessel, understanding of the individual pathoanatomy and hemodynamics of the specific aneurysm being treated, dissection of the aneurysm neck, manipulation of the aneurysm dome, selection of appropriate instruments and implants for the definitive treatment, and intraoperative control of the result.

Technical Considerations

Important technical requirements for minimally invasive aneurysm surgery are a high-quality operating microscope that is capable of indocyanine green (ICG) angiography, endoscopes with 0° and 30° viewing angle, and micro-Doppler sonography with 1 and 2 mm probes. In more complex aneurysms, where temporary occlusion or even cardiac arrest is anticipated, neurophysiological monitoring (somatosensory evoked potential [SSEP], motor evoked potential [MEP]) should be performed. Customized clip design and clip appliers are also very helpful to gain sufficient overview in limited craniotomies (**Fig. 1**).

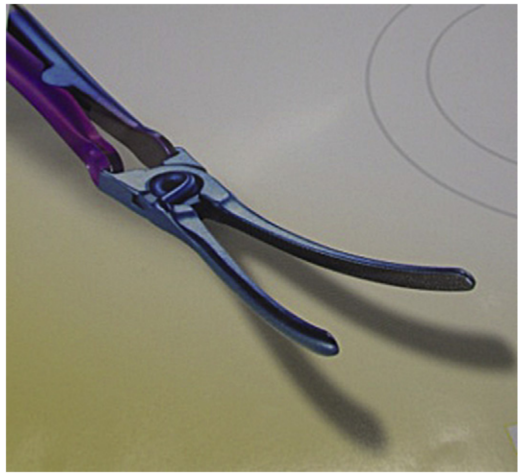

Fig. 1. Special clip applier for limited craniotomies, with fixation of the clip from inside leading to minimal obstruction of the operating field (Peter Lazic, Tuttlingen, Germany; with permission).

Consideration of all described aspects of minimally invasive aneurysm surgery in combination with proper use of intraoperative modern technology enables successful and safe treatment, with limited exposure in almost all patients with unruptured and ruptured aneurysms.

Specific Surgical Considerations and Illustrative Cases

Anterior circulation aneurysms

The vast majority (90%) of all intracranial aneurysms are located in the anterior circulation, specifically at the anterior communicating artery (AComA) in 30%, the internal carotid artery (ICA) including the posterior communicating artery (PComA) in 30%, and the middle cerebral artery (MCA) in 20%.[11]

The specific challenge for AComA aneurysms is for example the need for control of 2 proximal vessels, that is, the ipsilateral and contralateral A1 segments; for MCA aneurysms it is the high risk of subsequent stroke after temporary occlusion; and for some ICA aneurysms it is the difficulty with obtaining proximal control. However, even complex and large aneurysms may be managed safely through minimally invasive approaches. Preferred approaches for aneurysms of the anterior circulation are the supraorbital keyhole craniotomy (AComA, ICA, MCA), pterional minicraniotomy (ICA, PComA), and the interhemispheric minicraniotomy (pericallosal artery). An example of the technique for minimally invasive management of aneurysms of the anterior circulation is demonstrated in a patient with a previously endovascularly coiled AComA aneurysm.

Case 1: A 52-year-old man suffered from an SAH (Hunt & Hess [H&H] grade I). Angiography revealed an AComA aneurysm (**Fig. 2**A), which was treated by coiling (see **Fig 2**B). A surveillance angiogram 18 months later revealed reopening of