Microsurgical Treatment of Cerebral Aneurysms in Helsinki 2008 – a review

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"Every man owes it as debt to his profession to put on record whatever he has done that might be of use to others."

Francis Bacon (1561-1626)

Abstract

Object

Increasing use of endovascular techniques is shadowing the most recent developments of microvascular neurosurgery. This paper is focused on our large experience on open microsurgery of intracranial aneurysms. Our strategy is to perform simple, clean, and fast microsurgery while preserving normal anatomy.

Methods

Microneurosurgical techniques, initially introduced by Prof. Yasargil, have been modified by the senior author (JH) during surgery on more than 3000 aneurysm patients at two neurosurgical departments in Finland, Kuopio and Helsinki, which have altogether treated over 10000 aneurysm patients since 1936. Here we review our experience in treatment of both anterior and posterior circulation aneurysms.

Results

Most of the anterior circulation aneurysms are treated using the lateral supraorbital (LSO) approach, a less invasive frontally located modification of the classical pterional approach, while only distal anterior cerebral artery aneurysms (6 % of our patients) are operated using interemispheric approach. In the posterior circulation, basilar bifurcation aneurysms are approached either via the subtemporal or the transsylvian route depending on the height of the basilar tip, while most of the vertebral and posterior inferior cerebellar artery (PICA) aneurysms, if located at least 10 mm above the foramen magnum, can be treated by simple lateral suboccipital craniotomy without far lateral extension. The midbasilar region is the most difficult to approach by open surgery, and extensive skull base approaches are needed.

Conclusion

In our experience, microsurgical clipping is an effective and long-lasting method for treating intracranial aneurysm. With proper treatment strategy, microsurgical technique, and adequate training complication rate can be kept low.

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Key Words

lateral supraorbital approach, microsurgical technique, cerebral aneurysm, anterior circulation, posterior circulation, skull base surgery

Running title: Principles for aneurysms surgery

Abbreviations

ACA: anterior cerebral artery

CT(A): computed tomography (angiography)

DSA: digital subtraction angiography

ICG: indocyanine green

LSO: lateral supraorbital

MCA: middle cerebral artery

PICA: posterior inferior cerebellar artery

Introduction

Since the introduction of endovascular techniques by Serbinenko and the Russian school, many alternative methods have been developed to treat intracranial aneurysms, culminating in the development of coils by Guglielmi (12, 13, 37, 38, 41). Lately, strong increase in the use of the endovascular techniques has overshadowed the most recent developments of microvascular neurosurgery. As endovascular techniques remain expensive, and not all aneurysms can be treated with them, there is still place for high quality microsurgery. Here we review our large experience of treatment strategies in these challenging and difficult lesions. Our general philosophy in both anterior and posterior circulation aneurysms is to apply microsurgical techniques which are "simple, fast, and preserving normal anatomy". This surgical strategy originates from the microneurosurgical techniques introduced by Prof. Yasargil which have been modified and further developed by the senior author (JH) while operating on more than 3000 aneurysm patients at two of the five neurosurgical centers in Finland, Helsinki and Kuopio, which have altogether treated over 11 000 patients with intracranial aneurysms since 1936 (18, 19, 24, 26, 27, 47-49). According to our policy microneurosurgery should be as little invasive as possible, fast, with minimal retraction and manipulation of the brain; similar to the approach of the endovascular surgeons (19). We rely on careful preoperative planning and subsequent selection of small and focused exposures towards the aneurysm where pre- and postoperative imaging is done extra-arterially using tomography angiography (CTA). The high level of treatment originates not only from technical advances, but also from high case load and cumulative experience obtained by centralizing patients with cerebrovascular lesions in specialized centers. This approach has been serving our Finnish patients well.

Materials and Methods

We review the microsurgical experience of the senior author (JH) at two Finnish Neurosurgical University Hospital, Kuopio and Helsinki, which have treated more than 11.000 aneurysms patients since 1936, more than 10.000 of them during the microsurgical era beginning in mid 70's in this country. The personal microsurgical experience of the senior author has been collected since his first aneurysms operation in 1976.

Patients and aneurysms

All patients of Southern and Eastern Finland come, without selection bias, to our neurosurgical units from a catchment area of nearly 3 million people. Most of the patients with ruptured aneurysms (80%) are operated on during the first 24 hours after bleeding. Cyclocaprone, to prevent rebleeding, and nimodipine (p.o. or i.v.), to prevent vasospasm, are used in all patients with ruptured aneurysm. During the last years, nearly half of the aneurysms operated on are unruptured ones. Distribution of intracranial aneurysms in the Finnish population according to their site of origin is represented in Table 1.

Table 1

Frequency of aneurysms sites in the Finnish population, Helsinki and Kuopio

Location of the aneurysms	%
Middle cerebral artery	38%
Anterior communicating artery	26%
Internal carotid artery	23%
Pericallosal artery	6%
Vertebrobasilar arteries	7%

Radiological examinations

Since the late 70's, CT has become the primary diagnostic tool for detecting subarachnoid hemorrage (SAH), and to disclose intracerebral hematoma (ICH) or hydrocephalus. At our department, digital subtraction angiography (DSA) has been replaced by CTA since the year 2000 as the primary imaging method for intracranial aneurysms (29, 31). CTA is fast, noninvasive, and provides information about bony landmarks. 3D CTA images provide surgical view of the aneurysms (Fig. 1) (28). Postoperatively all patient undergo CT and

CTA. In case of complex, giant or previously coiled aneurysm we still perform DSA.

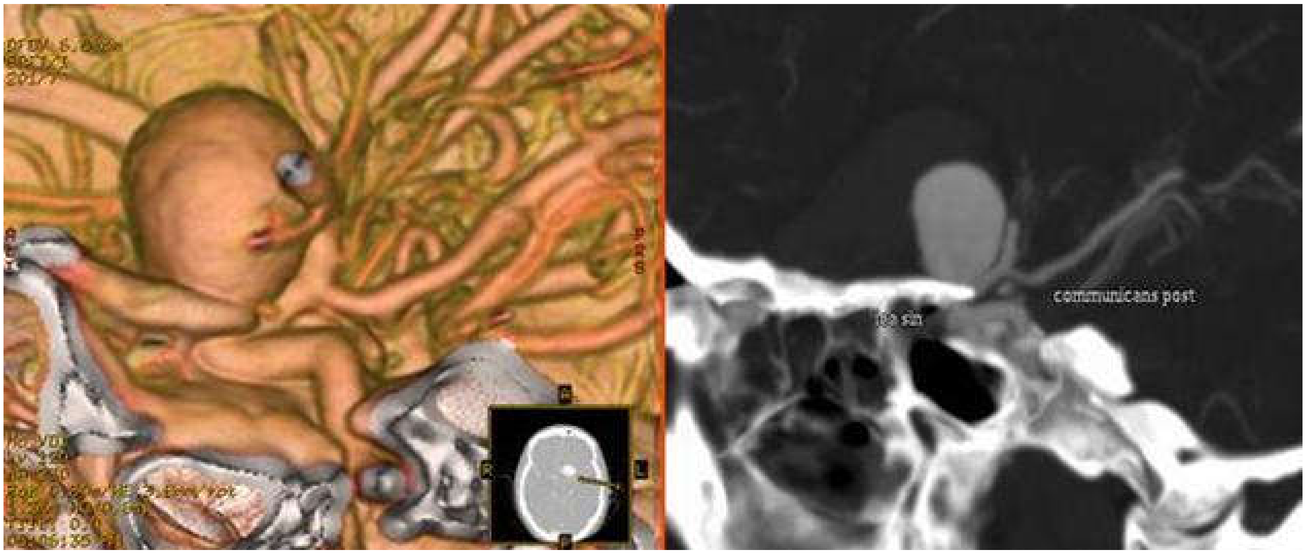

FIG. 1. 3D and 2D computed tomography angiography (CTA) showing the relationship between a left carotid-ophthalmic aneurysm and the anterior clinoid process.

Surgical Approaches

Anterior circulation's aneurysms

Nearly all aneurysms of the anterior circulation except those of the pericallosal artery have been treated by using the lateral supraorbital approach (LSO). The LSO approach has been used by the senior author (JH) for more than 20 years in treatment of both vascular (2-6, 19, 22, 24) and neoplastic lesions of the anterior cranial fossa (22). This approach is a less-invasive modification of the pterional approach. It is located more frontally with the bone flap of about 3 – 4 cm in diameter. It has been described in detail previously (22), and demonstrated on video in our article on M1 aneurysms (M1As) of the middle cerebral artery (MCA) in Surgical Neurology (4-6).

Briefly, the head fixed to the Sugita frame is 1) elevated clearly above the cardiac level; 2) rotated 15º to 30º toward the opposite side; 3) tilted slightly downward to have a good exposition of the deeper part of the anterior circulation (Fig. 2). The exact head position depends on the location of the aneurysm (3-6, 19, 20, 24, 32-36). It is our practice to adjust the position of the fixed head and body during the operation as needed (22, 24). After minimal shaving and injection of a local anesthetic with a vasoconstrictor included the skin incision is placed behind the hairline usually not longer than 7-9 cm (Fig. 3). One-layer skin-muscle flap is retracted frontally with spring hooks, and the superior orbital rim and the anterior zygomatic arch are exposed (Fig. 4). The upper and more anterior part of the temporal muscle is split and retracted towards the zygomatic arch. The extent of the craniotomy depends on the surgeon's experience and preferences. It may be tailored according to the location and the size of the aneurysm. Usually, a small LSO craniotomy is all that is necessary. A single burr hole is placed just under the temporal line in the bone, i.e., the superior insertion of the temporal muscle. A bone flap of 3x3 cm is detached mostly by side-cutting drill, and the basal part can be drilled before lifting (Fig. 5). Dura is incised curvilinearly with the base sphenoidally. Dural edges are elevated by multiple stitches, extended over craniotomy dressings. From this point on, all surgery is performed under the operating microscope, including the skin closure; our record in performing this skin to skin in an unruptured MCA aneurysm is 25 minutes with uneventful recovery of the patient. The faster operation is not the major goal in itself but allows more operations to be performed in a single OR during one day being thereby more cost effective.

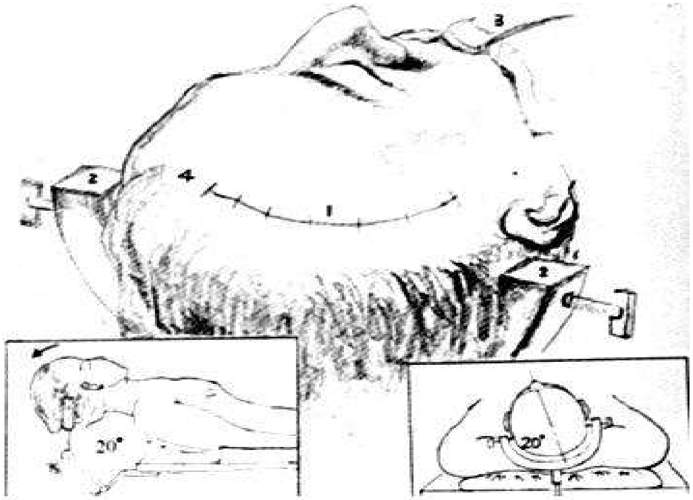

FIG. 2. Position and skin incision to perform the lateral supraorbital (LSO) approach.

FIG. 3. Skin incision to perform LSO approach, 7-9 cm are enough.

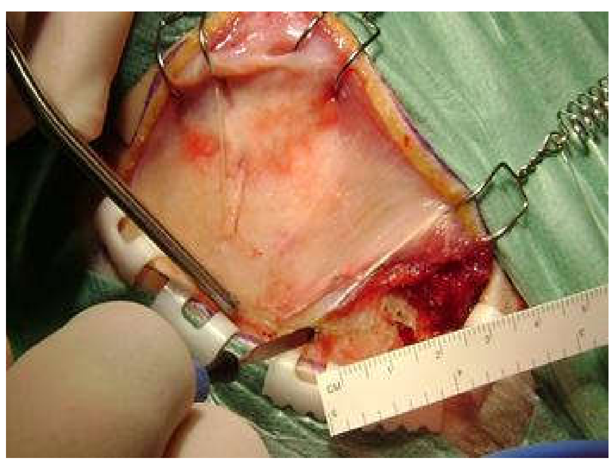

FIG. 4. The antero-superior part of the temporal muscle is splitted to expose the superior orbital rim and the anterior zygomatic arch.

FIG. 5. The craniotomy in the LSO.

Basilar tip aneurysms, with superior and anterior projection, located 10 mm or more above the posterior clinoid process can be treated by using the LSO approach.

To be able to perform this approach in unruptured and in ruptured aneurysms it's mandatory to have a slack brain to minimize brain retraction and to avoid extensive and usually unnecessary skull base approaches (19). A slack brain is achieved by a modern neuroanesthesia (39), and equally important are the surgical tricks for removal of cerebrospinal fluid (CSF) by opening the lamina terminalis and /or basal cisterns, or through puncturing the lateral ventricles or less invasively by lumbar drainage (3-6, 18, 19, 24, 26, 27).

Distal anterior cerebral artery (ACA) aneurysms are treated by using an interhemispheric approach after a small right frontal craniotomy (32-36).

Posterior circulation's aneurysms

Personal surgical experience of the senior author in posterior circulation's aneurysms accounts more than 400 aneurysms patients, and the institutional one exceeds 1.000 patients (16, 17, 20, 21, 25). All basilar tip aneurysms located below the posterior clinoid process and those with posterior projection but 10 mm or more above the posterior clinoid process are treated by using the subtemporal approach. This approach has been used by the senior author since the 1980s and was refined during the training period with Profs. Drake and Peerless (7, 21). They used the subtemporal approach in 80% of 1234 basilar bifurcations patients treated between 1959 and 1992.

Briefly, the head fixed with Sugita frame is 1) elevated above the cardiac level; 2) upper shoulder retracted. Right not dominant side is preferred unless the projection or complexity of the aneurysm, scarring from earlier operations, a left oculomotor palsy, a left sided blindness or a right hemiparesis, requires a dominant side approach. Spinal drainage or ventriculostomy are mandatory; usually 50-100 ml CSF are enough to achieve a slack brain before the dura is opened. The subtemporal approach can be converted to a pterional or posterior temporal bone flap if necessary. Skin incision is linear, 1cm anterior to the tragus, starting above the zygomatic arch up to 7-8 cm. Small craniotomy (usually 3x3 cm) is performed and the dura is opened (Fig. 6). The retraction of the temporal lobe should be slowly increased. The trick of the proper use of the subtemporal approach lies in getting quickly without heavy compression of the temporal lobe enough space to come to the tentorial edge.

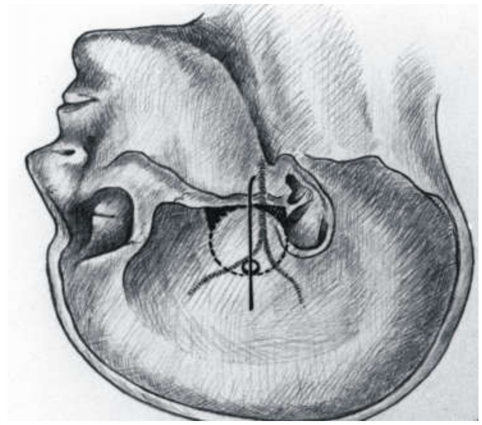

FIG. 6. Head position, skin incision and craniotomy to perform the subtemporal approach

The elevation of the uncus with the retractor exposes the opening to the interpeduncular cistern and the third nerve. This can be relaxed by the arachnoidal bands, and its palsy can occur after only a minimal dissection or sometimes surprisingly no palsy even after a long-lasting manipulation. Even with the uncal retraction of the third nerve, the opening into the interpeduncular cistern remains narrow. It can be widened by the original simple maneuver of placing a suture in the edge of the tentorium in front of the insertion and the intradural course of the fourth nerve. This suturing has been replaced by the use of a small Aesculap clip (23). If necessary, the tentorium is divided and fixed also with a small Aesculap clip(s) to get better access for temporary clipping of the basilar artery. In cases with a low lying basilar bifurcation the tentorium division remains absolutely necessary, and a more posterior approach with a larger flap is planned already at the beginning of the operation.

The arachnoidal bands are opened with further removal of CSF; the peduncle is retracted with dissecting instruments and cottonoids to see the basilar artery and the base of the aneurysm. The posterior clinoid is not removed as the work in this position is lateral (posterior) to it.

The midbasilar aneurysms are the most difficult to reach requiring extensive skull base approaches. Transpetrosal presigmoid approach can be used with the danger of cranial nerve injury or CSF leakage problems and prolonged operative time.

Most of the vertebral PICA aneurysms (usually 10 mm or more above the foramen magnum) can be treated by a simple lateral suboccipital craniotomy, and there is no need for a far lateral extension (16).

Temporary clipping in anterior and posterior circulation's aneurysms

For safe dissection of the aneurysm we use in 90% of cases short time temporary clipping of the parent artery(ies). When this is not suitable, we sometimes use a preoperative application of endovascular balloon in the parent artery. Recently, we have used intravenous Adenosine in basilar tip aneurysms surgery to have a few seconds of cardiac arrest allowing the surgeon to safely clip the aneurysm (11, 15).

Intraoperative monitoring

We have used in all aneurysms surgery the intraoperative videoangiography with indocyanine green (ICG) for three years, that has been very useful to verify the flow in the parent artery, perforating branches and inside of the aneurysm (2) (Fig. 7). In those with calcified or atherosclerotic wall is not useful and a careful checking of the base is needed before opening and coagulating the sac after clipping. Microvascular doppler is also always used. DSA is used to document the perfect clipping of those complex or blister-like aneurysms (29).

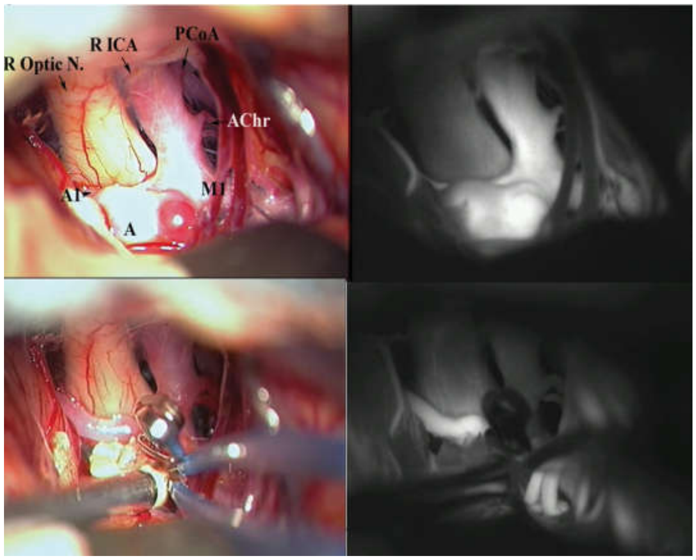

FIG. 7. Intraoperative angiography with indocyanine green (ICG) view of internal carotid artery bifurcation aneurysm before and after clipping

Bypass techniques

We have been using bypass techniques rather scarcely, and only in the last 11 years. 70 patients have had bypass (including the high flow ELANA bypasses) surgeries to treat their aneurysms. We think that these methods need refinement, and our goal is to develop as simple as possible bypasses done in local anesthesia with very short operative times.

Impractical aneurysms

Large or giant saccular and all non saccular, or calcified and trombosed aneurysms still present considerable problems and challenge in their treatment. With the growing number of the endovascular procedures we also see more incompletely coiled difficult aneurysms that may need open microsurgery for their ultimate treatment. This necessitates dedicated neurovascular centre to keep up and develop microsurgical skills.

Discussion

Through the years since the 80's the so-called 'lateral supraorbital' approach (LSO) was developed (22). In most anterior circulation aneurysms, our simple LSO approach has served the patients well. Exposure of most anterior circulation aneurysms, even of MCA aneurysms (the most common aneurysm in the Finnish population) (Table 1), can be performed by using the LSO approach. Further, it is our experience that removal of the orbital roof causes swelling of the orbital contents and thereby takes much (or all) of the extra space achieved. This is the reason we did not adapt any of the different modifications of the orbitozygomatic approch. Distal anterior cerebral artery aneurysms (6 % of our patients) require naturally a different approach: a small frontal paramedian, nearly always right sided, craniotomy (32-35).

Most of vertebral PICA aneurysms (10 mm or more above the foramen magnum) can be treated by simple 'tic' (lateral suboccipital) craniotomy, and there is no need for a far lateral extension (16). The midbasilar region is the most difficult to approach by open surgery, and therefore extensive skull base approaches have been developed (25). If necessary, transpetrosal approaches can be used but their use should be limited because of the possibility of many cranial nerve or CSF leakage problems and not to mention a prolonged operative time (19). When using the simple subtemporal route, a well functioning lumbar drainage is a must to avoid temporal lobe damage, when under retraction during surgery and also a quicker operation thereby per se reducing the retraction time (21, 25).

If needed, anterior and posterior clinoid processes are removed nowadays simply with the help of an ultrasonic aspirator (Sonopet Omni, Model UST-2001 Ultrasonic surgical system, Synergetics™, Inc., Miwatec CO., LTD, Kawasaki, Japan). The room achieved to improve proximal control, or to free the base of the aneurysm, is gained with Sonopet more safely as compared to drilling, and is very useful in treating parasellar carotid aneurysms or those of the basilar tip (19).

With the increasing use of endovascular surgery the number of those complex aneurysms that need further surgical treatment is growing. The coils make the aneurysm rigid, obscure the surgical field and reduce the room for applying the clip increasing the intraoperative rupture of the aneurysms. Sometimes it is necessary to remove the coils to gain space, and free the base of the aneurysm, and this can be dangerous because part of the coils can penetrate or are attached to the wall of the aneurysm and /or the parent artery (Fig. 8).

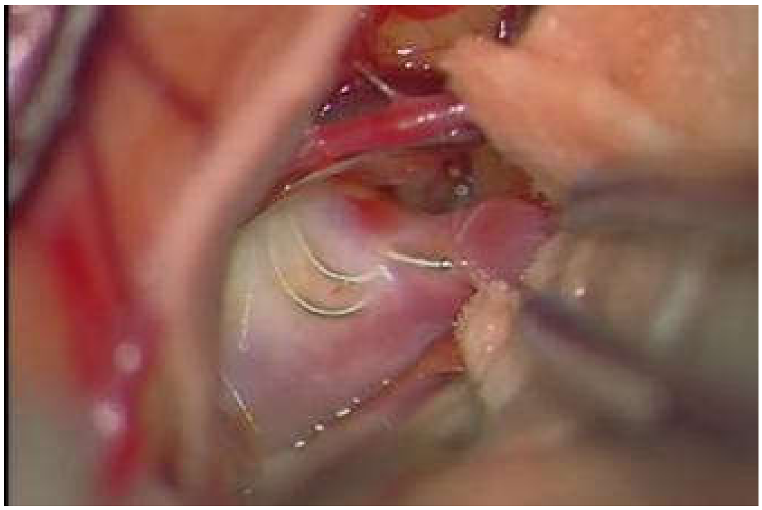

FIG. 8. Intraoperative view of large left middle cerebral artery (MCA) bifurcation aneurysm previously coiled. The coils are inside the wall of M1.

With the growing of the number of aneurysms treated by endovascular route, microsurgical experience is becoming less frequent. In order to minimize complications, cerebrovascular patients should be referred to only a few specialized centres. In 2008, we work in the era of minimal invasive techniques, but the future will be the era of the biologic solutions and identifying the aneurysms before their rupture. We are studying how to identify the gene defect carriers, and thereafter follow those patients who can develop these often deadly sacks. We also need to identify rupture prone ones with molecular imaging. This goal can be achieved by understanding the pathobiology of the aneurysm wall itself, e.g. the role of inflammation in the growth and rupture to be able to image molecular changes (19). The research on the aneurysm wall has just began, and will eventually make both microsurgical or endovascular approach complete obsolete. In fact, we believe that in a few decades many, if not most, aneurysms will be treated by local delivery of some agents to strengthen the aneurysm wall, and eventually with pharmaceutical therapy (1, 8-10, 14, 30, 40, 42-46).

Future trend

In the upcoming years we need to develop very simple techniques both low flow or high flow bypasses for combined treatment of many complex aneurysms. At the same time we will stop using some of the most extensive skull base approaches in favor of minimally invasive approaches " Simple, fast, preserve normal anatomy," is our universal goal. The best time to treat an aneurysm, irrespective of the treatment method, is before it ruptures. There is already some progress towards this directionon with more and more unruptured aneurysms being treated. Once we obtain some simple and inexpensive method to identify unruptured aneurysms in the large population, this will improve the management outcome of aneurysm patients more than any technical innovation or improvements in surgical skills .

Conclusion

In our experience, microsurgical clipping is an effective and long-lasting method for treating intracranial aneurysms. Our strategy is to perform simple, clean, and fast microsurgery while preserving normal anatomy. This policy is serving our patients well.

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