The Supraorbital Endoscopic Approach for Aneurysms

Robert Reisch1, Gerrit Fischer2,3, Axel Stadie4, Ralf Kockro1, Evaldas Cesnulis5, Nikolai Hopf6

Key words
- Intracranial aneurysms
- Keyhole neurosurgery
- Minimally invasive neurosurgery
- Supraorbital craniotomy
- Transcranial endoscope-assisted microneurosurgery

Abbreviations and Acronyms
ISAT: International Subarachnoid Aneurysm Trial
MCA: Middle cerebral artery
mRS: Modified Rankin scale
TEAM: Transcranial endoscope-assisted microneurosurgery

INTRODUCTION
The initial data from the International Subarachnoid Aneurysm Trial (ISAT) published in 2002 showed a significant superiority of endovascular coiling compared with surgical clipping as defined by the proportion of patients dead or disabled at 1 year in a carefully selected group of patients deemed suitable for either therapy (31). The results of this randomized, prospective, international controlled trial represented a landmark and radical change in the treatment of intracranial aneurysms (6, 9, 10, 28, 32, 33, 48). This significant superiority of interventional therapy is difficult to comprehend from a surgical point of view, particularly after comparison of both methods. Using surgical exposure, operative removal of blood clots with rinsing and cleaning of the subarachnoid spaces may decrease the risk of cerebral vasospasm and chronic hydrocephalus (14, 17, 20-22, 24, 29, 43, 46, 47, 53). With an additional opening of the lamina terminalis, the intracranial cerebrospinal fluid circulation also can be effectively improved (3, 27, 45). An operative approach allows adequate optical exposure of the individual anatomy of the aneurysm, with safe assessment of perforators and neighboring neurovascular structures (29, 33). In the case of rerupture of the aneurysm, immediate control of bleeding is possible (19). In addition, surgical clipping of the aneurysm offers a high reconstructive capacity of the vessel and high reliability of the occlusion resulting in minimal risk of postoperative rebleeding (39). Intervventional therapy cannot offer careful exploration of the subarachnoid spaces or the aneurysm.

OBJECTIVE: To review our surgical experience in minimally invasive transcranial endoscope-assisted microsurgical treatment of intracranial aneurysms, using the supraorbital keyhole craniotomy.

METHODS: The supraorbital keyhole approach was performed through an eyebrow skin incision in 793 cases for treatment of 989 intracranial aneurysms. Of patients, 474 were operated on after subarachnoid hemorrhage, and 319 were operated on under elective conditions. After lateral frontobasal burr hole trephination, a limited subfrontal craniotomy was created. To achieve adequate intraoperative exposure through the limited approach, endoscopes were used routinely. Surgical outcome was assessed using the modified Rankin scale.

RESULTS: The transcranial endoscope-assisted microneurosurgery technique was used routinely via a supraorbital approach. In 152 operations (19.1%), the endoscope provided important visual information in the vicinity of the aneurysm, revealing subsequent clip repositioning. The results of incidental aneurysms were excellent with a modified Rankin scale score ≤ 2 in 96.52%. The overall outcome of ruptured aneurysms was good with a modified Rankin scale score ≤ 2 in 72.2% of patients. There were no approach-related intraoperative or postoperative complications.

CONCLUSIONS: The minimally invasive supraorbital keyhole approach allowed safe surgical treatment of intracranial aneurysms, including after subarachnoid hemorrhage. The markedly improved endoscopic visualization increased the assessment of clip placement with ideal control of surrounding vessels including perforators for identification of incorrect clip position.

Several cases of insufficient aneurysm occlusion and postinterventional aneurysm recanalization were reported associated with increased risk of rebleeding (8, 33, 44, 49).

Nevertheless, operative therapy requires a surgical approach involving manipulation and retraction of the cortical surface and functionally relevant neurovascular structures. Almost all neurosurgical centers included in ISAT used standard microneurosurgical approaches to treat the ruptured aneurysm (31). We hypothesize that the reason for the significant superiority of endovascular coiling compared with surgical therapy in ISAT was the surgical morbidity and mortality of “standard,” large surgical approaches that were usually employed in this study (12). We believe that operative clipping as treatment of intracranial aneurysms can be
improved if surgeons are able to reduce its approach-related complications allowing minimally invasive and maximally effective aneurysm closure. The most effective solution for reducing intraoperative manipulation and retraction is the use of minimally invasive keyhole approaches in neurosurgery (7, 11, 23, 30, 35-38, 41, 49). However, marked reduction of the craniotomy size may result in different shortcomings during the procedure (39).

Because of the predefined direction of the operative exposure, the surgical corridor cannot be changed intraoperatively. Preoperative planning of the approach, including 1) thorough evaluation of preoperative diagnostic imaging of the lesion with respect to the individual anatomy of the patient, 2) definition of the size and site of the tailored craniotomy, 3) positioning of the patient according to the planned surgical corridor, and 4) skin-to-skin performance of the exact approach, is of particular importance in keyhole surgery of intracranial aneurysms (11, 12, 37, 46). An additional problem is the application and maneuverability of conventional instruments; the use of such instruments becomes limited if the size of the craniotomy is <15 mm (Figure 1). The application of special keyhole-adapted slender microsurgical instruments (e.g., clip appliers, scissors, suction devices) can effectively resolve this shortcoming (13, 35-37, 39, 42).

The most important disadvantage of small, less invasive keyhole approaches is the loss of intraoperative light and sight causing significantly reduced optical control during surgery (39). For the purpose of bringing light into the surgical field, the optical properties of surgical microscopes can be effectively supplemented by the intraoperative use of endoscopes (5, 7, 11-13, 15, 19, 23, 30, 37-39, 49). The main advantages of endoscopes are the increased light intensity, broadening of the viewing angles, enlarged focus range, and clear depiction of pathoanatomic details in close-up positions (Figure 2).

**MATERIALS AND METHODS**

We retrospectively evaluated 793 consecutive cases of intracranial aneurysms operated through a supraorbital keyhole craniotomy. There were 286 male patients and 524 female patients; patient age ranged from 14–82 years (mean age, 51.8 years). Of procedures, 474 were performed following an acute subarachnoid hemorrhage, and 319 were performed on patients with aneurysms that were found incidentally.

**Supraorbital Keyhole Technique**

After positioning the patient supine, anatomic landmarks of the frontal area, such as the supraorbital foramen, temporal line, level of the frontal cranial base, impression of the sylvian fissure, and zygomatic arch, are determined. Based on this careful anatomic surface orientation, the borders of the craniotomy and placement of the individual skin incision are defined.
After facultative use of neuro-monitoring, neuronavigation, and intra-operative imaging, the skin incision is started laterally from the supraorbital incisura within the eyebrow. To achieve an optimal cosmetic result, the incision should follow the orbital rim. To avoid frontal numbness, the skin incision should not extend medially to the supraorbital nerve. The subcutaneous dissection is continued in the frontal direction to achieve optimal exposure of the frontolateral region. The frontal muscle is cut with a monopolar knife parallel to the orbital rim in a medial-to-lateral direction (Figure 3A). As the temporal line is reached with the monopolar knife, the blade is turned 90 degrees. The incision follows the temporal line in a basal direction to the zygomatic process of the frontal bone. The temporalis muscle is dissected laterally; muscular mobilization is restricted to a necessary minimum (Figure 3B). The frontal and temporal muscles are retracted with sutures and hooks. A single frontobasal burr hole is made using a high-speed drill, avoiding penetration of the orbit (Figure 3C). After minimal enlargement of the hole with a thin Kerrison punch, a straight line is cut with a high-speed craniotome parallel to the orbital rim in a lateral-to-medial direction. The craniotomy is completed with a C-shaped incision. A limited craniotomy approximately 2 cm × 1.5 cm is created (Figure 3D). Careful removal of this inner bone edge can significantly increase the angle for visualization and manipulation. Small osseous extensions of the superciliary orbital roof, termed juga cerebra, should also be drilled extradurally to obtain optimal intradural visualization. The dura mater is opened in a simple C-shaped form and retracted in a basal direction, with minimal exploration of the brain surface (Figure 3F).

RESULTS

Using the supraorbital keyhole approach, 989 aneurysms in 793 patients were treated. There were 38 giant aneurysms, and 53 patients had space-occupying hematomas. Incomplete clipping was achieved in 19 cases (3.3%) with complex aneurysm anatomy, making additional interventional treatment necessary. The overall outcome of the acute cases on follow-up examination was good (modified Rankin scale [mRS] score ≤2) in 72.2% and poor (mRS score ≥3) in 27.8%. There were 319 operations performed on incidentally found aneurysms or as scheduled elective procedures. The surgical results were good (mRS score ≤2) in 96.6% and poor (mRS score ≥3) in 3.4% of the cases. The TEAM technique was...
used routinely. Endoscopes were used mainly to visualize the target area before and after clipping and rarely for actual endoscope-controlled clipping procedures. In 152 operations (19.1%), endoscopy revealed suboptimal or incorrect clip position with 1) residual neck, 2) narrowed vessel, or 3) occluded perforator, which was poorly seen or not seen at all with the microscope. In all cases, clip position was subsequently corrected; the markedly improved endoscopic visualization increased the likelihood of controlling ideal aneurysmal closure.

Illustrative Case
A 33-year-old woman whose sister had experienced severe subarachnoid hemorrhage underwent neurologic examination that included magnetic resonance imaging of the brain. Imaging detected bilateral aneurysms of the middle cerebral artery (MCA). There were no signs of subarachnoid hemorrhage.

Because of an irregular aneurysm surface, the family history, and the patient’s anxiety, the decision was made to treat the aneurysms. After performing digital subtraction angiography and an interdisciplinary discussion with the interventional neuroradiologists concerning the treatment modality, surgical treatment was chosen. Factors favoring surgery were the small size of the left-sided aneurysm, the unfavorable aspect ratio of the dome and neck of the right-sided aneurysm, and the patient’s request for surgical therapy (Figure 4A). Evaluation of magnetic resonance imaging and angiographic studies including three-dimensional planning software demonstrated that the left-sided aneurysm was proximally located near the early temporal branch. The right-sided aneurysm originated more distally at the MCA bifurcation (Figure 5). A right-sided supraorbital subfrontal exposure was chosen, treating both aneurysms through a single minimally invasive approach.

After performing the supraorbital keyhole approach (Figure 3), the suprasellar cisterns were opened, and the contralateral internal carotid artery was approached (Figure 6A). Gentle retraction was used; the elevator was placed between the frontal lobe and olfactory nerve, avoiding stretching the fila olfactoria. The contralateral sylvian fissure was opened, approaching the left-sided aneurysm.

Endoscopic inspection verified the aneurysm neck and its relationship to the early temporal branch (Figure 6B). A straight bayonet-shaped clip was placed under microscopic control, immediately closing the aneurysm. The use of a tube-shaft clip applier in the narrow corridor was crucial (Figure 6C). Complete aneurysm closure...
was controlled with the help of the endoscope (Figure 6D). The right sylvian fissure was opened without using the brain retractor. With microscopic visualization, the temporal branch of the MCA could not be visualized behind the dome of the aneurysm (Figure 6E); however, this hidden part of the field was ideally managed with endoscopic assistance (Figure 6F). After successful clipping without the use of a retractor (Figure 6G), the clip position was endoscopically controlled, confirming reliable aneurysm closure without narrowing the MCA bifurcation surrounding the perforators (Figure 6H). Patency of the MCA branches was confirmed with Doppler sonography and indocyanine green angiography. Using the TEAM technique, both aneurysms could be completely closed through the one-sided limited keyhole approach.

The patient had an uneventful recovery. Postoperative examination revealed no neurologic symptoms. Computed tomography scan showed no intracranial complications and optimal repositioning of the bone flap. Cerebral angiography showed complete closure of both aneurysms (Figure 4B). The patient was able to return to her previous employment, and the cosmetic result was excellent.

DISCUSSION

Since the beginning of neurosurgery, it has been widely accepted that exposure of brain tissue for several hours during surgery using extended craniotomies results in injury of the cortical surface by nonphysiologic surroundings, including room air, irrigation, cover material, and spatula pressure. In addition, it has been shown in many experimental and clinical studies that brain retraction causes significant intraoperative trauma to brain tissue and may lead to permanent neurologic deficits. To minimize brain retraction, various methods have been proposed (e.g., application of special anesthetic techniques to achieve brain relaxation, individual brain retractor systems, unusual positioning techniques of patient). However, the best retraction is no retraction. Careful choice of an adequate, least invasive
surgical approach with minimal brain exploration and dissection without the use of a retractor may result in a significant reduction of trauma to intracranial structures. With the excellent diagnostic capabilities of digital subtraction angiography, three-dimensional angiography, computed tomography, and MRI currently available, one can demonstrate and clarify the individual spatial anatomy of a patient including the smallest details. Anatomically suitable corridors for surgical dissection can be described and discussed in a meticulous preoperative planning procedure. With the knowledge of the individual anatomic details of a specific patient, it is possible to perform a tailored surgical procedure reducing the size of the skin incision, the craniotomy, and the extent of retraction and trauma to the brain surface to a minimum. In recent years, the ability to plan specific approaches has been improved further by using three-dimensional graphic tools of radiologic image processing consoles or planning software of surgical navigation systems. We have also worked extensively with virtual reality environments, allowing precise and comprehensive surgical planning with multimodality, patient-specific three-dimensional objects displayed in a spatial working environment.

The advantages of keyhole microsurgery may contribute to improved postoperative results, including shorter hospitalization time because of reduction of the risk for complications, such as bleeding or rebleeding with neurologic deterioration, leakage of cerebrospinal fluid, infection, scarring, and cosmetic disturbances. However, limited keyhole approaches cause a significant loss of optical control, especially in the deep-seated surgical field. The first neurosurgeons who realized the limitations of surgical microscopes and the advantages of endoscopic views during microsurgical procedures were Prott in 1974, when he performed endoscopic cisternoscopy of the cerebral aqueduct; Apuzzo et al. in 1977, when they introduced the so-called side-viewing telescope; and Oppel in 1981, when he applied intraoperative endoscopy during microvascular trigeminal decompression. All of these descriptions can be regarded as the initiation of endoscope-assisted microneurosurgery, which, along with other neuroendoscopic techniques, experienced an enormous revival in the 1990s. At this time, Perneeczky developed and refined the concept of endoscopic and endoscope-assisted neurosurgery using limited keyhole approaches in transcranial neurosurgery. As pioneer in minimal invasive techniques, Perneeczky became the teacher of countless residents and international fellows in the Neurosurgical Department of the University Mainz, Germany.

The TEAM technique enables neurosurgeons to approach deep-seated regions through narrow anatomic windows, without excessive retraction of sensitive neurovascular structures. The endoscopic pictures allow illumination and inspection of angles in hidden parts of the surgical field and, owing to the enormous optical depth of field of modern endoscopes, provide an almost three-dimensional aspect of anatomic structures. Frequent training of spatial eye-hand coordination, which is necessary for all endoscope-assisted microsurgical procedures, enables neurosurgeons to perform minimally invasive, maximally effective procedures. Rigid lens scopes are recommended for endoscope-assisted microsurgery because only the position of instruments with rigid shafts can be controlled precisely and because, at the present time, only lens scopes offer acceptable image quality. In addition, modern video and image processing technology with high-definition visualization is essential to achieve full benefit of endoscope-assisted microsurgery.

CONCLUSIONS

This article has provided a brief review of our experience with the endoscope-assisted suprabrow keyhole approach in surgical treatment of intracranial aneurysms. This method allowed safe intraoperative control of clipping of ruptured and incidental intracranial aneurysms. Because the limited approach-related trauma to the brain, postoperative results were favorable compared with the results of interventional treatment. Essential prerequisites of keyhole aneurysm surgery are 1) careful selection of cases, 2) accurate preoperative planning, 3) tailored placement of the clip, and 4) use of TEAM techniques. Intraoperative application of endoscopes is mandatory for adequate visualization, especially for control of clip placement and assessment of surrounding perforators. In 19.4% of our cases, endoscopy revealed suboptimal clip position with residual neck, narrowed parent vessel, or occluded perforator that was not clearly detected with the microscope. Endoscopic visualization increased markedly the likelihood of controlling optimal aneurysm closure and consequently achieving better surgical results.

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REFERENCES


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