Review

Henry W. S. Schroeder[a,]*

Transcranial endoscope-assisted skull base surgery – posterior fossa

Abstract: Endoscope-assisted microsurgery is a promising technique combining the advantages of the operating microscope with those of the endoscope. For lesions, which are visible in a straight line, the operating microscope, which provides a high resolution, excellent color fidelity, as well as stereoscopic vision, is the optimal visualization tool. For dissecting in deep and narrow surgical corridors and for working "around a corner", high-definition endoscopes with various angles of view are used to reduce the amount of retraction and skull base drilling. The endoscope-assisted microsurgical technique enables a safe surgery in the posterior fossa even when lesions are not visible in a straight line. Although the endoscope-assisted microsurgical technique reduces definitely the invasiveness of the approach, it still remains open whether it improves the results compared to standard microsurgery.

Keywords: Endoscope-assisted microsurgery; epidermoid meningioma; neuroendoscopy; skull base surgery; vestibular schwannoma.

[a]**Disclosure:** The author is consultant to Karl Storz GmbH & Co., Tuttlingen, Germany.
***Corresponding author: Henry W. S. Schroeder**, MD, PhD, Professor and Chairman, Department of Neurosurgery, Ernst Moritz Arndt University, Sauerbruchstr., D-17475 Greifswald, Germany, Tel.: +49-3834-866163, Fax: +49-3834-866164, E-mail: Henry.Schroeder@uni-greifswald.de

Introduction

After initially only being used in hydrocephalus, endoscopy has been established more and more in many fields of neurosurgery since the early 1990s. The endoscope can be the only visualization tool or can be used together with the microscope. The latter is the so-called endoscope-assisted microsurgical technique [7]. In my opinion, this combination of the microscope and endoscope provides many advantages compared to the pure microsurgical operation. Especially, in the posterior fossa, there are many useful applications of the endoscope in addition to the microscope.

Basic technical considerations of endoscope-assisted microsurgery

The operating microscope is from the optical point of view in terms of the resolution the better visualization tool. Because of the larger lens diameter, it has a better optical resolution. Only if the endoscope is used very close to the target area does the endoscopic resolution exceed the microscopic resolution. Additionally, the operating microscope provides a stereoscopic view. Therefore, the microscope is the ideal tool to visualize superficial structures. However, in very deep and narrow surgical corridors, we encounter a considerable loss of light at the entry site (Figure 1A). Furthermore, the manipulations with the surgical instruments within the light beam decrease the light intensity in the surgical field even more. Much more important is that we see with high magnification, which is required in these deep surgical fields, only a very narrow surgical field, which makes the orientation difficult sometimes. Another disadvantage of the microscope is that only the structures, which are in a straight line in front of the microscope, can be visualized.

The endoscope provides a completely different view. Because of the wide-angle viewing field, we get a fantastic panoramic view, which shows the anatomical relation of the structures nicely even in very narrow and deep surgical fields (Figure 1B). We still prefer Hopkins II® (Karl Storz GmbH & Co., KG, Tuttlingen, Germany) rod lenses, which are attached to a high definition (HD) camera. Although chip-on-the-tip endoscopes are increasingly offered, in neurosurgery, which requires small endoscope diameters, the best resolution is still provided by rod lenses in combination with HD technology. Because of the panoramic view, lesions that are not located in front of the endoscope tip can still be recognized early, which is a major advantage in narrow and deep surgical approaches. Furthermore, endoscopes with angulated optics allow a view around a

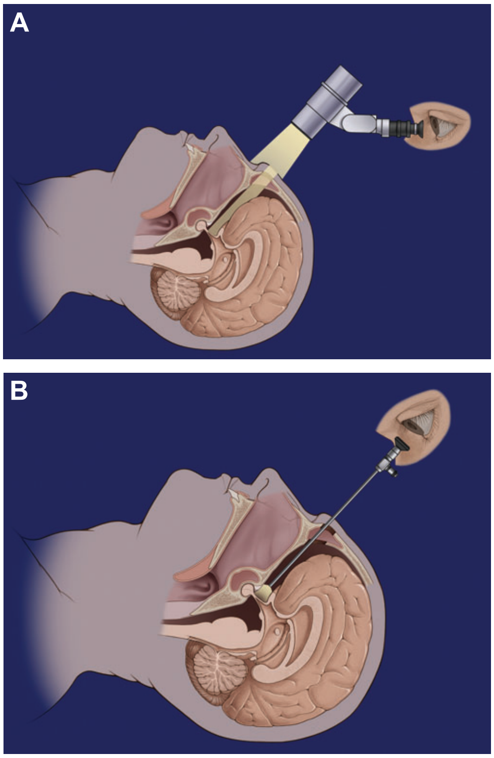

Figure 1 Schemata showing microscopic and endoscopic visualization.
(A) Microscopic visualization. (B) Endoscopic visualization.

corner or behind neurovascular structures, which is very useful in skull base surgery. The endoscope brings the surgeon's eye close to the target area with perfect illumination in the depth, and last but not the least, the endoscope provides an excellent depth of field. Refocusing, which is frequently necessary with the microscope particularly when using a high magnification, is rarely required.

The major drawback of current endoscopes is the lack of stereoscopic vision. But, the distorted endoscopic image, the so-called fish eye effect, gives a pseudo 3D impression. Furthermore, motion parallax, which means closer objects move more than distal objects, enhances the pseudo three-dimensional impression of an endoscopic image. Thus, the lack of a binocular vision is usually compensated for with some training. Furthermore, the lower resolution of the endoscope, compared to the microscope, is another disadvantage of the endoscope. Because of the smaller lens contained in endoscopes used in neuroendoscopy, the operating microscope has a better optical resolution. Additionally, when using the operating microscope, the surgeon looks directly with his eyes through the lens system. Therefore, the primary sensor is the retina, which has a much better resolution than the CCD chips in the mini video cameras, which are attached to the endoscope. Although HD cameras, which were introduced recently, generate images with 1080 lines and over 2 million pixels, the image quality is still inferior when comparing it with the direct look of the human eye through the microscope.

In conclusion, the microscope and endoscope are optical visualization tools, which have both advantages and disadvantages. Therefore, it seems to be reasonable to combine the advantages of both optical tools during neurosurgical procedures.

Endoscopic equipment

For endoscope-assisted procedures, we use endoscopes with angulated eye pieces to bring the video camera away from the surgical field avoiding conflict with the surgical instruments (Figure 2). Endoscopes with various angles of view (0°, 30°, 45°, and 70°) are available to inspect any corner in the surgical field (Karl Storz GmbH & Co., KG, Tuttlingen, Germany). The endoscope outer diameter should be small. We prefer scopes with 2.7-mm diameter, especially in narrow fields such as the cerebellopontine angle. These scopes can be inserted between the cranial nerves and leave enough space for manipulating with surgical instruments. Angulated instruments are necessary to remove tumor tissue (Karl Storz GmbH & Co., KG, Tuttlingen, Germany), which is located around a corner (Figure 3). HD video cameras should be standard in neuroendoscopy as the image quality is much better compared with the standard cameras [18]. Especially, the color fidelity is impressive. We use a xenon light source for illumination, which has a color temperature similar to sunlight (6000 K), which improves the color fidelity even more (Karl Storz GmbH & Co., KG, Tuttlingen, Germany).

Operative technique

In endoscope-assisted microsurgery, the surgical procedure is mainly performed under microscopic visualization because of the better image quality and the stereoscopic view (Figure 4A). Only some steps of the procedure

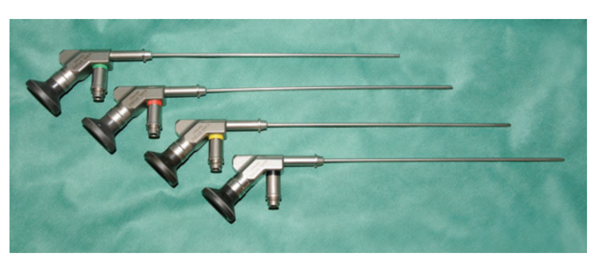

Figure 2 Endoscopes with angulated eyepieces with 0°, 30°, 45°, and 70° of view.

Figure 3 Curettes of various sizes for endoscope-assisted surgery with angulated tips.

Figure 4 Setup in the operating room.
(A) Microsurgical dissection. (B) Free-hand endoscopic inspection. (C) Bimanual endoscopic dissection with the endoscope fixed at a holding arm.

are performed under endoscopic view, mostly to look around a bony or dural corner or behind neurovascular structures. This reduces extensive skull base drilling and retraction. Additionally, the endoscope is used in narrow and deep surgical corridors to enhance the illumination and viewing field [17].

The endoscope is used free hand for inspection (Figure 4B). However, when tumor resection is required, the endoscope is attached to an endoscope holding arm. This allows that the neurosurgeon has both hands free for bimanual dissection (Figure 4C). The monitor is placed in front of the surgeon to provide ergonomic working conditions (Figure 4B).

When moving the endoscope or surgical instruments in and out in the surgical field, care has to be taken to avoid injury to the neurovascular structures, which are behind the endoscope tip and, therefore, not in the viewing field of the endoscope. Furthermore, it is of utmost importance to keep in mind that the endoscope tip can get really hot, which may cause damage to the neurovascular structures. As this is the case especially during prolonged dissections under endoscopic view, frequent irrigation is recommended in this scenario.

Indications

According to our experience, the endoscope-assisted technique is particularly useful in skull base tumor surgery, aneurysm clipping, and microvascular decompression [1, 2, 4–6, 8, 11–16, 19–21].

Epidermoids

Epidermoids frequently spread along the basal cisterns and have considerable extensions along the skull base. Sometimes, two or more compartments are involved, such as the posterior and middle cranial fossa. The endoscope is extremely helpful while removing tumor parts, which are hidden behind the dural (e.g., tentorium) or bony corners (Meckel's cave) as well as behind the neurovascular structures (Figure 5). The epidermoids, which are involving two compartments, can frequently be resected via a single craniotomy performed in one of the compartments [20].

Vestibular schwannomas

An endoscope-assisted retrosigmoid approach is a good indication in patients, with vestibular schwannomas

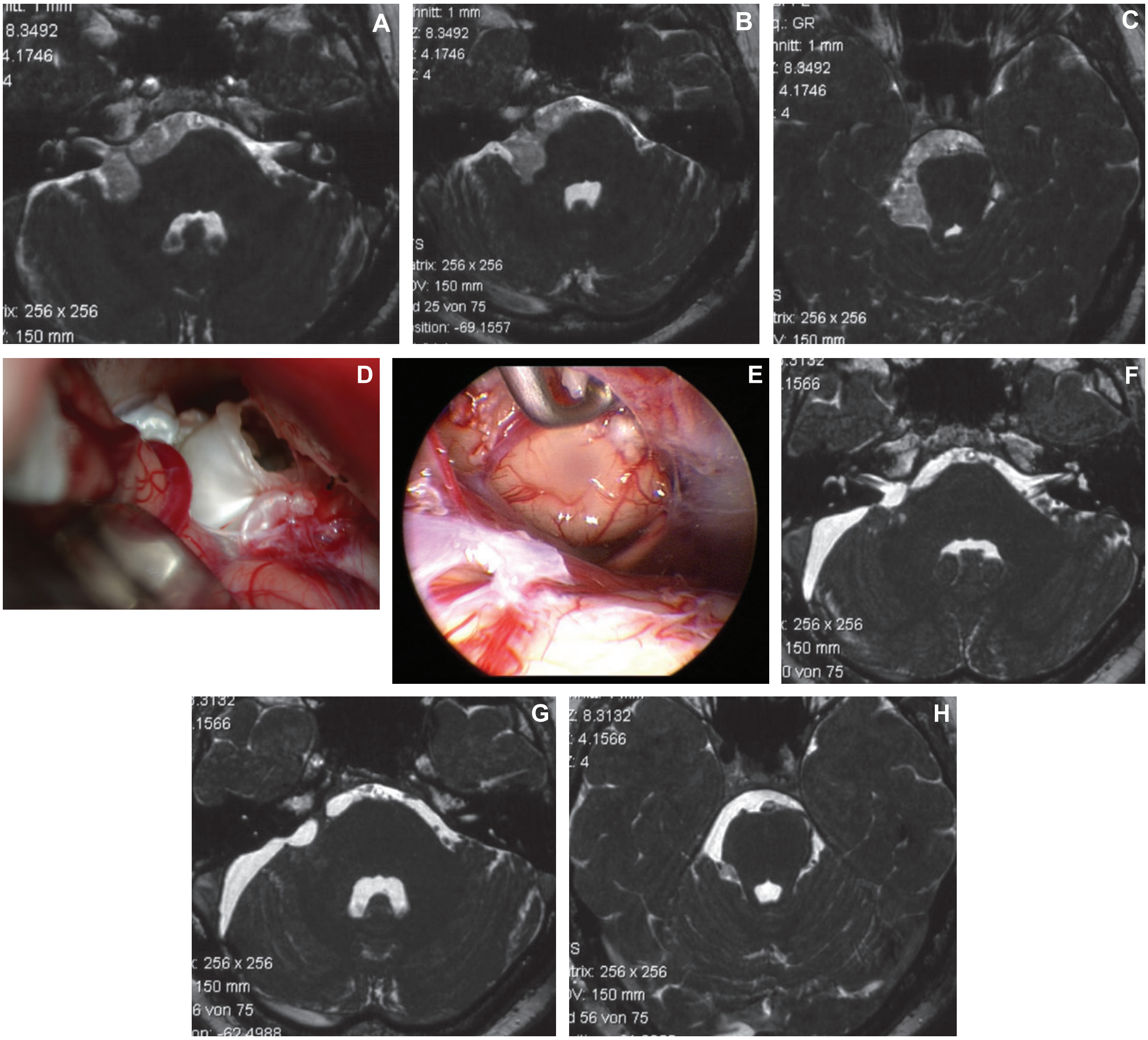

Figure 5 Epidermoid of the cerebellopontine angle in a 39-year-old male presenting with dizziness and balance problems.
(A–C) Axial CISS MR images showing a large space-occupying lesion within the cerebellopontine angle. (D) Microscopic view of the pearly tumor. (E) Endoscopic tumor removal. (F–H) Axial CISS MR images obtained 3 years after surgery showing no recurrent tumor.

with tumor extension far into the fundus of the internal auditory canal, who have still a useful hearing (Figure 6). When hearing preservation is the goal, the amount of drilling of the posterior wall of the internal auditory canal is limited by the posterior semicircular canal and the vestibule. The view via the operating microscope does not allow an inspection of the fundus of the internal auditory canal even after extensive drilling of the posterior wall of the internal auditory canal (Figure 6E). That is why, under the microscope, a blind dissection of the distal tumor pole is done with the aid of a hook dissector. However, with a 30° or 45° endoscope, a perfect visualization of the fundus can be obtained (Figure 6H). The endoscope is used free hand for inspection after tumor resection to ensure that a gross total resection has been achieved and to inspect the drilled area of the internal auditory canal to identify open air cells, which might cause CSF leak (Figure 6I). For tumor dissection, the endoscope is fixed to enable a bimanual dissection of the tumor located in the fundus.

Posterior fossa skull base meningiomas

In meningiomas, the endoscope-assisted technique is frequently used in tumors of the posterior cranial fossa while removing tumor tissue hidden behind bony corners, such as the jugular tubercle, Meckel's cave, or internal auditory

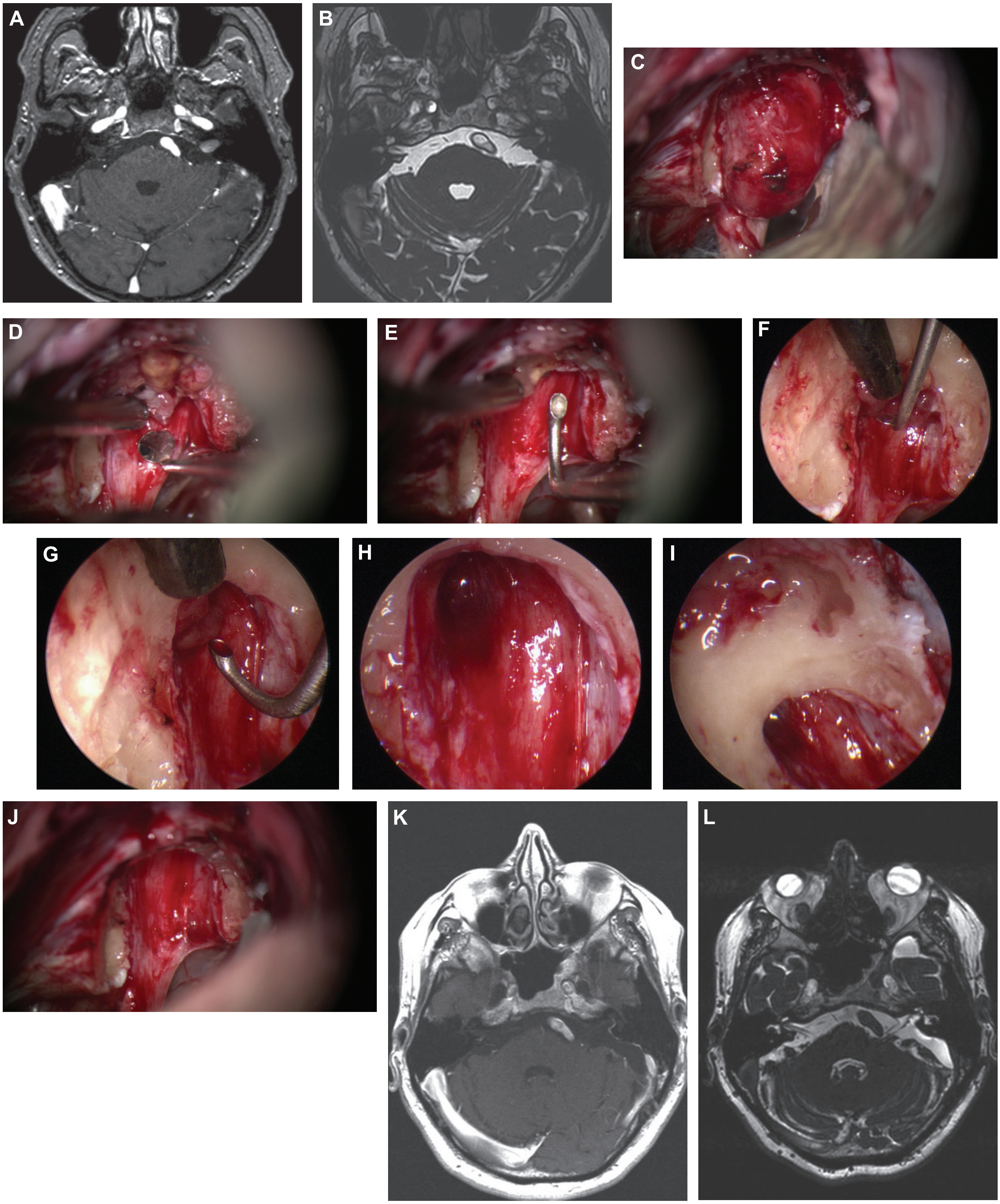

Figure 6 Intrameatal vestibular schwannoma in a 56-year-old male presenting with hearing loss.
(A) T1-weighted axial MR image showing a contrast-enhancing lesion within the left internal auditory canal. (B) Axial CISS MR image showing the accurate extension of the lesion with the internal auditory canal and the nerves VII and VIII, which are displaced anteriorly by the tumor. (C) Microscopic image of the tumor after drilling of the internal auditory canal. (D) Tumor resection under microscopic view. (E) The tumor part within the fundus is not visible with the microscope. (F) Bimanual endoscopic resection of the tumor. (G) Removal of the most lateral tumor part with a curved curette. (H) Endoscopic inspection of the fundus after tumor removal showing preserved facial and cochlear nerve. (I) Endoscopic inspection of the drilled auditory canal showing an opened air cell. (J) Final microscopic view after total tumor resection. (K and L) Axial T1-weighted contrast-enhanced (K) and axial CISS (L) MR image obtained 3 months after surgery showing no tumor remnant.

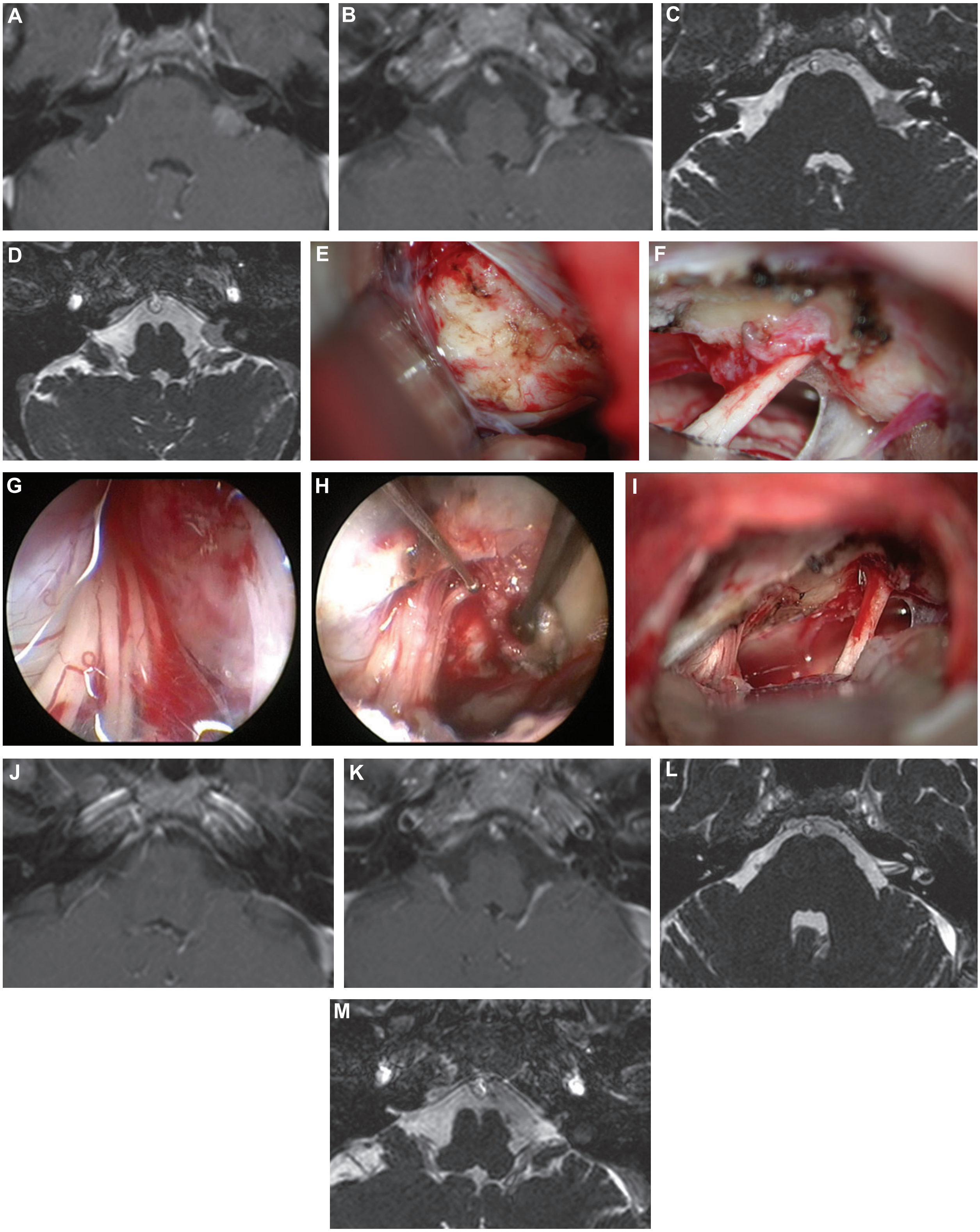

Figure 7 Jugular tubercle meningioma in a 51-year-old female presenting with headache and swallowing problems.
(A–B) Axial T1-weighted MR images showing a contrast-enhancing lesion arising from the jugular tubercle. (C–D) Axial CISS MR images showing the relation to the cranial nerves and the growth into the jugular foramen. (E) Microsurgical exposure of the tumor via a retrosigmoid approach. (F) Microscopic view after partial tumor resection. (G) Endoscopic view with 30° optic into the jugular foramen showing residual tumor. (H) Bimanual tumor resection under endoscopic view. (I) Final microscopic view showing the total tumor resection. (J–K) Axial enhanced T1-weighted MR images obtained 4 years after surgery showing total tumor resection and no recurrence. (L–M) CISS MR images obtained 4 years after surgery showing the free internal auditory canal and jugular foramen.

canal, to reduce the amount of skull base drilling (Figure 7). When using small craniotomies, which allow only a nearly coaxial vision, the endoscope is mandatory to inspect any corner of the surgical field [19].

Aneurysms

Because of the narrow and deep approaches for aneurysms of the posterior circulation, the application of an endoscope is beneficial to get a perfect overview of the anatomy before applying the clip and to check the clip position after clipping [3, 5, 8, 9–12]. The endoscope is useful when the aneurysm neck with parent and efferent arteries or perforators cannot be visualized with the microscope. We used the endoscope for aneurysms at the basilar tip or PICA origin, but nearly always only for inspection before and after clipping (Figure 8). In our attempts of using the endoscope during the aneurysm clipping itself, the endoscope mostly interfered with the suction and clip applier because of the narrow spaces in the surgical field.

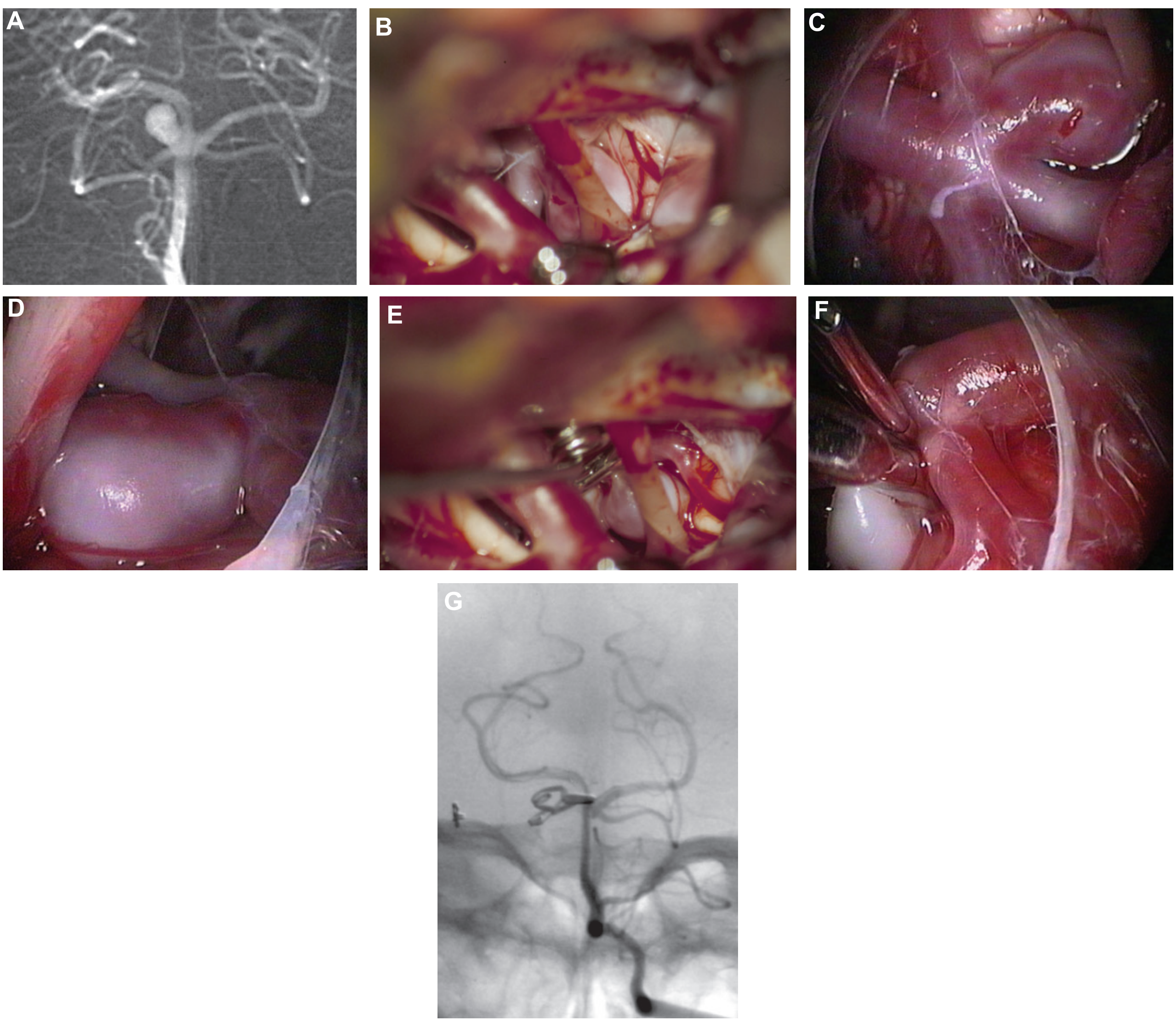

Figure 8 Unruptured superior cerebellar artery aneurysm in a 53-year-old female. The aneurysm was an incidental finding. (A) DSA showing a superior cerebellar artery aneurysm. (B) Microsurgical exposure via a pterional approach. (C) Endoscopic visualization with a 30° endoscope shows nicely the aneurysm. (D) Endoscopic inspection showing a perforator in front of the neck. (E) Microsurgical view after aneurysm clipping. (F) Endoscopic inspection showing the accurate clip position. (G) DSA obtained 5 days after surgery showing the complete obliteration of the aneurysm.

Microvascular decompression in trigeminal neuralgia and hemifacial spasm

In microvascular decompression for trigeminal neuralgia, the endoscope is used to inspect the entire course of the trigeminal nerve from the root entry zone at the brain stem to the entrance into Meckel's cave [14, 22]. The veins, which cause compression of the trigeminal nerve, are frequently found at the entry into Meckel's cave. A large suprameatal tubercle can prevent a direct microscopic view to this area. With a 30° or 45° endoscope, this area can be visualized without the need for drilling of the suprameatal tubercle. In hemifacial spasm, we found the endoscope even more helpful than in trigeminal neuralgia because the compression site is often very medially located. Direct microscopic visualization can only be obtained with considerable retraction of the cerebellum. In our experience, this resulted frequently in a decrease and delay of the acoustic evoked potentials. With the 30° and 45° endoscopes, the compression site can be inspected avoiding any retraction (Figure 9). The course of the perforators can be indentified early during the dissection, which increases the safety of the surgery.

Conclusion

Endoscope-assisted microsurgery combines the advantages of the microscope and the endoscope. The microscope with a high resolution, excellent color fidelity, and binocular view is applied for the dissection of structures that are visible in a straight line. For working in deep and narrow surgical corridors or for dissecting "around a corner", the endoscope is used to reduce the degree of retraction and skull base drilling. I am pretty sure that high-resolution 3D video camera systems will replace the surgical microscope in the future. The surgeon will look at only one screen where all information including the navigation data and preoperative MR images will be displayed. In the near future, however, the surgical microscope will

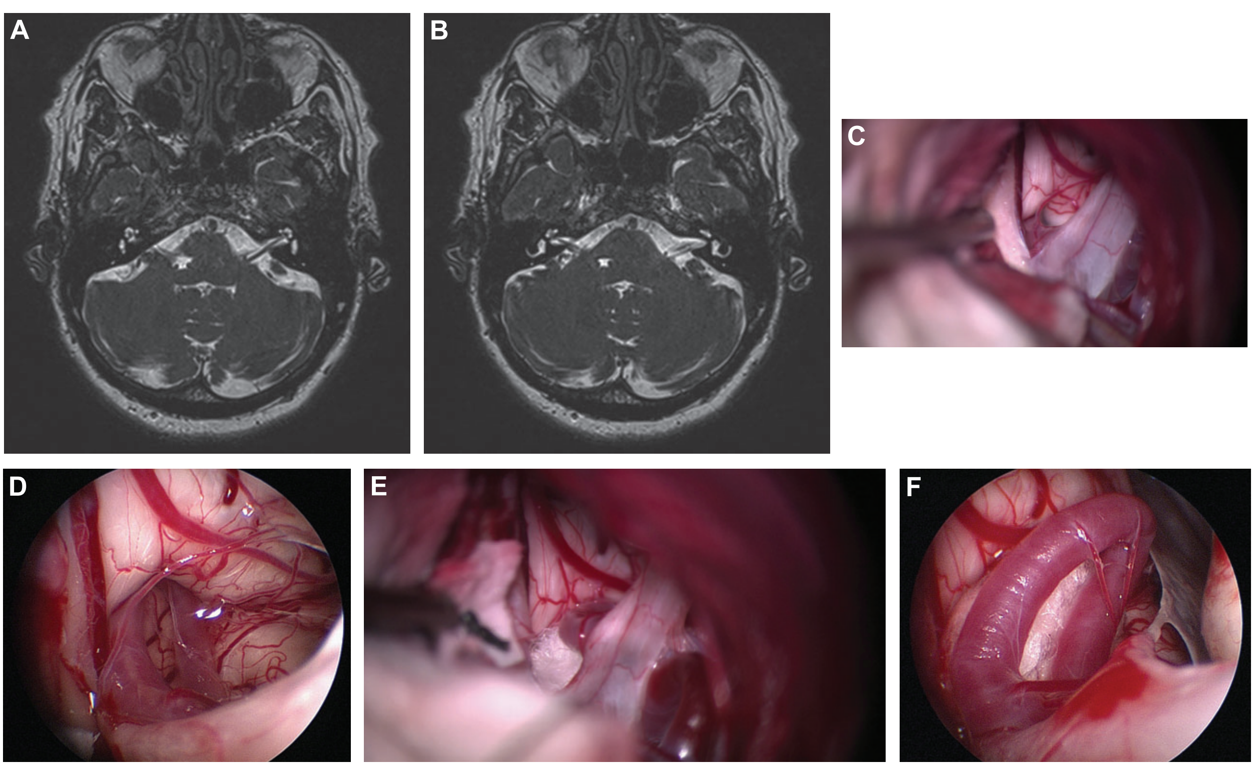

Figure 9 A 70-year-old female presenting with hemifacial spasm on the right side.
(A and B) Axial CISS MR images showing the severe pontine impression at the root exit zone of the facial nerve by a loop of the posterior inferior cerebellar artery. (C) Microscopic visualization of the compression site via a lower retrosigmoid craniotomy. (D) Endoscopic inspection with a 45° endoscope showing the compression site much better. (E) Microscopic view after decompression. (F) Endoscopic view after decompression with Teflon pledget.

remain the most frequently used optical tool in neurosurgery, which can be assisted by the endoscope in some procedures.

Although the endoscope-assisted microsurgical technique enables a safe surgery and reduces, definitely, the invasiveness of the approach, it still remains open whether it improves the results compared to the standard microsurgery. Only prospective randomized trials can answer this question, but I doubt that such trials will be performed in the future.

Received October 3, 2012; accepted December 17, 2012

References

[1] Baldauf J, Junghans D, Schroeder HW. Endoscope-assisted microsurgical resection of an intraneural ganglion cyst of the hypoglossal nerve. J Neurosurg. 2005;103:920–2.
[2] Cohen AR, Perneczky A, Rodziewicz GS, Gingold SI. Endoscope-assisted craniotomy: approach to the rostral brain stem. Neurosurgery. 1995;36:1128–30.
[3] Fischer G, Stadie A, Reisch R, Hopf NJ, Fries G, Böcher-Schwarz H, et al. The keyhole concept in aneurysm surgery: results of the past 20 years. Neurosurgery. 2011;68:45–51.
[4] Fries G, Perneczky A. Endoscope-assisted brain surgery: part 2 – analysis of 380 procedures. Neurosurgery. 1998;42:226–32.
[5] Fries G, Perneczky A. Endoscope-assisted keyhole surgery for aneurysms of the anterior circulation and the basilar apex. Oper Tech Neurosurg. 2000;3:216–30.
[6] Grotenhuis JA. Endoscope-assisted craniotomy. Tech Neurosurg. 1996;1:201–12.
[7] Hopf NJ, Perneczky A. Endoscopic neurosurgery and endoscope-assisted microneurosurgery for the treatment of intracranial cysts. Neurosurgery. 1998;43:1330–6.
[8] Kalavakonda C, Sekhar LN, Ramachandran P, Hechl P. Endoscope-assisted microsurgery for intracranial aneurysms. Neurosurgery. 2002;51:1119–26.
[9] Kato Y, Sano H, Nagahisa S, Iwata S, Yoshida K, Yamamoto K, et al. Endoscope-assisted microsurgery for cerebral aneurysms. Minim Invas Neurosurg. 2000;43:91–7.
[10] Kinouchi H, Futawatari K, Mizoi K, Higashiyama N, Kojima H, Sakamoto T. Endoscope-assisted clipping of a superior hypophyseal artery aneurysm without removal of the anterior clinoid process. Case report. J Neurosurg. 2002;96:788–91.
[11] Menovsky T, Grotenhuis JA, de VJ, Bartels RH. Endoscope-assisted supraorbital craniotomy for lesions of the interpeduncular fossa. Neurosurgery. 1999;44:106–10.
[12] Perneczky A, Boecher-Schwarz HG. Endoscope-assisted microsurgery for cerebral aneurysms. Neurol Med Chir (Tokyo). 1998;38(Suppl):33–4.
[13] Perneczky A, Fries G. Endoscope-assisted brain surgery: part 1 – evolution, basic concept, and current technique. Neurosurgery. 1998;42:219–25.
[14] Rak R, Sekhar LN, Stimac D, Hechl P. Endoscope-assisted microsurgery for microvascular compression syndromes. Neurosurgery. 2004;54:876–81.
[15] Reisch R, Perneczky A. Ten-year experience with the supraorbital subfrontal approach through an eyebrow skin incision. Neurosurgery. 2005;57:242–55.
[16] Reisch R, Perneczky A, Filippi R. Surgical technique of the supraorbital key-hole craniotomy. Surg Neurol. 2003;59:223–7.
[17] Reisch R, Stadie A, Kockro RA, Hopf N. The keyhole concept in neurosurgery. World Neurosurg. 2012 Feb 10. pii: S1878-8750(12)00157-X. doi:10.1016/j.wneu.2012.02.024. [Epub ahead of print].
[18] Schroeder HW, Nehlsen M. Value of high-definition imaging in neuroendoscopy. Neurosurg. Rev. 2009;32:303–8.
[19] Schroeder HW, Hickmann AK, Baldauf J. Endoscope-assisted microsurgical resection of skull base meningiomas. Neurosurg Rev. 2011;34:441–55.
[20] Schroeder HW, Oertel J, Gaab MR. Endoscope-assisted microsurgical resection of epidermoid tumors of the cerebellopontine angle. J Neurosurg. 2004;101:227–32.
[21] Tatagiba M, Matthies C, Samii M. Microendoscopy of the internal auditory canal in vestibular schwannoma surgery. Neurosurgery. 1996;38:737–40.
[22] Teo C, Nakaji P, Mobbs RJ. Endoscope-assisted microvascular decompression for trigeminal neuralgia: technical case report. Neurosurgery. 2006;59:ONSE489–90.

The author stated that there are no conflicts of interest regarding the publication of this article