Alexander König
Uwe Spetzger *Editors*

Surgery of the Skull Base

Practical Diagnosis and Therapy

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Editors
Alexander König
Neurochirurgische Klinik
Städtisches Klinikum Karlsruhe
Karlsruhe, Baden-Württemberg
Germany

Uwe Spetzger
Neurochirurgische Klinik
Klinikum Karlsruhe
Karlsruhe, Baden-Württemberg
Germany

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Contents

Contributors

Sinan Barazi
Department of Neurosurgery
King's College Hospital, Denmark Hill
London, SE5 9RS, UK
sbarazi@nhs.net

Konstantinos Barkas
Department of Neurosurgery
King's College Hospital, Denmark Hill
London, SE5 9RS, UK
konstantinos.barkas@nhs.net

Gerd Becker
RadioChirurgicum, CyberKnife®-Südwest
Eichertstr. 3, D-73035
Göppingen, Germany
becker@radiochirurgicum.de

Marcel Biegler
Neurochirurgische Klinik, Klinikum Karlsruhe,
Moltkestr. 90, D-76133
Karlsruhe, Germany
marcel.biegler@klinikum-karlsruhe.de

Martin Bleif
RadioChirurgicum, CyberKnife®-Südwest
Eichertstr. 3, D-73035
Göppingen, Germany
bleif@radiochirurgicum.de

Hamid Borghei-Razavi
Surgical Neuroanatomy Lab
Department of Neurological Surgery
UPMC Presbyterian, Suite B-400
200 Lothrop Street
Pittsburgh, PA 15213, USA
shbr61@yahoo.com

Juan Fernandez-Miranda
Surgical Neuroanatomy Lab
Department of Neurological Surgery
UPMC Presbyterian, Suite B-400
200 Lothrop Street
Pittsburgh, PA 15213, USA
fernandezmirandajc@upmc.edu

Kåre Fugleholm
Neurokirurgisk klinik, Rigshospitalet
Blegdamsvej 9, DK-2100
København Ø, Denmark
kaare.fugleholm.buch@regionh.dk

Takanori Fukushima
Division of Neurosurgery, Duke University
Medical Center, Carolina Neuroscience Institute
4030 Wake Forest Rd suite 115
Raleigh, NC 27612, USA
fukushima@carolinaneuroscience.com

Nikolai Hopf
NeuroChirurgicum, Maybachstraße 50
D-70469, Stuttgart, Germany
hopf@neurochirurgicum.com

Goh Inoue
Department of Neurosurgery
Duke University, INERF
4030 Wake Forest Road Suite 115
Raleigh, NC 27609, USA
inoue5@tsc.u-tokai.ac.jp

Alexander König
Neurochirurgische Klinik, Klinikum Karlsruhe
Moltkestr. 90, D-76133
Karlsruhe, Germany
alexander.koenig@klinikum-karlsruhe.de

Peter Kurucz
Neurochirurgische Klinik, Klinikum Stuttgart
Katharinenhospital
Kriegsbergstraße 60
D-70174, Stuttgart, Germany
p.kurucz@klinikum-stuttgart.de

Torstein Meling
Nevrokirurgisk avdeling, Rikshospitalet
Sognsvannsveien 20, N-0372
Oslo, Norway
tmeling@ous-hf.no

Anthony Mélot
Service de Neurochirurgie
Hôpital Nord
F-13015, Marseille, France
anthony.melot@ap-hm.fr

Yoichi Nonaka
Department of Neurosurgery
Fukushima Takanori Skull Base Center
Shin-yurigaoka General Hospital
255 Furusawa Asao-ku, Kawasaki
Kanagawa, 215-0026, Japan
ynonaka1971@yahoo.co.jp

Sebastian Ranguis
Department of Otolaryngology
Head and Neck Surgery
St. Vincent's Hospital Sydney
390 Victoria St
Darlinghurst, NSW 2010, Australia
scranguis@gmail.com

Robert Reisch
ENDOMIN - Zentrum für endoskopische
und minimalinvasive Neurochirurgie
Witellikerstrasse 40
CH -8032, Zürich, Switzerland
robert.reisch@hirslanden.ch

Pierre-Hugues Roche
Service de Neurochirurgie, Hôpital Nord
F-13015, Marseille, France
proche@ap-hm.fr

Uta Schick
Neurochirurgie, Clemenshospital
Düesbergweg 124
D-48153, Münster, Germany
neurochirurgie@clemenshospital.de

Outouma Soumare
Service de Neurochirurgie, Hôpital Nord
F-13015, Marseille, France
outouma.soumare@ap-hm.fr

Uwe Spetzger
Neurochirurgische Klinik
Klinikum Karlsruhe
Moltkestr. 90
D-76133, Karlsruhe, Germany
uwe.spetzger@klinikum-karlsruhe.de

Nick Thomas
Department of Neurosurgery
King's College Hospital, Denmark Hill
London, SE5 9RS, UK
nick.thomas1@nhs.net

Lucas Troude
Service de Neurochirurgie, Hôpital Nord
F-13015, Marseille, France
lucas.troude@hotmail.fr

Ali Zomorodi
Department of Neurosurgery
Duke University, INERF
4030 Wake Forest Road Suite 115
Raleigh, NC, 27609, USA
lori@carolinaneuroscience.com

Introduction into Skull Base Surgery

Uwe Spetzger

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1.1 Concepts and Strategies in Skull Base Surgery

Modern skull base surgery has developed to a multidisciplinary specialty with a specific collaboration between several diagnostic and therapeutic medical disciplines. Due to the complex anatomy and important functional structures, there are specific conditions for surgical procedures at the skull base. They require a maximum of precision, persistency and well-grounded anatomical knowledge. Furthermore, a skilled tactile surgical realisation of the treatment strategy is required for the maintenance of neurological functions.

In this book therapeutical concepts and treatment strategies are depicted from the perspective of a neurosurgeon but with appropriate cross references to interdisciplinary «interfaces» and further medical specialties. Therefore, in every chapter selected and experienced, skull base surgeons describe therapeutical concepts in cases of tumourous, traumatic, vascular or congenital triggered diseases of the skull base including brilliant photographic images of surgical procedures. By means of clinical cases, the diagnostics, planning of treatment and steps of surgical procedures are depicted consecutively and with relation to clinical practice. For all relevant skull base pathologies, surgical strategies and alternative modern treatment concepts are described, and, finally, a future perspective about the further development of skull base surgery is given.

1.2 From Function-Preserving to Function-Improving Skull Base Surgery

In principle, skull base surgery has experienced a basic strategical change in the last 25 years. The dogma of maximum radicalness with the goal of complete and radical tumour removal has given way to the principle of function-preserving skull base surgery. Today the treatment philosophy in modern skull base surgery can be formulated so that by an optimisation of surgical approaches with all technical possibilities the surgeon tries to remove the tumour or lesion at best and keeping in mind that the main goal is preserving neurological function but not maximum radicalness. That means that vascular structures, cranial nerves and functional areas of the brain have to be treated with care and if necessary a multimodal and repeated treatment strategy with different therapeutical methods such as endovascular embolisation or radiosurgery has to be applied.

With a historical view on the development of skull base surgery, a big milestone was the introduction of the operating microscope that enabled better visualisation and thereby a more precise microsurgical dissection and preservation of relevant structures while resecting skull base pathologies. The introduction of microsurgery and the refinement of microsurgical techniques brought an important improvement of surgical results and a significant reduction of surgical morbidity and mortality. On the other hand, due to the improved visualisation skull base surgery became a more and more aggressive surgery in the 1980s and 1990s because the microscopical view enabled more invasive and more aggressive approaches. Especially the surgery in the region of the cavernous sinus reached a technical overkill that resulted in increased morbidity in the publications from that period without resulting in a significant improvement of the patients' long-term prognosis.

The introduction of navigation technology can be considered as the next milestone. It offered a better planning, simulation and an image-guided demonstration of the several surgical steps. At the same time the multimodal intraoperative electrophysiological monitoring was significantly improved which resulted in further risk minimisation and improvement of surgical results.

Due to the interdisciplinary collaboration of the different medical specialties, the surgical expertise for the treatment of skull base lesion has been continuously improved. A good example for this is the increasing use of endoscopic techniques in skull base surgery whereupon from a neurosurgical point of view the transnasal approach to the pituitary gland and to the anterior skull base as well as the combination of endoscopy and microsurgical techniques play the most important role.

A further improvement resulted from the optimisation of the delineation of cranial nerves in high-resolution MR imaging. Hereby, it will result in a more detailed visualisation and delineation and, thus, a more precise navigation. But also the increasing therapeutical expertise of interventional radiologists in vascular skull base surgery will be of relevance. The highly precise and selective embolisation techniques or the vessel wall reconstruction by individualised crafted stents and flow diverters for the treatment of vascular lesions and aggressive skull base tumours infiltrating main blood vessels will bring a significant improvement.

An increasing and important contribution comes from highly precise irradiation techniques in which an exact three-dimensional dose planning is possible with modern stereotactic radiosurgery (Gammaknife and CyberKnife). Thus, the combination of radiosurgery and image-guided microsurgery will open a wide field and bring further benefit for our patients. In the course of further spreading of modern skull base surgery, the specific surgical education and training has to undergo further structuring and improvement.

Skull base surgery is an interdisciplinary domain since it requires surgical expertise from different specialties: neurosurgery, ENT surgery, maxillofacial surgery and ophthalmology. Due to the fact that an increasing number of endovascular procedures are used for the treatment of skull base pathologies, interventional neuroradiologists become more and more involved. Furthermore, oncologists with an expertise in the treatment of head and neck neoplasms as well as radiotherapists performing stereotactic radiosurgery are part of the skull base team.

With a balanced corporate action and interdependent trustful collaboration, the optimum treatment for the patient is achieved. Therefore personal communication and a good understanding of the different surgical methods of the several disciplines are crucial. It is well proven to determine the course of surgery in terms of chronology and organisation. That means that the members of the surgical team and the leading specialty are appointed and the sequence of who is doing what is determined.

From this follows that a complex skull base operation depends on qualified single surgical steps, like in a well-rehearsed orchestra where the individual contributions of soloists result in a magnum opus. In this respect, the basic principle is that the specialist with the highest expertise for a certain anatomical area will do the part of the surgical procedure there. This kind of interdisciplinary skull base surgery requires a cooperative and respectful behaviour as well as a mutual trust. Especially in the case of surgically induced morbidity, the complication management can be a big challenge.

The use of computer-assisted surgery also had an important impact on the interdisciplinary cooperation in skull base surgery. The platform of navigation allows the different disciplines an optimal image-guided planning with precise delineation of the pathology and possible approaches by computer-assisted simulation. Thus, by means of navigation, the exact surgical strategy can be determined by the surgeons at the computer screen. During computer-assisted simulation, specific problems and different surgical approaches can be discussed. Finally, interdisciplinary planning with the navigation system allows the determination of a perfect individual course of surgery.

This book about skull base surgery focuses on the neurosurgical therapeutic options but again and again shows the relevant interfaces to other specialties at the same time. Exemplarily three selected clinical cases are presented that are characteristic for interdisciplinary collaboration and show the neurosurgical point of view as well as the therapeutical strategy.

1.3 Illustrative Cases

1.3.1 Neuroma of the Maxillary Nerve

Interdisciplinary treatment planning by neuroradiology, maxillofacial surgery, ENT surgery, neurosurgery and radiotherapy

Due to massive facial pain in the region of the maxilla, our 45-year-old patient underwent dental examination and, finally, a cranial MRI. The latter showed a space-occupying lesion in the pterygopalatine fossa (Fig. 1.1).

After an interdisciplinary conference with colleagues from ENT surgery, a surgical procedure with direct approach to the tumour through the maxillary sinus was planned (Fig. 1.2). The planning included an intraoral incision by maxillofacial surgeons and was conducted with the help of a BrainLab navigation system (BrainLab, München, Germany) which was also used for intraoperative orientation (Fig. 1.3).

As planned, the intraoral incision and the skull base approach through the maxillary sinus were performed by maxillofacial surgeons. After

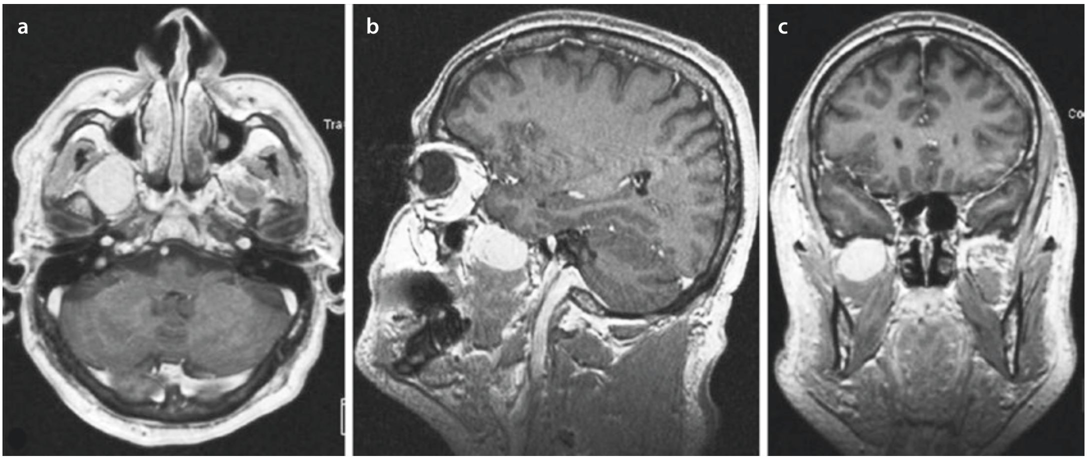


Fig. 1.1 MRI with contrast in the axial **a**, sagittal **b**, and coronal plane **c** shows a tumour mass with contrast enhancement in the right pterygopalatine fossa that was suspected to be a neuroma of the second branch of the trigeminal nerve

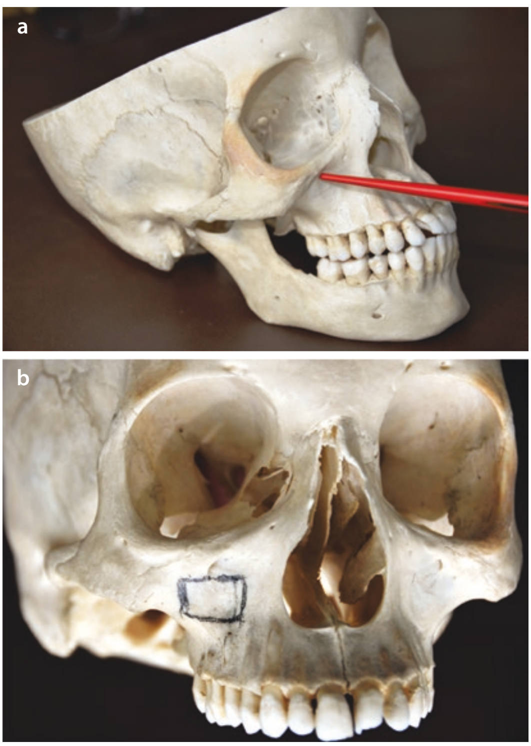


Fig. 1.2 Demonstration of the planned surgical approach with a trajectory through the maxillary sinus **a**. Designated opening of the anterior wall of the maxillary sinus directly below the foramen of the right infraorbital nerve **b**

dissection of the oral mucosa, the anterior wall of the maxillary sinus was cut out with a piezo-driven ultrasonic saw just below the foramen of the infraorbital nerve and, thus, the nerve could be preserved. Under microscopic view after the removal of the mucosa inside the maxillary sinus, the posterior wall of the maxillary sinus was resected with a 3-mm diamond drill which enabled a direct view onto the tumour. The lesion was then reduced in size by using an ultrasonic surgical aspirator (CUSA), a bipolar forceps and tumour forceps as it can be seen in the accompanying surgical video. Afterwards the tumour was microsurgically dissected from the maxillary nerve and removed from the pterygopalatine fossa. Intraoperative histological analysis confirmed the diagnosis of a benign neuroma (schwannoma).

Maxillary nerve and infraorbital nerve, respectively, could be preserved in their course at the roof of the maxillary sinus. Postoperatively the patient's facial pain disappeared within 2 days with preserved sensory function in the V_2 dermatome. The only postoperative deficits were a mild hypaesthesia and dysaesthesia at the right upper lip.

1.3.2 Partially Thrombosed Giant Aneurysm of the Left Vertebral Artery

Interdisciplinary treatment planning by oncology, neuroradiology and neurosurgery

A 57-year-old female patient had previous surgery for a tonsillar carcinoma (staging: T2N2M0-G3). Due to a slight gait ataxia and per-

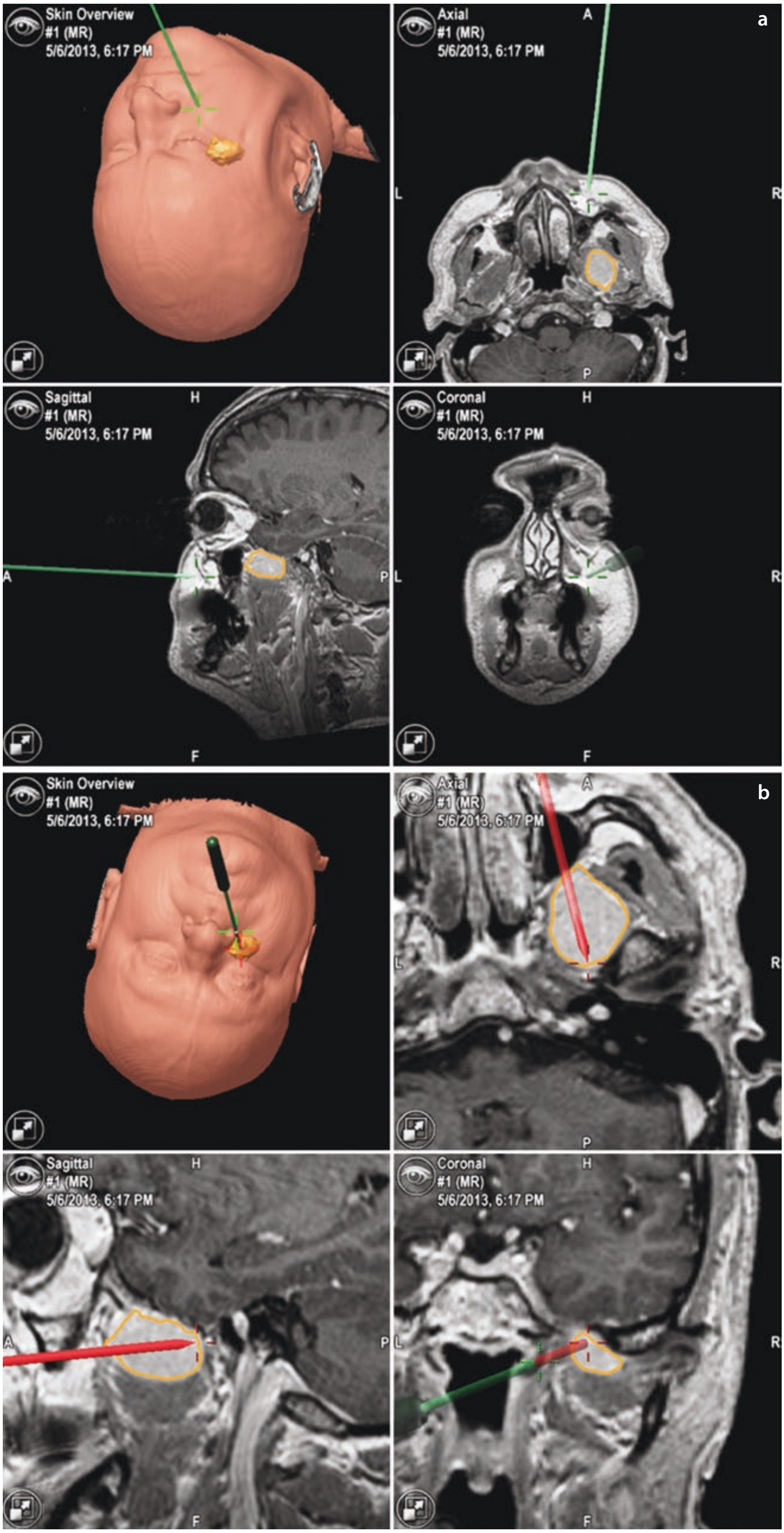
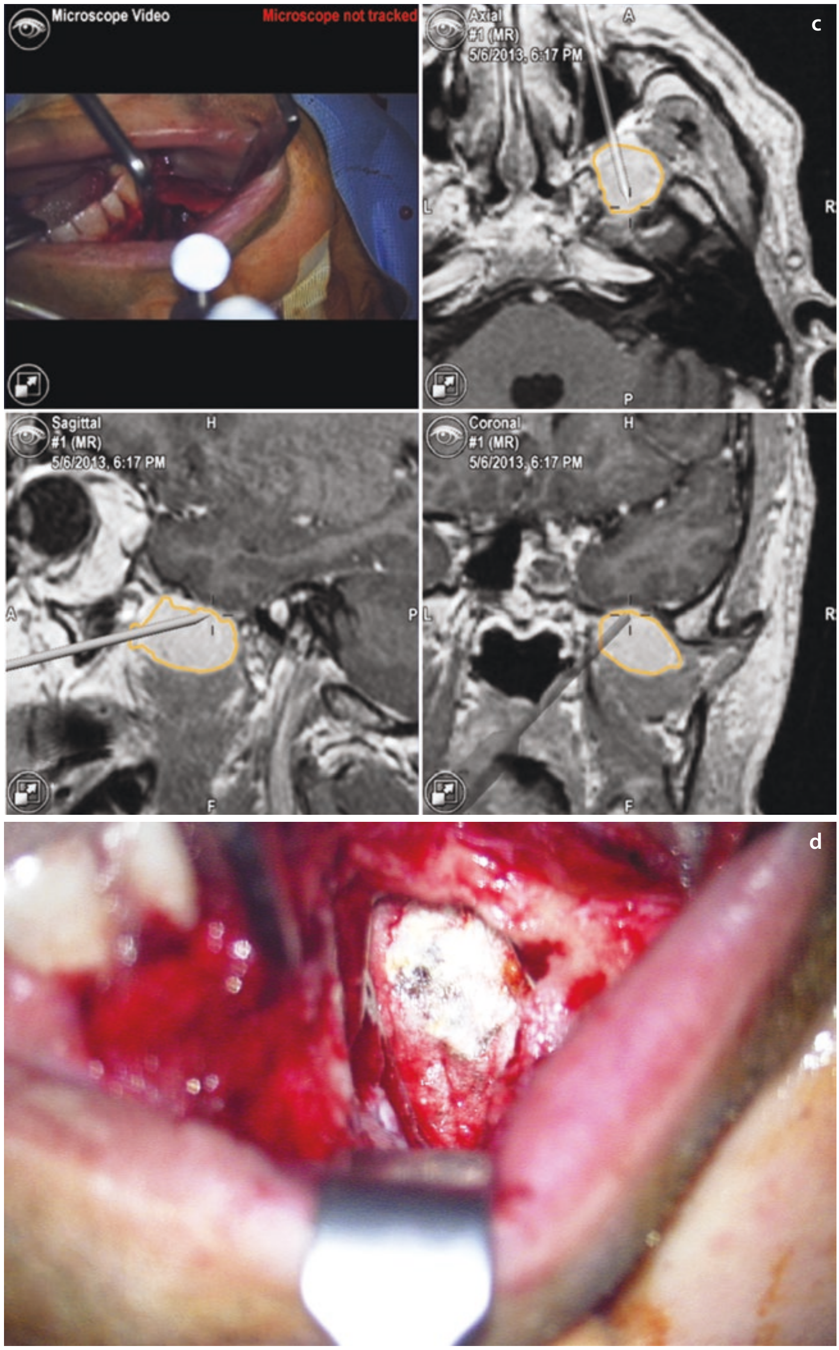


Fig. 1.3 Intraoperative planning of the approach by using neuronavigation. The pointer is positioned at the lower edge of the maxillary sinus after lifting the upper lip **a**. Intraoperative planning of the trajectory and simulation of the surgical approach through the maxillary sinus with virtual elongation of the pointer (*red*) until the posterior edge of the tumour into the direction of the foramen rotundum **b**. Surgical field of the transoral transmaxillary approach during tumour resection while the tip of the pointer is located at the temporal skull base close to the upper posterior edge of the right maxillary sinus **c**. View into the resection cavity through the maxillary sinus after total resection of the neuroma. The posterior wall of the maxillary sinus was reconstructed with TachoSil **d**



■ **Fig. 1.3** (continued)

sisting dysphagia, our oncologic colleagues initiated a cranial MRI to rule out cerebral metastases. MRI showed a partially thrombosed giant aneurysm of the left vertebral artery with compression of the lower cranial nerves and the brainstem (■ Figs. 1.4, 1.5, 1.6, and 1.7). Cerebral digital subtraction angiography confirmed the relatively small part of the aneurysm neck with blood flow and showed the origin of the posterior inferior cerebellar artery (PICA) right beside the aneurysm neck as well as irregularities of the tunica intima of the left vertebral artery. This case with

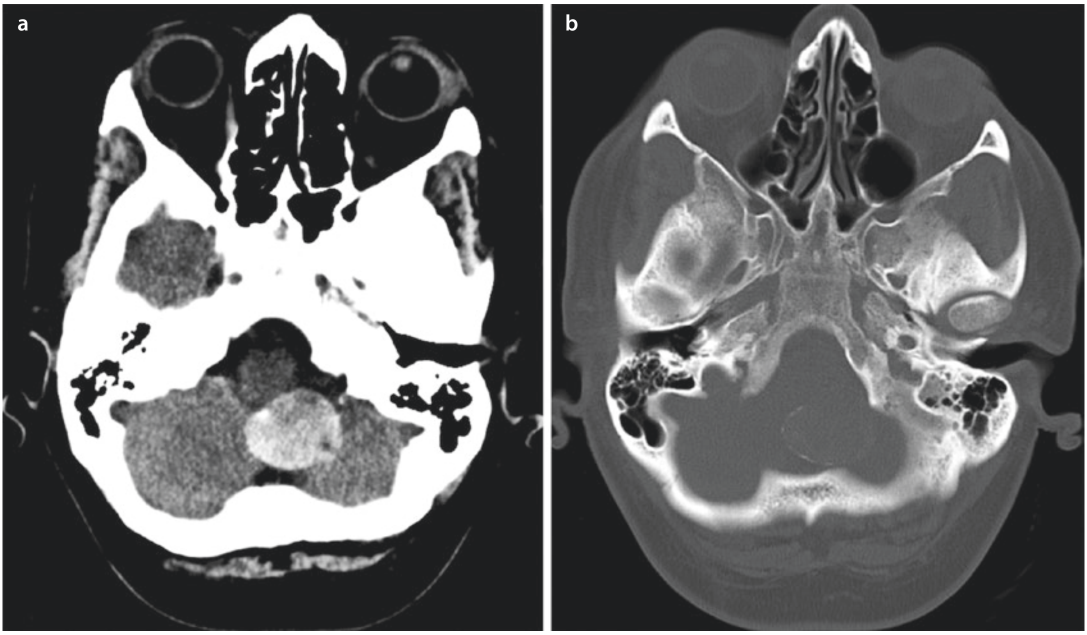


Fig. 1.4 Preoperative cranial CT scan. The axial slices show the thrombotic giant aneurysm in the posterior fossa with contact to the medulla oblongata **a**. In the bone window CT scan, the calcifications of the aneurysm wall can be visualised **b**

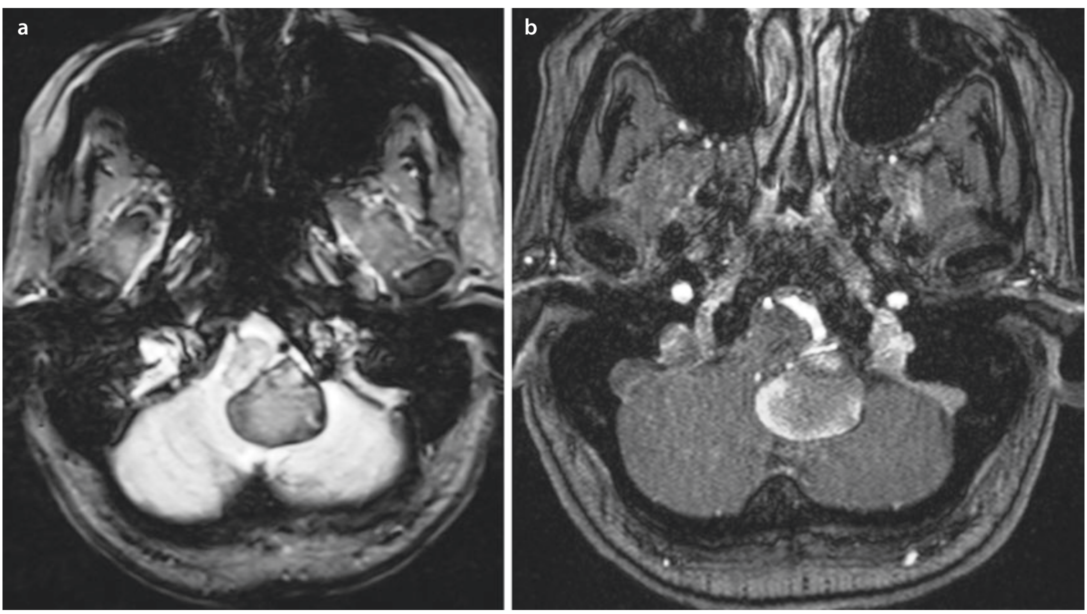


Fig. 1.5 Axial MRI. The T2-fl2d image shows the thrombotic part of the aneurysm as well as the space-occupying effect inside the cerebellum with consecutive compression of the brainstem **a**. The TOF-3D MRI shows the thick left vertebral artery with the crossing PICA course **b**

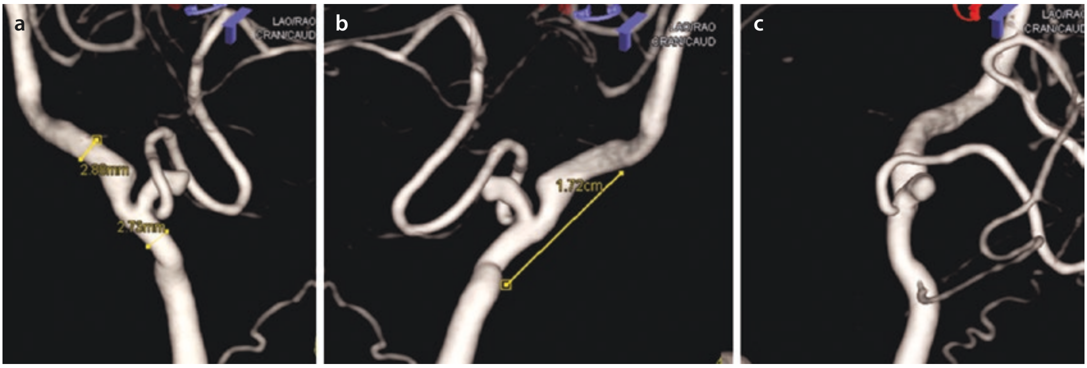


Fig. 1.6 Reconstructed images of the digital 3D rotational angiography. The relatively small perfused aneurysm neck, the irregularities in the diameter of the vertebral artery and the origin of the PICA are shown in different projections **a**-**c**. Length and diameters were measured to plan a potential endovascular treatment with stent-supported coil embolisation **a**, **b**. The PICA runs below and behind the aneurysm neck and crosses the vertebral artery **c**

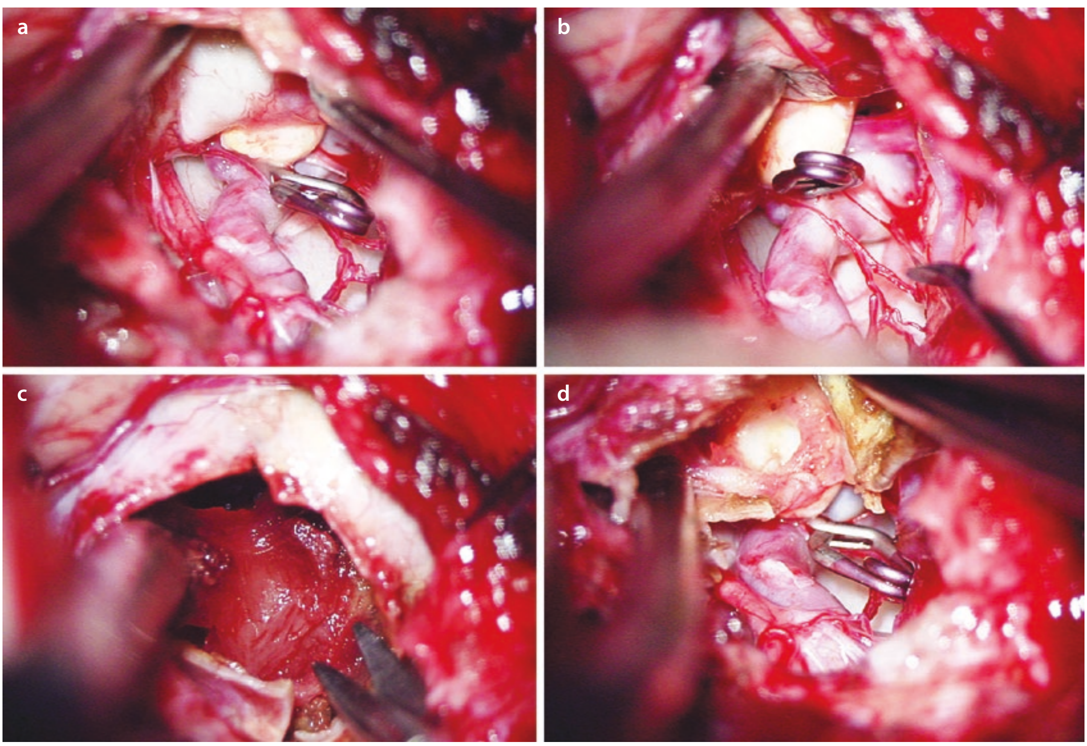


Fig. 1.7 Intraoperative images showing the microsurgical clipping of the partial thrombosed giant VA aneurysm. Application of a straight 7-mm Yasargil mini clip that completely occludes the point of rupture and the aneurysm neck **a.** The PICA which crosses behind the aneurysm and the small perforating arteries are intact **b.** Opening of the aneurysm and reduction of the solid thrombotic material with micro scissors to decompress the brainstem **c.** View in the formerly perfused part of the aneurysm after clipping of the aneurysm base and after partial resection of the aneurysm wall at the end of surgery **d**