ENDOSCOPIC RHINO-NEUROSURGERY
The concept of minimally invasive, tailored transnasal skull base surgery

Robert REISCH
Hans Rudolf BRINER
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With the kind support of

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Acknowledgments

Rhino-neurosurgery is teamwork!

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We extend our particular thanks to the surgical team of the Hirslanden Clinic, Zurich, for their daily support and outstanding commitment to rhino-neurosurgery as well as to our families for their tremendous support.

The authors
Endoscopic rhino-neurosurgery –
The concept of minimally invasive, tailored transnasal skull base surgery
Robert Reisch¹ and Hans Rudolf Briner²

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Online videos

In this publication, the Play button shown below next to a number and title refers to a video clip made by the authors. Click on it to open your web browser and play the video.

1 https://go.karlstorz.com/96025018-en-1
   Click here to see video 1.

Alternatively, you can access and play the online video clip by scanning the QR code or entering the short link.

https://go.karlstorz.com/96025018-en-1
Foreword I

On the basis of the great worldwide success of endoscopic sinus surgery (ESS) and the associated paradigm shift that has taken place since the mid-1980s, multidisciplinary skull base teams began to establish themselves in the early 2000s. Composed mainly of rhinologists and neurosurgeons, such centers gradually developed new techniques and therapeutic options that would have simply been unthinkable, even audacious, only a decade earlier. Some of these multidisciplinary skull base centers now routinely perform procedures endoscopically via a transnasal approach, not only to access the pituitary gland but also the anterior, middle, and posterior cranial fossa for treating benign and malignant tumors, comorbidities of physical trauma, and vascular processes; intraconal orbital lesions are among the more recent indications.

A common trait of most of the above procedures is that they use the nasal and paranasal sinuses as corridors and access routes by which endoscopes – as visualization tools – and operating instruments are introduced to perform neurosurgical dissection once the anatomical boundaries of the skull base have been passed. In the late 2000s, the term “endoscopic Rhino- NeuroSurgery” (eRNS) was coined for these procedures.

Robert Reisch and Hans Rudolf Briner with their Zurich team are among the leading endoscopic skull base centers not just in German-speaking countries, but worldwide. With the presentation of this Silver Manual, they provide insights into the fascinating techniques and options available in endoscopic rhino-neurosurgery. This publication features a clear didactic structure, excellent explanations, and practical pearls – the schematic diagrams and images as well as the accompanying videos are among the best published on this topic. In this regard, I would like to thank the KARL STORZ company for the excellent design, which makes reading and studying an enjoyable experience!

The authors clearly emphasize the risks related to the complex anatomy and its variations, the migration of structures, or even tumor infiltration. This clearly reflects the great importance that the leading team players, rhinosurgeon and neurosurgeon – in terms of patient safety and optimal outcome of treatment – need to base their decisions on an intense interdisciplinary teamwork (including radiologists, endocrinologists, histopathologists, oncologists, interventional radiologists, pediatricians, ophthalmologists, anesthesiologists, intensive care specialists, etc.).

I sincerely hope that this outstanding Silver Manual will be widely distributed and receives the recognition deserved by its authors and their staff!

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Foreword II

The authors provide a comprehensive overview of all important aspects of endoscopic endonasal skull base surgery. Particularly for expanded endonasal approaches to the skull base, the use of endoscopes versus microscopes offers many advantages. It is therefore unsurprising, that endoscopic approaches have gained widespread acceptance and become the standard of care. The endoscope’s panoramic view affords excellent anatomic orientation, thereby ensuring safer microsurgical dissection. Since the surgical access is narrow and deep, endoscopes offer far better illumination of the surgical site than microscopes. When it comes to radical excision, it is crucial that endoscopes with a direction of view other than 0°, which permit “looking around the corner”, are used to detect and remove hidden tumor portions otherwise missed under a surgical microscope.

Robert Reisch and Hans Rudolf Briner compellingly demonstrate that the cooperation between rhinosurgeons and neurosurgeons is instrumental to an optimal outcome of treatment. With the preoperative imaging modalities available today, planning of the approach is tailored collaboratively on an interdisciplinary level to match the individual circumstances of the patient and to define an access route that is as minimally invasive as possible. The postoperative outcome is considerably determined by a tissue-sparing approach preserving the integrity of nasal anatomy and mucosa. Considering skull base reconstruction as early as during the planning stage is important as well. Descriptions of the planning strategy, equipment, and surgical technique are followed by interesting case reports that clearly illustrate the authors’ philosophy.

Finally, I wish to congratulate the authors on their excellent publication, which provides valuable advice to both beginners and experienced skull base surgeons.

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Foreword III

When my friend Professor Reisch asked me to write a brief preface, parallels to my profession came to mind. Since the beginnings of the art of watchmaking in the 15th century, the most important developments have been dominated by miniaturization, precision, and innovation. The same qualities and advancements characterize minimally invasive surgical techniques today.

The most valuable and prestigious aspect, the key to the art, however still remains in the hands and fingers of our master watchmakers. And the same seems to be true for surgeons.

Despite all the extraordinary technical progress, the surgeon remains the key figure with the dexterity and precision of his or her fingers, which strictly follow the instructions and rhythm set out by the exceptional brain of a human being. It therefore stands to reason that in cases where everyone benefits from the same technology, it will always be the surgeon with his or her abilities that will make the difference. The value of the human being will always remain the decisive and dominating aspect.

Jean-Claude Biver
President of the Watches Division of the LVMH Group, Paris, France
Chairman of Hublot, TAG Heuer and Zenith
Preface

For decades, conventional microsurgery performed with a surgical microscope was the gold standard in transnasal surgery of pituitary adenoma and tumors of the central skull base. Current studies, however, demonstrate that much better control of tumor resection and more favorable functional results can be achieved with endoscopic surgical techniques.

Through multidisciplinary rhino-neurosurgical collaboration, the transnasal endoscopic technique can also reduce access-related surgical trauma and demonstrably improve the postoperative rhinological quality of life.

This manual presents the concept of minimally invasive transnasal endoscopic skull base surgery. We describe the technique for tailored approaches, present the instruments used, and discuss illustrative case reports.

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1.1 Introduction

The microsurgical transnasal approach to pituitary adenomas and tumors of the central skull base is performed under a surgical microscope. Though first described over 50 years ago, the approach is still widely accepted in the field.

However, given the narrow intranasal anatomy, the microscopic approach is fraught with some challenges (Fig. 1.1a). Even though the main nasal cavity is dilated by a speculum, the long and narrow surgical corridor has the drawback of a considerable loss in light intensity. Neal et al.,[47] Reisch et al.[50][51] as well as Higgins et al.[27] have demonstrated that the limited visual control poses some risk of missing a tumor remnant, even if meticulous total resection is attempted (Fig. 1.2). In a study performed by Nimsky et al.,[48], intraoperative magnetic resonance imaging (MRI) was used during macroadenoma surgery; the study showed that even in the hands of highly experienced surgeons, 42% of patients had a significant residual tumor that required continuation of the procedure. Bohinski et al.[4] were “surprised” about the size of the residual tumor as shown by a high-resolution intraoperative MRI scan during a microscopic approach. Mattozo et al.[43] examined a group of patients with recurrent macroadenoma who underwent prior microsurgery and found that each patient exhibited insufficient opening of the sellar floor, resulting in subtotal removal and subsequent recurrence of disease.

More than 40 years ago, the use of endoscopes was already identified as offering great advantages in the surgical treatment of pathologies of the nasal and paranasal sinuses (Messerklinger W., Stammberger H.[45][60]). The same holds true for endoscopic transnasal approaches to the skull base (Fig. 1.1b). Among the advantages derived from the use of endoscopes are a wider field of view, considerably improved light intensity and detail recognition, particularly of structures shown in the depth of the image.

In addition, HOPKINS® rod lens telescopes with an angled direction of view (e.g., 30°, 45°) offer a direct view of adjacent areas which are otherwise not amenable to exploration and therefore permit an adequate level of safety needed to provide surgical treatment under visual control.

Fig. 1.1
The schematic diagram illustrates the general differences between microscopic and endoscopic transnasal surgery. Because of the long and narrow surgical corridor, lateral structures remain hidden in the microscope-based technique. Some cannot be visually controlled during surgery (a). The endoscopic technique offers optimal visualization of the deep surgical field with direct visual control of the lateral structures of the skull base (b).

Fig. 1.2 a–b
Coronal T1-weighted MRI scan of a skull base chordoma (a).
The postoperative MRI shows the limits of the speculum-based microsurgical technique – the surgeon removed only the central part of the tumor, which was visible with the microscope, and therefore missed relevant remnants on both sides and at the tumor base (b).
The concept of minimally invasive transnasal surgery

The introduction of high-resolution (HD) and 4K video technology and now 3D endoscopy have greatly contributed to today’s general availability of excellent image quality, so that the resolution of the video image no longer represents a limiting factor when compared to microscopy (Fig. 1.3).

Another crucial benefit of the endoscopic approach is the significantly improved degree of transnasal maneuverability needed for surgical dissection. Furthermore, the technique offers a considerably enlarged view of the surgical site as compared to the narrow corridor associated with the use of a nasal speculum, and therefore allows for improved maneuverability of surgical instruments and endoscope.

The surgeon has a better view of the tumor and higher chances for removal (Fig. 1.4). A study conducted by Anand et al.\(^\text{[1]}\) revealed that tumor remnants were detected by intraoperative MR imaging at a lower rate after endoscopic resection when compared to a microscopic approach. Furthermore, surgeons were found to assess the residual tumor volume more accurately when based on endoscopy versus microscopy.

Another key benefit of the endoscopic approach is that triangulation and ergonomics are considerably improved as compared to a microscopic approach. In turn, this accounts for improved maneuverability of instruments and allows the range of indications amenable to minimally-invasive surgical treatment to be broadened. The transnasal approach can be tailored and expanded, and the paranasal sinuses offer an optimal transnasal route to the entire central skull base.

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**Fig. 1.3**
Endoscopic view of the nasal cavity, taken with an SD camera unit in the 1990s (a). A modern endoscope with HD camera offers excellent image quality (b).

**Fig. 1.4**
Endoscopic view showing the resection of a large pituitary adenoma. The sellar diaphragma and medial wall of the cavernous sinus on the left can be identified (a). Following complete resection, sagging of the diaphragma and the thin pituitary tissue is noticeable. The medial wall of the cavernous sinus is demonstrated on both sides, with the clivus in the background (b).

Compared to the preoperative MRI (c), the postoperative scan (d) confirms complete resection of the tumor.
As a result, even extensive lesions can be removed through the nostrils, particularly tumors which previously used to be amenable to surgical treatment only by embarking on a challenging skull base procedure via a transfacial or lateral approach. (Fig. 1.5).

Koutourousiou et al.\textsuperscript{[33]} reported that gross total resection was achieved in 82.9\% of patients who underwent primary surgical treatment of clival chordoma and stated: “The endoscopic endonasal approach is a competitive alternative to transcranial approaches with minimal morbidity and high success rate of gross total resection when performed by experienced cranial base surgeons.” In the transnasal endoscopic resection of 103 craniopharyngeomas, Cavallo et al.\textsuperscript{[8]} achieved gross total resection in 68.9\% of cases.

The resection of residual or recurrent tumors is technically challenging. The same group reported a gross total resection rate of 40.9\% in 2009 and 62.1\% five years later.

The endoscopic technique permits skull base pathologies to be included in the range of indications treated via an endoscopic transnasal approach. Without the limitations inherent to the use of a nasal speculum, the transnasal approach can be expanded. Large tumors can be optimally visualized and subjected to extensive resection while maintaining a high level of safety.

Along with the technical advantages derived from the use of an endoscope, current meta-analyses not only show a better degree of resection, but also improved functional results. Dorward\textsuperscript{[14]}, Goudakos\textsuperscript{[20]} and Rotenberg\textsuperscript{[54]} as well as Kurschel et al.\textsuperscript{[34]} conducted conclusive studies and reported better outcomes for endoscopic transnasal surgery, both in terms of endocrinological and ophthalmological criteria.

Using additional outcome measures, a meta-analysis by Strychowsky et al.\textsuperscript{[62]} included mean operative time and intraoperative blood loss, among others. For both criteria, endoscopy was significantly superior to a conventional microsurgical approach.

According to current literature, the use of endoscopic approaches is associated with superior surgical and functional outcomes.

However, the preservation of nasal functions is as important as the primary objective of complete tumor removal. There is no evidence suggesting that postoperative impairment of nasal aerodynamics and olfactory capacity is linked to skull base pathology. Therefore, such symptoms are considered a purely access-related complication which can present a clinically significant stress burden in the postoperative period (Fig. 1.6). Postoperative patient satisfaction is considerably determined by the morbidity of the transnasal approach. Even the best tumor-specific surgical result can be marred by postoperative nasal breathing impairment, crust formation, synecchia, or hyposmia. In their study on large patient populations, Graham et al.\textsuperscript{[21]} showed that the postoperative rhinological outcome is significantly better after a surgical procedure performed using an endoscopic versus a microscopic approach with the use of a speculum.

The use of endoscopic transnasal approaches is associated with reduced surgical morbidity, better rhinological outcomes and lower surgical risks.

Despite these advantages, many skull base surgeons are reluctant to adopt the endoscopic technique, which is mainly
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related to a lack of experience with endoscopy, as well as to a long and arduous learning curve. It is of paramount importance that surgeons-in-training have a basic understanding of rhinology and thorough knowledge of the anatomy of nasal cavities, paranasal sinuses and skull base. Beginners to the technique are advised to attend special hands-on training courses on endoscopic anatomical dissection (Fig. 1.7). Berhouma et al.[2] developed a tumor model for cadaver dissection and observed that young surgeons-in-training readily develop the skills which are needed to perform well in the learning process.

It is certainly difficult to determine the minimum number of procedures needed to develop a good level of proficiency in the endoscopic technique. A study by Zaidi et al.[68], however, showed that after 100 procedures, the surgical outcomes of an inexperienced endoscopic surgeon are comparable with those of a very experienced surgeon using an operating microscope (n > 1800).

In the beginning, surgical procedures take longer than average due to the unfamiliar anatomic environment, the surgeon's not being conversant with endoscopic dissection, and a lack of self-confidence. Qureshi et al.[49] studied 78 endoscopic pituitary surgeries and found that mean operative time is considerably longer at the start of the learning curve. Particularly in the resection of complex tumors, increasing experience plays an important role. For clival chordoma, Kassam et al.[29] discovered that the learning curve plays a critical role in the completeness of tumor resection and the rate of intraoperative and postoperative complications. Kshettry et al.[35] made a similar finding with regard to craniopharyngeomas. As experience grows, the rate of gross total resection climbs from 20% to 65%, and the risk of severe complications drops from 15% to 4%.

During the transition from microscopy to endoscopy, Yang et al.[67] finds it helpful to continue using the surgical microscope and checking the operative site endoscopically, as required. At an advanced stage of the learning curve, familiarity with the fully endoscopic method is then fortified with the support of a rhinologist.

The advantages of endoscopic surgery in the multidisciplinary collaboration between rhinosurgeons and neurosurgeons have been recognized for years. Stammberger[34], for instance, coined the term “endoscopic rhino-neurosurgery” at an early time.

Fig. 1.6
Typical nasal pathologies encountered after transnasal surgeries: Septal perforation (a), adhesions, and scarring (b) as well as crust formation (c).

Fig. 1.7
Training in an anatomy laboratory and attending endoscopic hands-on dissection courses can considerably shorten the surgical learning curve. Shown is the initial testing of the TIPCAM® 3D endoscope at the Budapest Anatomy Institute (a) and transnasal pre-dissection (b) during a course at the KARL STORZ Visitor and Training Center Berlin, Germany.
As regards the therapeutic protocols currently established at leading skull base centers, there is consensus about the particular importance of a multispecialty team concept, which usually comprises a rhinosurgeon and a neurosurgeon, who work closely with each other on both the individualized surgical approach and the overall treatment plan. All steps are carried out cooperatively. This applies to decision-making on the indication, treatment planning, preoperative counseling and informed consent of the patient, the entire surgical procedure, and postoperative follow-up care including the management of any complications.

1.2 Diagnostics and preoperative imaging

Disorders in the area of the skull base can lead to a variety of symptoms, which often are non-specific. For instance, hormone-inactive pituitary adenomas are characterized by visual disturbances, hormone-active adenomas by abnormalities affecting a specific hormone axis, and olfactory neuroblastomas by impaired olfactory function and blocked nasal breathing. Tumors that invade the inner skull can cause focal neurological deficits, epileptic seizures, and signs of increased intracranial pressure due to blockage of cerebral fluid circulation.

Consequently, the diagnostic workup comprises a comprehensive clinical assessment provided by a multidisciplinary team of experts. The overall clinical picture of the medical condition is drawn up by a neuroradiologist, neurologist, ophthalmologist, endocrinologist, radio-oncologist, pathologist, otorhinolaryngologist, and a neurosurgeon. Special emphasis of preoperative diagnostic evaluation is laid on rhinological function testing. Apart from endoscopic assessment of the individual nasal anatomy, Simmen and Jones advise to evaluate olfactory function with an objective olfactory test and to assess the rhinological quality of life by using the SNOT-20 questionnaire 7 (Fig. 1.8).

The basic radiological assessment is established using contrast-enhanced MRI for optimal visualization of soft tissues and non-enhanced CT images to demonstrate and evaluate the osseous situation (Table 1.1, Table 1.2).

In pituitary adenoma, a dynamic contrast-enhanced series facilitates localizing the tumor in the gland (Fig. 1.9); TOF MRI can precisely display the course of the internal carotid artery. Blitz et al. additionally recommend a 3D MRI of the skull base, including thin-slice T2 imaging (Constructive Interference in the Steady State, CISS) (Fig. 1.10).

Schuknecht emphasizes the importance of preoperative diagnostic imaging based on high-resolution CT scans of the paranasal sinuses and the skull base (Fig. 1.11). If necessary, the 3D CT and MRI data obtained in the preoperative period can be merged and used for intraoperative navigation.

Table 1.1 Imaging for assessment of skull base pathologies. Abbreviations: Time-of-Flight (TOF); Magnetic resonance angiography (MRA); Balloon Test Occlusion (BTO); Constructive Interference in the Steady State (CISS)

<table>
<thead>
<tr>
<th>Standard procedures</th>
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<tbody>
<tr>
<td>MRI with T1/T2 standard sequences with/without contrast agent</td>
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<tr>
<td>TOF MR angiography</td>
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<tr>
<td>Non-enhanced CT of the skull and paranasal sinuses with bone window</td>
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<tr>
<th>Optional procedures</th>
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<tr>
<td>Special MRI sequences</td>
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<tr>
<td>1. Dynamic contrast-enhanced pituitary scan</td>
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<tr>
<td>2. Thin-slice T2 sequence of the parasellar region (CISS)</td>
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<tr>
<td>3. 3D MR angiography with contrast agent</td>
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<tr>
<td>Contrast-enhanced CT with 3D CT angiography</td>
</tr>
<tr>
<td>Diagnostic angiography with balloon test occlusion (BTO) and optional occlusion of the internal carotid artery</td>
</tr>
<tr>
<td>Whole-body CT and PET-CT (malignant tumors)</td>
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</tbody>
</table>

Fig. 1.8 Olfactory function and nasal quality of life are assessed preoperatively and postoperatively. The standard assessment includes nasal endoscopy and an olfactory test with Smell Discettes® (inset image).
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Fig. 1.9
Coronal MR imaging of an intrasellar pituitary adenoma. Through the comparison of T2-weighted (a), non-enhanced (b), and dynamic contrast-enhanced (c) images, the gland can be differentiated from tumor tissue. TOF MR angiography with 3D reconstruction is an integral part of the diagnostic workup before transnasal procedures (d).

Fig. 1.10
Thin-slice T2-weighted MR images of the central skull base (Constructive Interference in the Steady State, CISS) allows to distinguish between cranial nerves and vessels.
When compared to contrast-enhanced T1-weighted imaging (a), the sagittal plane can be used to exactly assess the pathologically altered anatomy of a complex craniopharyngioma, particularly the relationship between the tumor, optic chiasm, and pituitary stalk (b).

Fig. 1.11
High-resolution CT imaging in three planes is mandatory when planning a transnasal approach. The coronal CT scan is particularly useful to examine the anatomy of the nasal cavity and paranasal sinuses (a). Sagittal (b) and axial (c) scans are well-suited to visualize pneumatization patterns and septations of the sphenoid sinus.

Fig. 1.12
The coronal T1-weighted contrast-enhanced, fat-suppressed MR imaging of a skull base carcinoma (a) reveals tumor invasion of the right internal carotid artery.
Given the considerable risk of carotid injury, a balloon test occlusion was conducted (b).
Depending on the type and location of the pathology, the use of additional imaging modalities may be advisable. To visualize the parasellar vascular anatomy, MRI or CT angiography, and in selected cases, digital subtraction angiography (DSA) may be employed. If there is a risk of carotid injury, Sylvester et al.\(^{26}\) recommend balloon test occlusion (BTO) of the internal carotid artery. In special cases, and given adequate perfusion from collateral vessels, the internal carotid artery may be preventedly occluded during the intervention (Fig. 1.12). For malignant pathologies, staging examinations may be indicated with whole-body CT and/or PET-CT.

The preoperative diagnostic work-up comprises neurological examination, detailed neuro-radiological imaging, endocrinological analysis, ophthalmological tests including visual acuity and field of vision, and rhinological assessment comprising nasal endoscopy, olfactory testing, and measurement of the sinonasal quality of life.

### 1.3 Multidisciplinary treatment planning

Once the detailed diagnostic work-up is complete, the diagnosis and therapeutic options are discussed with the patient. In case of malignant tumors, the recommendation of the multidisciplinary tumor board is presented. If surgical treatment is indicated, the patient is jointly informed about the planned procedure.

It is important for the patient to understand the principles of the planned surgery and to be informed about the postoperative implications, long-term prognosis, and potential complications.

The technical planning of the rhino-neurosurgical procedure is also done on a multidisciplinary basis. Depending on the localization, type, and extent of the pathology, an approach is planned which enables maximum surgical control and safe resection while preserving as much as possible the integrity of the nasal anatomy. In the presence of large tumors extending to the orbits or the facial skull, specialists experienced in orbital / oculoplastic, maxillofacial, or plastic surgery are included in the surgical team. In case of malignant tumors, intraoperative cryosection analysis may be planned and reviewed with the pathologists.

The option of intraoperative cranial nerve monitoring is evaluated with the neurologists. If the planned procedure carries the risk of iatrogenic injury to major arteries or even involves resection of the carotid artery, angiography and balloon test occlusion are performed beforehand. Interventional neuroradiologists are also involved in planning the procedure and are on standby at all times during surgery in case iatrogenic injury of the carotid artery necessitates immediate embolization. The need for intraoperative imaging is discussed in advance as well and planned as required (Table 1.3).

It is imperative to anticipate and plan for special situations which may emerge in the course of surgery, e.g., if a tumor is not amenable to surgical removal via the planned approach. Koechlin\(^{32}\) advises to have a backup plan for such situations, e.g., by combining the chosen approach with a craniotomy or by opting for another transfacial access (Fig. 1.13). For such backup measures to kick in promptly and effectively, the entire procedure must be coordinated proactively making sure that all team members involved are given sufficient time to respond as required.

The concept of interdisciplinary teamwork is applicable in all stages of the patient management and care, including decision-making for indication, treatment planning, informed consent of the patient, preparation for surgery, teamwork during surgery, postoperative follow-up care, and management of complications.
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<table>
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<th>Checklist</th>
<th>Comment</th>
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<td>Surgical approach</td>
<td>Uniportal or biportal approach?</td>
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<td></td>
<td>Paraseptal – transeptal – combined?</td>
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<td>Other surgical specialists needed</td>
<td>Maxillofacial surgery</td>
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<td>Plastic surgery</td>
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<td>Intraoperative cryosection analysis</td>
<td>Pathology</td>
</tr>
<tr>
<td>Intraoperative neuromonitoring</td>
<td>Neurology</td>
</tr>
<tr>
<td>Risk of iatrogenic injury to the internal carotid artery</td>
<td>Preoperative angiography, balloon test occlusion (BTO)</td>
</tr>
<tr>
<td></td>
<td>Interventional neuroradiology in “stand-by”</td>
</tr>
<tr>
<td>Intraoperative imaging</td>
<td>Intraoperative CT or MRI</td>
</tr>
<tr>
<td></td>
<td>Radiology</td>
</tr>
<tr>
<td>Sufficient time</td>
<td>All members of the involved team</td>
</tr>
</tbody>
</table>

**Table 1.3**
Checklist for treatment planning.

**Fig. 1.13 a–c**
Backup measure or “Plan B” for the transnasal resection of a recurrent craniopharyngioma (a). Treatment planning includes the option of adding a transcranial supraorbital approach in case complete tumor resection is not feasible via the transnasal approach (b). The postoperative MRI shows the complete resection of the craniopharyngioma (c). In this case, purely transnasal tumor resection was feasible, making the use of Plan B unnecessary.

**Fig. 1.13 d–f**
A transplanum approach allowed to dissect the tumor which was firmly adherent to the optic chiasm (d). Solid portions were stripped off the tip of the basilar artery and the mamillary bodies (e). Following tumor resection, the anterior cerebral arteries, the optic chiasm, and the preserved pituitary stalk were clearly demonstrated. In the background, the opened third ventricle is shown (f).
2.1 Preparation in the operating room and OR setup

The intubated patient is put under general anesthesia and positioned supine. If an optoelectronic navigation system is used, the patient’s head is clamped, elevated above the thoracic level, slightly retroflexed, tilted to the side, and rotated to the right (Fig. 2.1).

Electromagnetic navigation does not require fixing the head in place. An intraoperative CT or MRI is employed, if necessary, and the navigation is registered.

If the face is draped, the eyes are always excluded to enable intraoperative assessment of any orbital complications. Decongestion of the nasal mucosa is provided by cotton swabs soaked in epinephrine (1:100,000) and tetracaine (1%), and placed in the nasal cavities (Fig. 2.3). After giving adequate time for vasoconstriction (3 minutes), both nasal cavities are inspected and a definite decision is made as to the side chosen for the approach. At this point, swabs with undiluted epinephrine solution (1:1000) are placed specifically in the area of the planned approach to optimally decongest the mucosa.

The periumbilical region is disinfected and left undraped as well to allow the harvest of abdominal fat and fascia of the rectus abdominis muscle for skull base repair. If more fascia is needed, the lateral thigh can be prepared for harvesting fascia lata (Fig. 2.2).

If necessary, the lateral thigh is also disinfected to harvest fascia lata.

During surgery, the face is left undraped in order to allow assessment of any orbital complications and pupil motor function.

The abdomen is also left undraped to allow abdominal fat and fascia to be harvested from the rectus abdominis muscle for skull base repair.

If necessary, the lateral thigh is also disinfected to harvest fascia lata.
Endoscopic rhino-neurosurgery

Fig. 2.3
Upon initial nasal endoscopy, the mucosa often appears with signs of hypertrophy (a). Following the targeted placement of epinephrine-soaked swabs (b), the mucosa appears significantly decongested (c).

Preparation in the operating room is performed by the surgeons. They are responsible for ensuring correct positioning, registering the navigation, and decongesting the nasal mucosa.

Both surgeons stand or sit to the right of the patient and perform surgery using the bimanual 4-hand technique. The monitors for the endoscope and the navigation are placed on the opposite side in such a way that the two surgeons have the best possible view, maintaining an ergonomic head posture (Fig. 2.4).

The surgical nurse sits or stands on the left side. The nurse prepares the instruments, operates the surgical devices on a touchscreen, controls the illumination and music in the operating room, and monitors the video documentation (Fig. 2.4). The nurse follows the surgical steps on a separate monitor and provides irrigation for both the surgical field and the endoscope. The technical assistant takes charge of the complex endoscopic equipment, the navigation system, and the intraoperative imaging, if necessary, and assists the surgical nurse.

Fig. 2.4 a–b
Schematic illustration of the operating room setup (a). The two surgeons sit or stand next to each other to the right of the patient (b) and have a straight, ergonomic view of the surgical and navigation monitors.
2.2 The bimanual endoscopic surgical technique (4-hand technique)

The traditional transnasal endoscopic technique leaves the surgeon only one hand free to dissect because the other hand is needed to guide the endoscope. Drawbacks of the technique become evident when faced with challenging situations, e.g., in the event of incipient bleeding or if a skull base tumor needs to be dissected. Accordingly, the bimanual endoscopic surgical technique has been designed such, that one surgeon is entrusted with the role of guiding the endoscope while leaving the second surgeon both hands free for dissection (Figs. 2.5, 2.6). The method was described by May as well as by Briner and Simmen and is also known as "4-hand technique". It permits precise bimanual dissection while allowing to gain rapid control of bleeding because a suction device is always kept ready for use in the surgical field.

Taking into account that lesions of the skull base need to be managed surgically by accurate and safe dissection, it is imperative that any rhino-neurosurgical procedure be performed using a bimanual surgical technique. As a rule, during the transnasal stage of the approach, the neurosurgeon holds the endoscope while the dissection work is performed by the rhinosurgeon. The roles are reversed when it comes to resection of skull base pathology (Fig. 2.6).

Rhino-neurosurgery is bimanual microsurgery performed under endoscopic control.

Fig. 2.5
In the bimanual surgical technique (4-hand technique), one of the surgeons guides the endoscope allowing the other surgeon to use both hands (a). The “camera operator” may also assist the surgeon if additional instruments are needed in the surgical field. (b). The bimanual surgical technique is an integral part of any rhinosurgical procedure.

Fig. 2.6
Rhino-neurosurgery is teamwork. The camera operator is not a passive staff member who only guides the endoscope – he or she actively assists the surgeon currently performing dissection, anticipates the needs of the surgeon, and contributes ideas on how to continue surgery.
2.3 Rhino-neurosurgery

Neurosurgical procedures are principally aimed at the complete removal of a tumor, because clinical evidence has demonstrated that the degree of resection is correlated with the duration of progression-free survival.

However, the benefit of maximum radicality is reduced if quality of life is at stake owing to extensive surgical trauma. The goal is therefore to achieve the best possible surgical result while causing the least possible trauma. This goal can be achieved by a minimally invasive transnasal skull base approach which is based on multidisciplinary rhino-neurosurgical teamwork and individually tailored access routes.

Endoscopic rhino-neurosurgery is geared toward safely achieving the best possible outcome while sparing healthy structures and causing only minimal access-related morbidity. Transnasal approaches are individually tailored to the pathological and anatomical circumstances of each patient. The rule of thumb is: “As much as necessary, but as little as possible!”

The objective is to achieve the highest degree of local tumor control through complete resection while sparing the nasal septum, turbinates, olfactory cleft, and nasal mucosa. Adhering to the basic principles of minimally invasive surgery is crucial to prevent postoperative crusting and preserve physiologic airflow conditions in the nose.

Sparing the mucosa is paramount to postoperative wound healing and the prevention of rhinological complications. Harsh contact, senseless tearing, and extensive monopolar coagulation of the mucosa are obsolete – whereas gentle, sharp dissection, and targeted bipolar coagulation are permissible in the nose. The nasal mucosa should be treated with as much care as the surface of the brain (Fig. 2.7).

In the nose, the key principles of functional endoscopic sinus surgery (FESS) must be adhered to. Preserving integrity of the nasal septum, turbinates, olfactory cleft and nasal mucosa is critically important in minimally invasive transnasal surgery.

2.4 Tailored approaches

Multidisciplinary teamwork and accurate preoperative treatment planning are the pillars on which any individually tailored surgical approach is built. Depending on tumor location and extension, the patient-specific anatomy plays a crucial role in the decision-making as to which access route will be taken (Table 2.1a, b). Accordingly, the final dimension of the approach is tailored to the specific needs of each patient. In our clinical practice, it has proven sensible to use a reference scheme ranging from XS to XXL, similar to that used to define garment sizes. The final dimensions of such a tailored approach are defined as small as possible but as large as necessary. Major contributing factors are subject to the ability of the surgical team to specify the appropriate anatomic landmarks – which serve to guide the approach in the nasal cavity and paranasal sinuses – and to identify them correctly during surgery (Fig. 2.8).
### Table 2.1 a
Transnasal endoscopic uniportal approaches to the skull base.

<table>
<thead>
<tr>
<th>Uniportal approaches</th>
<th>Surgical steps</th>
<th>Target region</th>
<th>Indication</th>
</tr>
</thead>
</table>
| XS                   | Direct paraseptal approach | 1. Lateralization of the middle and superior turbinates  
2. Exposure of the sphenoid recess  
3. Mucosal flap of the anterior sphenoid wall  
4. Rostrectomy  
5. Sphenoidotomy | Sphenoid sinus  
Central skull base | Small midline tumors  
Pituitary adenomas  
Rathke cleft cysts |
| S                    | Lateral transethmoidal approach | 1. Medialization of the middle turbinate  
2. Uncincetomy  
3. Exposure of the natural ostium of the maxillary sinus  
4. Resection of the ethmoid bulla  
5. Opening of the basal lamella of the middle turbinate  
6. Resection of the posterior ethmoid air cells  
7. Assessment of the sphenopalatine foramen  
8. Sphenoidotomy | Maxillary sinus  
Pterygopalatine fossa  
Infratemporal fossa  
Cavernous sinus  
Anterior knee of carotid artery  
Petros apex | Laterally located sinonasal tumors  
Angiofibromas  
CSF fistulas |
| M                    | Combined transethmoidal-paraseptal approach | XS and S in succession | XS and S | Pituitary adenomas  
Chordomas  
Craniopharyngiomas  
Meningiomas |

### Table 2.1 b
Transnasal endoscopic biportal approaches to the skull base.

<table>
<thead>
<tr>
<th>Biportal approaches</th>
<th>Surgical steps</th>
<th>Target region</th>
<th>Indication</th>
</tr>
</thead>
</table>
| L                   | Unilateral ethmoidectomy combined with a bilateral paraseptal approach | XS on one side, M on the other | From the olfactory fossa to the clivus and anterior vertebrae C1/C2  
On one side, lateral to the cavernous sinus, pterygopalatine fossa, petrous apex, and infratemporal fossa | Pituitary adenomas  
Esthesioneuroblastomas  
Meningiomas  
Chordomas  
Chondromas  
Sarcomas and carcinomas |
| XL                  | Bilateral ethmoidectomy combined with a bilateral paraseptal approach | M bilaterally | From the olfactory fossa to the clivus and anterior vertebrae C1/C2  
On both sides, lateral to the cavernous sinus, pterygopalatine fossa, petrous apex, and infratemporal fossa | Pituitary adenomas  
Esthesioneuroblastomas  
Meningiomas  
Chordomas  
Chondromas  
Sarcomas and carcinomas |
| XXL                 | Combined transnasal-transcranial approaches | M, L, or XL combined with transoral, transfacial, or transcranial approaches (e.g., supraorbital, pterional, subtemporal, or retrosigmoid) | Expanding skull base tumor with invasion of the facial skull or the anterior, middle or posterior cranial fossa | Pituitary adenomas  
Esthesioneuroblastomas  
Meningiomas  
Chordomas  
Chondromas  
Sarcomas and carcinomas |
Intraoperatively, a systematic nasal endoscopy allows to identify the relevant anatomic landmarks comprising the inferior (a), middle (b), and superior turbinates (c) with sphenethmoidal recess. The middle nasal meatus with uncinate process and ethmoid bulla are shown beneath the middle turbinate (d). Passing along the inferior turbinate, the choana (e) and epipharynx with the laterally located tubal ostium (f) are visualized.
In the presence of smaller, centrally located lesions and given a wide nasal cavity, an uniportal paraseptal approach is chosen (Fig. 2.9). In this case, the middle and superior turbinates are lateralized on one side, and the sphenoethmoidal recess is exposed. To obtain as much mucosa as possible, a small, inferiorly pedicled mucosal flap is created at the anterior sphenoid wall along with the posterior septum and temporarily transposed into the choana. Subsequently, the perpendicular plate of the ethmoid bone is detached from the sphenoid crest. An osteotome is used to perform a conservative posterior septectomy (no more than 10 mm), rostrectomy, and a wide bilateral sphenoidotomy. In that way, the sphenoid sinus and central skull base are usually displayed adequately.

To ensure optimal wound healing, the previously created mucosal flap is repositioned toward the vomer base after completion of tumor resection.

Fig. 2.9 a–i
The nasal cavity is inspected after mucosal decongestion. The head of the middle turbinate is identified as a landmark (a). The turbinates are cautiously mobilized laterally using a blunt dissector, and the sphenoethmoidal recess is exposed (b). Following linear coagulation of the mucosa (c), an inferiorly pedicled mucosal flap is created (d), the perpendicular plate of the ethmoid bone is dissected away from the sphenoid crest and vomer, sparing the septal mucosa on the contralateral side (e). Subsequently, an osteotome is used to mobilize (f) and remove (g) the anterior sphenoid sinus wall. Intersphenoidal septa are resected (h), and the sphenoid sinus with the sellar floor is exposed. Removal of the mucosa of the sella turcica should be strictly limited to the anticipated area of tumor resection (i). The following anatomic landmarks are shown: Optic canal, internal carotid artery, and clivus.
In the presence of far lateral lesions, an ethmoidectomy is performed through a single access (uniportal transthyroidal approach) (Fig. 2.10). The middle turbinate is medialized, and the middle nasal meatus is exposed. Following uncinectomy, the natural ostium of the maxillary sinus is exposed, the ethmoid bulla is removed, and the basal lamella of the middle turbinate is identified. Once the latter structure has been partially resected, the posterior ethmoid air cells are opened. After assessing the sphenopalatine foramen with the branches of the sphenopalatine artery contained therein, the anterior wall of the sphenoid sinus is displayed and opened. The uniportal ethmoidectomy gives access to lesions of the maxillary sinus, pterygopalatine fossa, infratemporal fossa, cavernous sinus, anterior carotid knee, and petrous apex.

![Fig. 2.10 a–i](image-url)

Once the middle turbinate is medialized and the middle nasal meatus has been exposed, the uncinate process is incised using a sickle knife (a). Following completion of uncinectomy with straight Zurich scissors (b), the ethmoid infundibulum is revealed. Given narrow anatomical conditions, the mucosa of the lateral nasal wall is incised at the level of the middle turbinate (c) to enable an anterior access to the maxillary sinus (d). Sparing the nasolacrimal duct, the natural ostium is enlarged, and the maxillary sinus is inspected (e). The ethmoid bulla is resected as far as the basal lamella (f). Partial resection of the basal lamella reveals the posterior ethmoid air cells (g). The anterior sphenoid sinus wall is opened, giving access to the sphenoid sinus (h). The lateral sphenoidotomy is now enlarged downward, followed by inspection of the sphenopalatine artery branches emerging from the sphenopalatine foramen (i).
In the presence of larger tumors of the central skull base, paraseptal exposure is combined with a transethmoidal approach (Fig. 2.11). In the uniportal transethmoidal paraseptal approach, the middle and superior turbinates are lateralized following unilateral ethmoidectomy, and a paraseptal corridor is created to gain access to the sphenoid sinus as described above.

Through the wide sphenoidotomy, the central skull base can be viewed from the planum sphenoidale to the clivus and the cavernous sinus on both sides without removing the turbinates, without extensive septal resection, and without causing injury to the olfactory cleft.

The uniportal combined transethmoidal-paraseptal approach permits broad exposure of the skull base and is therefore suitable for most skull base pathologies.

Fig. 2.11 a–i
Initially, the ethmoid bulla is resected following uncinectomy (a). After inspection of the maxillary sinus, the basal lamella of the middle turbinate is bluntly opened (b). The posterior ethmoid air cells are partially resected, and the anterior wall of the sphenoid sinus is opened with a punch (c). Next, the middle turbinate is cautiously lateralized (d). The sphenoethmoidal recess and the sphenoid ostium are accessed along the midline, and the mucosa is protected by means of surgical gauze (e). Here, the sphenoid rostrum and posterior septum are exposed after forming a mucosal flap (f). Using the osteotome, conservative posterior septectomy is performed, and the anterior wall of the sphenoid sinus is removed (g). After wide bilateral sphenoidotomy, the intrasphenoidal septa are resected (h), and the sellar floor is opened using a burr while sparing the mucosa (i).
Given extensive tumor growth with bilateral invasion of the skull base and intracranial lesions, insertion of the endoscope via the same corridor can compromise maneuverability of surgical instruments. Instead of opting for resection of the turbinates or the nasal septum, in these cases, we advise that a second portal for transnasal visualization be created (Fig. 2.12). If needed, the unilateral transethmoidal-paraseptal approach can be enlarged by contralateral paraseptal exposure providing more space for dissection – the endoscope is then inserted from the opposite side, making it far less prone to interfere with surgical dissection (“L” approach). Given very large tumors or if additional working space is needed to manage particularly challenging dissections, bilateral ethmoidectomy can expand the space for unimpeded transnasal surgery (“XL” approach). Sparing the middle turbinates and cautious resection of the posterior nasal septum are essential in these circumstances.

Fig. 2.12 a–i
Endoscopic view of the middle nasal meatus with uncinate process and ethmoid bulla (a). The uncinate process is resected (b), and ethmoidectomy is performed (c). In the posterior ethmoid, the sphenoid sinus is exposed inferiorly and medially (d). Upon completion of sphenoidotomy, the anterior carotid knee is shown as a typical landmark (e). Following lateralization of the right turbinate, a nasoseptal flap is created (f). Sparing the superior turbinate, the sphenoid sinus is now accessible in a paraseptal direction (g). On the contralateral side (h), a left transethmoidal-paraseptal approach is used, and in this case, the endoscope can be inserted from the left without spatial restrictions, while providing adequate visual control during the most likely very demanding tumor resection (i).
If there is doubt about achieving adequate surgical control via an uniportal transnasal approach, a combined transnasal-transcranial procedure should be planned and conducted accordingly (Fig. 2.13). When there is a need for tumor resection in the anterior and central cranial fossa, it may be sensible to combine the transnasal approach with a minimally invasive supraorbital or pterional approach. When access to the middle cranial fossa is needed, a subtemporal approach, and to the posterior cranial fossa, a retrosigmoidal approach may be added.

In rare cases, the transnasal approach can be combined with a transoral or transfacial approach. The concept of tailored approaches is the basis of minimally invasive endoscopic transnasal surgery.

Fig. 2.13
In case of significant intracranial tumor growth, the transnasal approach can be combined with a transcranial approach in the same session. Shown is the real rhino-neurological teamwork as needed in the case of a combined approach. Here, the transnasal approach is combined with a left pterional craniotomy. Both surgeons have their own monitor to work from, and the instruments “meet” at the operative site in the skull base.

Fig. 2.14 a–e (next page)
A series of clinical cases which required the use of a combined approach. For treatment of recurrent skull base metastasis, the transnasal endoscopic approach was combined with a supraorbital approach (a). For recurrent chondrosarcoma, a pterional approach (b), for recurrent angiofibroma, a subtemporal approach (c), and for recurrent chordoma, a retrosigmoidal approach (d) was added. For treatment of a C0–C2 chordoma, the transoral approach was expanded (e).
2.5 Postoperative follow-up

After tumor resection, the nasal structures – which have been temporarily mobilized during the transnasal approach – are repositioned anatomically, returning the superior and middle turbinates to their previous positions. Typically, no nasal packing is used, allowing patients treated by endoscopic surgery to enjoy the postoperative benefit of unobstructed nasal breathing.

Postoperative surveillance is provided on the intermediate care unit (Table 2.2). From the first postoperative day, the mucosa is treated topically with nasal ointment, and the inhaled air is humidified with a nebulizer. After a follow-up control including CT or MRI, patients are mobilized on the ward (Fig. 2.14).

<table>
<thead>
<tr>
<th>Time</th>
<th>Follow-up care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day of surgery</td>
<td>Intermediate care, IMC</td>
</tr>
</tbody>
</table>
| From postoperative day 1 | CT or MRI  
Mucosal care with nasal ointment and nebulizer |
| Postoperative day 2 | Endoscopic inspection and nasal care                                           |
| Postoperative day 3 | Discharge after clinical follow-up exam and endocrinological exam            |
| Postoperative day 14 | Rhinological and endocrinological follow-up exams                          |
| 3-month follow-up | MRI and rhinological follow-up with measurement of sinonasal function (SNOT-22 smell test) |
| 12-month follow-up | MRI and rhinological follow-up with measurement of sinonasal function (SNOT-22 smell test) |

Table 2.2
Postoperative follow-up care and rhino-neurosurgical follow-up monitoring.

On the second postoperative day, nasal endoscopy is performed with careful cleaning and care of the nasal cavity (Fig. 2.15). Independent mobilization is permissible. On the third postoperative day, patients are commonly discharged from the hospital, depending on their condition. Rhinological and endocrinological examinations are performed at the 2-week follow-up visit. Any hormonal substitution therapy is optimized, if necessary. At 3-month follow-up, use of non-invasive imaging techniques is the current standard of care. Additional follow-up measures and those indicated to manage the course after rhino-neurosurgical procedures are determined on the basis of the treated pathology and surgical outcomes.

Chester et al.\cite{9} describe various methods for measuring the sinonasal outcome. At our hospital, sinonasal function is evaluated on the basis of a clearly defined algorithm. Preoperatively, and also at 3- and 12-month follow-up, nasal endoscopy is performed, the sinonasal quality of life is assessed using the SNOT-22 (Sino-Nasal Outcome Test) questionnaire, and olfactory function is measured bilaterally with an olfactory test (Smell Diskettes\textsuperscript{e}). For our patient group, Eördögh et al.\cite{15} reported no surgery-related deterioration of sinonasal function in 50 consecutive cases. On the contrary, a trend toward improved rhinological function was observed regardless of the surgically treated pathology.

Fig. 2.14
Following overnight monitoring, patients are transferred to the ward on postoperative day 1. No nasal packing is needed, nasal ointment is applied to the mucosa, and the inhaled air is humidified by a nebulizer.

Fig. 2.15
At nasal endoscopy on postoperative day 2, the nose is cautiously cleaned.

Thorough postoperative follow-up is as important as a tissue-sparing and meticulous surgical technique.
2.6 Prevention and management of surgical complications

Transnasal endoscopic surgery is associated with a risk of nasal, paranasal, orbital, parasellar, and intracranial complications. The most effective means to treat complications is to prevent them from occurring in the first place. A detailed and well-adapted strategy planning on which surgical approach will be adopted – paying careful attention to anatomic variants, consistent neuronavigation, and accurate dissection – is sine qua non to ensure the safest possible surgery. In his review on preventing complications, Stamm\textsuperscript{[59]} emphasized: “Surgeons must always remember that, although high technology such as endoscopes, image-guided surgery systems, imaging studies, and advanced anesthetic drugs were essential for the development and improvement of the skull base surgery, the success of this type of surgery depends on perfect knowledge of the anatomy, intense endoscopic surgery training, and a multidisciplinary partnership.”

2.6.1 Endonasal complications
Preserving integrity of the nasal anatomy and mucosa to the best possible degree is critical in minimally invasive surgery. Any surgical treatment performed hastily or without adequate care is prone to produce iatrogenic trauma to the nasal mucosa, leading to postoperative synechiae and impaired drainage of the affected sinuses. The scar-related complete obstruction of a paranasal sinus cavity accounts for mucocele formation which necessitates surgical treatment. Resection of the turbinates and nasal septum can adversely affect nasal aerodynamics and often results in excessive crusting. Adhesions in the olfactory cleft frequently lead to postoperative hyposmia or anosmia.

Swanson et al.\textsuperscript{[61]} have demonstrated that resection of the middle turbinate is associated with a significantly higher risk of chronic rhinosinusitis. Gliklich et al.\textsuperscript{[19]} have shown that chronic rhinosinusitis leads to a considerably decreased quality of life. Rice et al.\textsuperscript{[53]} stressed: “An excessive turbinectomy might lead to crusting, bleeding, paradoxical breathing difficulty, recurrent infections, nasal odor, pain and often clinical depression and empty nose-syndrome.”

The mucosa is handled cautiously and protected with cotton patties, if necessary (Fig. 2.7, p. 23). Diffuse bleeding should not be controlled using extensive monopolar coagulation. It is better to apply epinephrine-soaked swabs or focal bipolar coagulation (Fig. 2.16).

Briner et al.\textsuperscript{[6]} recommend using a bipolar coagulation suction cannula. Bleeding from branches of the sphenopalatine artery is coagulated in a targeted and consistent manner to prevent postoperative epistaxis, among others.

Endonasal complications can be avoided by minimizing trauma to the nasal anatomy and the mucosa.

---

**Fig. 2.16**
Diffuse mucosal bleeding can be controlled by local application of epinephrine-soaked conical pledges (a). Hemostasis of local arterial bleeding is achieved in a targeted manner using a bipolar coagulation forceps (b) or a bipolar suction coagulator (c). Extensive monopolar coagulation of the mucosa is obsolete in minimally invasive transnasal surgery. A monopolar suction cannula should only be used to manage diffuse osseous bleeding (d).
2.6.2 Paranasal and orbital complications

During ethmoidectomy, there is an inherent risk of iatrogenic injury to adjacent anatomic structures such as orbital contents. If the lamina papyracea is inadvertently perforated, adipose tissue bulges into the ethmoid. It is generally not necessary to place a cover layer onto the protruding orbital contents (Fig. 2.17a). Injury to the eye muscles, particularly the medial rectus muscle, and the optic nerve in the posterior orbital apex is associated with severe consequences. The result can be permanent vision impairment and/or permanent diplopia. The posterior ethmoid – particularly with a sphenoidethmoidal (Onodi) cell extending to the optic canal – is a predilection area for complications (Fig. 2.17b). Inadvertent injury to the optic nerve leads to postoperative blindness.

Transection of the anterior ethmoidal artery can cause severe complications as well. The injured vessel often retracts into the orbit, resulting in rapidly expanding hematoma with intraorbital pressure rise. Graham et al.\(^{[22]}\) recommend immediate lateral canthotomy and cantholysis for decompression of orbital contents to prevent postoperative blindness (Fig. 2.17c).

**Fig. 2.17**
Inadvertent perforation of the lamina papyracea with herniation of orbital fat. Injury to the eye muscles and/or the optic nerve can have severe consequences (a). In an Onodi cell, the posterior ethmoid air cells extend to the optic canal – during ethmoidectomy, the optic nerve is potentially at risk (b). Severe intraorbital bleeding after injury to the anterior ethmoidal artery. Vision can be preserved by performing immediate canthotomy and cantholysis (arrow) (c).

**Fig. 2.18**
The coronal MRI scan shows a recurrent adenoma behind the anterior carotid knee in the left cavernous sinus (a). Once the operative site has been checked on the navigation monitor, the internal carotid artery is skeletonized. The course of the vessel is assessed by micro-Doppler ultrasound (b), and the tumor is resected under solid control (c). In the postoperative image (d), no residual tumor can be detected.
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2.6.3 Paranasal and intracranial complications
It is not always easy to keep one’s orientation in the anatomical environment of the central skull base. Septa in the sphenoid sinus can serve as landmarks. In the presence of a concha-
type sphenoid sinus or when embarking on revision surgery in the absence of anatomical landmarks, the use of image-guided intraoperative navigation is mandatory.

The most dreaded complication in the parasellar space is iatrogenic injury to the internal carotid artery which causes major neurological symptoms and is associated with an elevated risk of postoperative mortality.[10] Prevention and adequate preparatory measures are paramount and involve assessing both CT and MRI data, optional preoperative angiography with balloon test occlusion, consistent use of intraoperative surgical navigation and micro-Doppler ultrasound (Fig. 2.18).

During the preoperative team time-out, a final check confirms that interventional neuroradiology is on standby. This also applies to the availability of the angiography system if a more complex procedure is anticipated (Table 2.3). Following patient positioning, the common carotid artery is palpated cervically. In case of major bleeding, targeted compression of the carotid is immediately provided (Fig. 2.19). Direct local packing is applied to the site of injury; Valentine et al.[66] recommend using muscle tissue (Fig. 2.20).

Once the dura is opened, we advise against the use of nonspecific “massive packing” to prevent the occurrence of uncontrolled intracranial bleeding. In a population of 2015 treated patients, Gardner et al.[18] reported a total of 7 carotid injuries (0.3%). Four of the injured vessels were occluded, and none of the patients suffered a postoperative stroke. In their literature review, Sylvester et al.[64] found 105 published carotid artery injuries; in 46 cases, the internal carotid artery was interventionally occluded, but 10 patients had a permanent neurological deficit (21.7%). Venous bleeding from the cavernous sinus can be controlled with anti-Trendelenburg head-up positioning, local compression, and/or modern thrombin-based hemostatic materials (e.g., Floseal®, Surgiflo®) (Fig. 2.21). Hemodynamically relevant blood loss is rare, but the bleeding can considerably complicate tumor resection.

Intraoperative CSF leakage is not rare in transnasal endoscopic surgery. In a single-center study of 129 surgical procedures, 110 of which were adenoma surgeries, Sade et al.[55] reported 43 cases with intraoperative CSF leakage (33.3%). The incidence of postoperative leakage largely depends on the patient population and closure technique and is reported to range from 5 to 75% in the literature. In a multicenter study, Boling et al.[5] studied the course of 982 pituitary surgeries and found a postoperative leak in 5.5% of patients. Risk factors included young age (< 40), obesity (BMI > 30), female sex, and intraventricular tumor growth.

**Table 2.3**
Checklist for the team time-out to ensure the effective management of complications in case of carotid injury.

| Internal carotid artery identified in the CT/MRI data? | ✔ |
| Angiography with/without BTO? | ✔ |
| Navigation prepared? | ✔ |
| Micro-Doppler ultrasound prepared? | ✔ |
| Neuroradiology on standby is confirmed? | ✔ |
| Cervical course of carotid artery palpated? | ✔ |
| Nasal packing available? | ✔ |

![Fig. 2.19](image1.jpg) Palpation of the cervical course of the carotid artery – preparation for the intraoperative emergency of iatrogenic carotid injury.

![Fig. 2.20 a](image2.jpg) Preparation of Spongostan®, Tabotamp®, and TachoSil® balls for local compression.

![Fig. 2.20 b](image3.jpg) Use of muscle tissue from the rectus abdominis muscle in case of carotid injury.
Thrombin-based hemostatic materials (e.g., Floseal®, Surgiflo®) can be used to effectively control diffuse venous bleeding from the cavernous sinus.

Coverage of a minor CSF diapedesis (a) in case of capsular dissection of adenoma using a thrombin-coated fibrinogen matrix (TachoSil®) (b). For larger defects (c), we recommend meticulous coverage with abdominal adipose tissue (d), which is usually harvested from the paraumbilical region (e).

Reconstruction of the skull base after resection of an esthesioneuroblastoma of the frontal base (a). The fascia lata is fixed in place at the dura using single-knot sutures to prevent dislocation and achieve water-tight closure. The knot is tied extranasally (b), slid down to the surgical field using grasping forceps or a knot pusher, and secured there (c).
Various materials are used to close intraoperative leaks. Autologous tissue is commonly harvested as abdominal fat or fascia and often fascia lata. Allografts, xenografts, or synthetic material are used more rarely. In case of minimal CSF diapedesis, we recommend closing the diaphragma and the sellar floor with a thrombin-coated fibrinogen matrix (TachoSil®). In the presence of pronounced discharge of CSF, the defect is closed with abdominal fat (Fig. 2.22). For wide open subarachnoid spaces, abdominal fascia or fascia lata, which can be secured in place with single sutures, is recommended (Fig. 2.23).

When treating extensive skull base tumors such as chordomas, craniopharyngiomas, and meningiomas, the CSF space is opened wide, and reconstruction of the skull base can pose a complex challenge. The use of a nasoseptal flap (Hadad-Bassagasteguy Flap, HBF) to cover the skull base has revolutionized transnasal skull base surgery and significantly reduced the occurrence of postoperative CSF leaks (Figs. 2.24, 2.25).

**Fig. 2.24 a–f**
Preparation of a nasoseptal flap (a–c). Incision of the nasal mucosa for creating the nasoseptal flap, which is dorsally pedicled at the septal branch of the sphenopalatine artery. If a long nasoseptal flap is needed, the anterior incision can be placed up to the level of the nasal vestibule (a). Detachment of the nasal mucosa from the nasal septum. The cranial incision is made approx. 1.5 cm below the cribiform plate. The caudal margin is at the level of the nasal floor (b). The mobilized nasoseptal flap remains pedicled to the mucosa of the anterior wall of the sphenoid sinus (septal branch of the sphenopalatine artery) (c). Placement and creation of the flap (d–f). The mobilized flap is placed on the skull base defect which has previously been reconstructed with abdominal fat (d). The nasoseptal flap covers the entire skull base defect (e). Fixation of the nasoseptal flap with absorbable material (Spongostan®) (f).

**Fig. 2.25**
The postoperative non-enhanced T1-weighted MR images show the course of healing of a nasoseptal flap after 1 day (a), 1 month (b), and 1 year (c). Following administration of the contrast agent, normal vascularization of the flap is demonstrated (d).
Horiguchi et al. compared the postoperative outcome with and without nasoseptal flap in complex procedures and found a postoperative fistula in 9.5% of cases in the HBF group and in 27.3% in the non-HBF group. Similar results were found by Harvey et al. in their systematic meta-analysis: Among 609 complex cases, a postoperative CSF leak was found in a total of 70 patients, with the free graft technique being associated with a rate of 15.6% and the HBF with a rate of 6.7%. Harvesting of a nasoseptal flap is associated with a significantly higher risk of rhinological complications, however. In 41 surgical cases, Dolci et al. described postoperative synechiae in 19.5% and olfactory deficits in 39.0% of cases. Therefore, the flap should not be used routinely but only in selected cases of skull base defects which are difficult to repair.

There is controversy in the literature about the need for routine use of a lumbar drain. Complications such as pneumocephalus and meningitis are not rare (Fig. 2.26). Some proponents always place a drain in the event of an intraoperative CSF defect, although there is no evidence to support its benefit. Gardner et al. recommend a lumbar drain to be used in cases of high-flow leaks, particularly when the need arises to resect suprasellar lesions involving surgical opening of the ventricular system. However, in the latter case, a technically flawless skull base reconstruction with a nasoseptal flap seems to be more important than postoperative drainage.

Intracranial complications related to injury of the vasculature, nerves, and the brain itself are rare and there is some inconsistency in the literature as to their frequency. In a study on pituitary adenoma, Boling et al. reported an incidence of 7.3%. Risk factors are intraventricular growth and a previous history of radiotherapy. In a single-center study of 800 patients treated by endoscopic endonasal skull base surgery, Kassam et al. reported the incidence of permanent neurological deficits as 1.8% and of intracranial infections as 1.6%. Systemic complications unrelated to the approach occurred in 2.1% of patients.

To prevent intraoperative complications, Christian et al. recommend the consistent use of a checklist and repeated intraoperative team time-outs. Laws states: “Although general checklists are already in place in most institutions, a specific checklist for endonasal transsphenoidal anterior skull base surgery was developed to help safeguard patients, improve outcomes, and enhance teambuilding.”

Parasellar and intracranial complications are dreaded events. Through careful planning, structured preparation, repeated team time-outs, and of course, tissue-sparing dissection, most intraoperative incidents can be avoided. Rhino-neurosurgical teamwork also involves that two surgeons with their joint wealth of experience can detect and manage critical situations at an early time.

Fig. 2.26
Following resection of an esthesioneuroblastoma, the creation of a nasoseptal flap was not feasible owing to tumor infiltration. In order to facilitate skull base reconstruction, a lumbar drain was placed. On postoperative day 3, severe pneumocephalus was demonstrated by CT (a, b) – a life-threatening complication. The revision surgery revealed dehiscence of the dural reconstruction (c).
3.1 Special surgical instrument sets

It is prudent to have a few dedicated instrument sets available which are used as dictated by the complexity of the planned procedure. A basic set includes all surgical instruments needed for a standard rhino-neurosurgical procedure, such as pituitary surgery. An extended set contains additional instruments which are needed to perform complex tumor resections in the skull base area. Apart from that, a few rarely used specialized instruments should nonetheless be available to meet the demands of exceptional situations.

3.1.1 Basic instruments

Basic instruments are mandatory to perform a standard rhinosurgical procedure and include suction cannulas, surgical knives and scissors, osteotomes, sharp elevators for tissue dissection, and forceps for tissue removal.

**Suction Cannula**

The suction cannula is probably the most important instrument in transnasal endoscopic surgery because in its absence, blood would immediately accumulate in the surgical site, impeding adequate anatomic orientation and thereby making safe dissection virtually impossible.

A key benefit which can be drawn from the bimanual surgical technique is the option of keeping the suction cannula in the operative field during the entire surgical procedure. It is also valuable to use suction cannulas with tips that can be synchronized to a surgical navigation system allowing for continuous image-guided control. (Figs. 3.1a–b).

Suction cannulas are not only available in various sizes and lengths, but may also be chosen according to tip design. The use of laterally angled suction tips has proven helpful in endoscopic skull base surgery, particularly when blood or tissue needs to be removed from laterally adjoining areas, which are difficult to access with a straight suction tip. (Fig. 3.1c).

**Surgical Knives**

Knives are essential for precise dissection. Standard blades, such as scalpel no. 15 with a long handle, are part of the basic instrument set (Fig. 3.2).

Sickle knives or other blades with angled tips may also be needed to transect tissue running parallel to the access path.

---

**Fig. 3.1**

In the bimanual dissection technique, the surgeon typically holds a suction cannula in the left hand (a). The suction tip is used to dissect, to retract tissue, aspirate secretions and blood from the surgical field, and if necessary, the tip can be tracked by a navigation system (b). Using a curved suction cannula, it is possible to work “around the corner”, such as shown in panel (c) during resection of a clivus chordoma.

**Fig. 3.2**

A no. 15 standard blade is used during partial turbinectomy (a) or when the nasal mucosa needs to be precisely incised, e.g., to create a nasoseptal flap (b).
corridor, as for instance, to incise the uncinate process prior to its resection, which is the first step of ethmoidectomy (Fig. 3.3). A smart instrument is the surgical knife with retractable blade, which can be used to open the sellar floor. During transnasal insertion, the blade is within its protective sheath to minimize the risk of injury to the nasal mucosa (Fig. 3.4).

**Scissors**

Scissors permit controlled, precise dissection and play a crucial part in nasal microsurgery. Specially designed, slightly sturdier types of microscissors, such as the Zurich model, have been developed and engineered for dissection in the area of the ethmoid sinuses (Fig. 3.5). For microdissection of skull base lesions, small microscissors are available in various sizes and directions of cutting (Fig. 3.6).

**Elevators**

Elevators and disectors allow tissue to be dissected precisely. Blunt elevators protect the mucosa and provide good tactile feedback, while their sharp counterparts allow precise tissue dissection.

---

**Fig. 3.3**

Using a sickle knife, the uncinate process is incised (a). The same instrument is used to meticulously transect thin mucosal layers (b).

---

**Fig. 3.4**

A retractable micro-knife is used to incise the sellar floor for adenoma treatment (a). The same instrument is used to open the frontobasal dura mater for resection of a craniopharyngioma (b).

---

**Fig. 3.5**

Special nasal scissors (Zurich model) enable a sharp, tissue-sparing microdissection in the paranasal sinuses. The uncinate process (a) is resected, whereas in panel (b), a nasoseptal flap is created.

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**Fig. 3.6**

Upturned microscissors are used to open the dural layer of the sellar floor (a). Straight or laterally curved microscissors enable a precise microdissection, as for instance, needed for resection of a craniopharyngioma (b).
The double-ended MASING elevator with blunt / sharp tips has proven particularly useful (Fig. 3.7).

The basic instrument set for endoscopic rhino-neurosurgery also includes special skull base elevators and curettes (Fig. 3.8).

The double-ended probe with ball-shaped tips is a special type of dissector which is frequently used for palpation of the paranasal sinuses and ethmoid air cells as well as for intracranial manipulations (Fig. 3.9).

**Chisels**

Chisels enable a precise and efficient resection of bone and have proven useful in removing the sphenoid rostrum and parts of the sphenoid sinus wall (Fig. 3.10). However, the use of chisels is prohibitive in the vicinity of neural structures, as for instance, the optic nerve, or larger vessels like the internal carotid artery.

**Fig. 3.7**
The MASING elevator is among the most important basic instruments used in endoscopic rhino-neurosurgery. The blunt tip serves to mobilize structures (a), while its sharp tip can be used, e.g., to mobilize the mucosa of the posterior septum (b).

**Fig. 3.8**
Skull base microdissectors and curettes permit precise dissection in layers. Here, the capsule of a pituitary adenoma is dissected (a), and a suprasellar craniopharyngioma is mobilized (b).

**Fig. 3.9**
Upon completion of uncinectomy, the maxillary sinus is palpated with a ball end probe. Delicate lamellae are dissected with the same instrument (a). Using a JACOBSON probe, a craniopharyngioma is dissected free from the anterior communicating artery (b).

**Fig. 3.10**
The sphenoid rostrum (a) and anterior sphenoid wall (b) are mobilized with a 3-mm chisel.
**Forceps, grasping forceps**
The basic instrument set includes bayonet-shaped forceps which can be used to apply gauze patties or cotton for mucosal decongestion.

Grasping forceps are also needed for retracting and removing tissue. The grasping forceps which are part of the basic instrument set, such as the BLAKESLEY or WEIL models, are available with straight or upward curved jaws (Fig. 3.11).

As a rule, grasping forceps should only be used to remove loose tissue fragments. Using grasping forceps to dissect tissue may be a feasible option, but it is less precise as compared to cutting instruments. Plucking tissue away is prone to cause more bleeding than cutting or punching tissue.

Micro grasping forceps may be used to resect deeply seated tumors (Fig. 3.12).

**3.1.2 Instruments for tissue resection**
Cutting forceps or punches are used for precise tissue removal. The boundaries of the removed tissue fragments are well-defined, and resection margins are slightly squeezed by the cutting action, making them less prone to bleeding.

**BLAKESLEY through-cutting forceps / GRÜNWALD forceps**
Through-cutting forceps, such as the BLAKESLEY model, are part of the basic instrument set (Fig. 3.13).

For removing slightly thicker bony lamellae, as may be needed when resecting an intersphenoid septum, a more sturdy model, such as the GRÜNWALD through-cutting forceps can be used. (Fig. 3.14).

When removing tissue as described above, however, any rotary motion must be avoided because the attachment of the intersphenoid septum is at risk of breaking off, which, depending on individual anatomy, can lead to iatrogenic injury of the carotid artery.

**Fig. 3.11**
The BLAKESLEY or WEIL grasping forceps are used to mobilize bony fragments (a) or to remove tumor portions (b).

**Fig. 3.12**
Micro grasping forceps are used to resect, e.g., a pituitary tumor (a) or a craniopharyngioma (b).

**Fig. 3.13**
Using the BLAKESLEY RHINOFORCE® through-cutting forceps, bony lamellae can be removed (a). When performed with the distally curved model, sharp dissection can help reduce trauma to the nasal anatomy (b).
Punches

Punches allow tissue to be safely and precisely removed, even in case of a slightly thicker bone layer. They are available in models of various size and design, with upward or downward oriented cutting openings.

The key instrument for ethmoidectomy is the upbiting KERRISON bone punch available in sizes of 2 mm or 3 mm. The 90° upbiting ‘rhinologic’ type of KERRISON punch makes it an ideal instrument for resection of ethmoid septa which often have a perpendicular orientation.

The 60° forward upbiting ‘neurosurgical’ type of KERRISON punch is better suited for removing the posterior sphenoid sinus wall and the sellar floor (Fig. 3.15).

Shaver, burr, ultrasound aspirator

Powered instruments such as a shaver and ultrasound aspirator are widely accepted for use in transnasal skull base surgery (Fig. 3.16). The shaver is particularly suited for removing soft tissue, especially for polypectomy in cases of chronic rhinosinusitis.

Fig. 3.14
With the sturdy GRÜNWALD-HENKE forceps, thicker bony lamellae (a) and septa (b) can be removed.

Fig. 3.15
The KERRISON punch, available in sizes of 2 mm and 3 mm, is possibly the most important instrument in transnasal endoscopy.

The 90° upbiting ‘rhinologic’ type of KERRISON punch is used in the paranasal sinuses (a). The 60° forward upbiting ‘neurosurgical’ type of KERRISON punch is better suited for removing the sellar floor or for opening the skull base (b).

Fig. 3.16
Powered instruments permit a precise removal of soft tissue. The intranasal shaver is typically used for mucosal resection in the paranasal sinuses (a).

Soft tumors of the skull base, such as a clivus chordoma, can be resected using an ultrasound aspirator (b).

Fig. 3.17
Using a high-speed burr with a long shaft, the anterior sphenoid wall or dense intrasphenoid septa (a) can be resected. The same instrument may also be used to open the bony sellar floor (b).
Taking into account, that rhino-neurosurgeons are rarely faced with clinically relevant findings of chronic polyposis, the authors ascribe only minor importance to the use of shavers. Ultrasound-based ablative instruments (Cavitron Ultrasonic Surgical Aspirator, CUSA) can be used to precisely resect both soft tissue and bone. They are particularly useful in removing deep tumors such as chordomas.

Another useful powered instrument is the high-speed burr. With its ergonomic-shaped handle and a particularly slender and long sheath, the burr permits precise bone removal with good tactile feedback, which makes it an indispensable tool for skull base surgery (Fig. 3.17).

### 3.1.3 Instruments for coagulation

Intraoperative hemostasis through targeted coagulation is key to a safe and precise surgery. Similar to the preflight checks compulsory in aviation, operational reliability of electrocoagulation devices needs to be confirmed prior to initiating dissection because they may not work properly right away.

#### Monopolar coagulation instruments

Monopolar coagulation instruments, such as the SIMMEN monopolar suction cannula, are very efficient and particularly useful to control diffuse osseous bleeding (Fig. 3.18).

In monopolar instruments, however, the collateral effect of thermal energy on adjacent tissue cannot be controlled precisely enough because it spreads spherically around the coagulation electrode and is largely dependent on tissue impedance. Furthermore, there is a risk of the monopolar electrode to adhere to the coagulated tissue, which may, for instance, result in a CSF leak at the ethmoid roof. Therefore, monopolar coagulation should not be used in the vicinity of fragile structures such as the orbital cavity, the optic nerve, or the remnant parts of the skull base.

#### Bipolar coagulation

Bipolar instruments permit coagulation to be performed more precisely than with their monopolar counterparts because only the tissue located between the two electrodes is included in the electrical circuit. The resulting thermal effect between the electrodes is localized and thus can be managed reliably. To that end, bipolar coagulation is less traumatic to adjacent tissue, which is why bipolar instruments should be the first-line option when electrocoagulation is needed in rhino-neurosurgery.

Standard bipolar coagulation forceps commonly used in surgery do not fully match the special needs of transnasal endoscopic surgery because narrow anatomical conditions often cause the branches to be randomly pressed together, making coagulation more difficult or even impossible. In order to overcome this drawback, pivot-point bipolar forceps were developed for rhino-neurosurgery (Fig. 3.19). These forceps have a fixed bar in the middle of the instrument which serves as a pivot point. Applying pressure on the proximal part of the instrument, the resulting force is transmitted beyond the pivot point, which causes the distal tips to move apart, allowing the surgeon to use bipolar coagulation in a controlled manner. This design feature makes the instrument indispensable for bipolar coagulation in the very narrow anatomy of the skull base.

The BRINER bipolar suction cannula is highly useful to control bleeding in the paranasal sinuses and anterior skull base (Fig. 3.20). Owing to the integrated suction cannula located between the branches, the coagulation electrodes are constantly kept apart at a relatively large distance which remains unchanged irrespective of the compressive forces randomly generated through contact with the adjacent tissue. This instrument is particularly suited for bipolar coagulation in narrow anatomical conditions. The design features above facilitate an efficient coagulation of tumors. Bipolar coagulation forceps are based on the same design concept, however, in view of their size, they cannot be used in all circumstances.

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Required</th>
<th>Optional</th>
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<tr>
<td>Basic instruments</td>
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<td>■ Straight suction cannulas in various sizes</td>
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<tr>
<td></td>
<td>Knives</td>
<td>■ Scalpel no. 15 with long handle&lt;br&gt; ■ Sickle knife</td>
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<tr>
<td></td>
<td>Scissors</td>
<td>■ Nasal scissors, Zürich model&lt;br&gt; ■ Microscissors, straight / curved</td>
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<tr>
<td></td>
<td>Osteotomes</td>
<td>■ 3 mm osteotome</td>
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<td></td>
<td>Dissectors</td>
<td>■ MASING elevator, double-ended, semi-sharp and blunt</td>
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<tr>
<td></td>
<td>Curettes</td>
<td>■ Pituitary curettes</td>
</tr>
<tr>
<td></td>
<td>Forceps</td>
<td>■ Forceps, bayonet-shaped&lt;br&gt; ■ BLAKESLEY-WEIL grasping forceps, straight jaws / curved jaws</td>
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</table>

Table 3.1 a

Surgical instruments for rhino-neurosurgery.
Table 3.1b
Surgical instruments for rhino-neurosurgery.

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Required</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instruments for tissue resection</strong></td>
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<td>BLAKESLEY cutting forceps, straight jaws / curved jaws</td>
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<td></td>
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<td></td>
<td>Punches</td>
<td>KERRISON punches, upbiting, opening 90° and 135°, size 2 mm and 3 mm</td>
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<td></td>
<td>Micropunches</td>
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<td>Actively steerable elevators and forceps</td>
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<td>Bipolar forceps, bayonet-shaped, angled, with bar</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>SIMMEN monopolar suction cannula</td>
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</tbody>
</table>

Fig. 3.18
Coagulation of diffuse osseous bleeding at the lateral nasal wall using a SIMMEN monopolar suction cannula.

Fig. 3.19
The bayonet-shaped bipolar forceps feature a fixed bar (pivot point) in the center of the instrument. The force applied on the proximal part of the instrument is transmitted beyond the pivot point and causes the distal tips to move apart, allowing the surgeon to use bipolar coagulation. This instrument is indispensable in the very narrow anatomic conditions of the skull base. In (a), straight pivot-point forceps are used to resect a craniohypopharynxoma, whereas in (b), resection of a chondrosarcoma is shown using a pivot-point forceps with curved jaws.

Fig. 3.20
The BRINER bipolar suction cannula permits the precise hemostasis of mucosal bleeding (a). Even in narrow anatomical conditions, the coagulation electrodes are kept apart irrespective of the compressive forces randomly generated through contact with tissue. The integrated suction cannula allows blood to be continuously aspirated (b).
3.1.4 New developments

In view of the scientific and technical evolution, bringing forth innovation, applications in rhino-neurosurgery are continuously being reviewed and expanded. The new concepts which take advantage of the generated momentum, mandate that design features of instruments are constantly adapted to the needs of specific applications. For example, existing instruments do not fully meet the demands of surgical procedures involving tumor resection at a lateral site of the endoscopic access corridor. The authors believe that future innovations should, among others, focus on the development of instruments suitable for being used lateral to the access corridor.

Malleable instruments

One option which enables the surgeon to dissect lateral to the access corridor, is the use of individually malleable instruments.

Malleable suction cannulas and elevators are already available, but more sophisticated instruments such as grasping forceps and punches are still in a developmental stage. A revolutionary new design concept is implemented in the next generation of special instruments. Among those are dissecting instruments such as elevators or forceps, which have an actively steerable distal tip, allowing surgical maneuvers to be performed in all planes and axes of motion. Undoubtedly, these instruments will further expand the indication range of rhino-neurosurgery.

Robot-controlled systems also allow the working ends of instruments to be steered in all three spatial dimensions. However, robotic instruments have not yet reached the level of miniaturization necessary for routine use in rhino-neurosurgery.

3.2 Navigation and intraoperative imaging

Intraoperative navigation is part of the standard protocol in transnasal endoscopic surgery. Lobo et al.\textsuperscript{36} describe the fundamental role of the surgical navigation technique. Its use allows to correlate in real time the position and size of a tumor with the endoscopic image, which facilitates anatomic and surgical orientation even in critical situations. Scientific studies have demonstrated that the use of surgical navigation is not as time-intensive as it may seem. According to Han et al.,\textsuperscript{24} no evidence of any increase in operative time was revealed. In fact, according to Metson et al.,\textsuperscript{46} image fusion of both CT- and MR-based data allows surgical landmarks to be more readily identified, and has proven to save operative time (Fig. 3.21).

The use of surgical navigation is not only valuable in facilitating anatomic and surgical orientation, but also enhances the surgeon’s confidence during the operation and, based on the experience of Louis et al.,\textsuperscript{36} shortens the surgical learning curve. In challenging situations, particularly revision surgeries, intraoperative navigation is an indispensable modality. Modern navigation systems not only allow to track the endoscope, they even provide the option of virtual image guidance by superimposing a path onto the endoscopic image, thereby offering a supportive augmented reality, which facilitates gaining access to a predefined target structure (Fig. 3.22).\textsuperscript{36}

Surgical navigation is particularly critical in the absence of reliable reference structures upon which anatomic orientation can be based. According to Lasio et al.,\textsuperscript{36} intraoperative navigation is mandatory in the presence of a conchal-type sphenoid sinus, in large tumors with effacement of anatomic landmarks, and in the surgical treatment of recurrent tumors (Fig. 3.21).

The method of electromagnetic navigation has been described in detail in the rhinological literature. In endoscopic skull base and brain surgery, Hermann et al.\textsuperscript{26} identified considerable benefits, such as the absence of a rigid headrest. The patient’s head is placed on the electromagnetic field generator and can be repositioned as needed, which enables the surgeon to adopt ergonomic working postures throughout a transnasal endoscopic approach (Fig. 3.23). The registered suction cannula may also be used as a real-time navigation tracker, with the instrument tip serving as a pointer indicating the current intraoperative position. Electromagnetic interference is rare with modern devices, for example when using a burr.

Navigation has been found to facilitate anatomic and surgical orientation and enhances the surgeon’s intraoperative confidence, particularly during early stages of the learning curve. In challenging situations, especially in revision cases, the use of surgical navigation is a sine qua non.

When comparing optical and electromagnetic systems in transnasal surgery, Sieskiewitz et al.\textsuperscript{17} found no differences regarding precision, but electromagnetic navigation was described as being more user-friendly: “Surgeon’s comfort during operative procedures was assessed as slightly higher for the electromagnetic systems, especially if four-hand or bimanual techniques were used and if constant neuronavigation was indispensable.”
Some controversy has been engendered about the need for intraoperative imaging in transnasal endoscopic surgery. Theodosopoulos et al.\[65\] have demonstrated that the endoscopic technique commonly provides excellent visualization of the anatomic landmarks, which is why they addressed the issue whether adjunctive costly and time-consuming CT- or MRI-based scrutiny is indeed indicated during surgery. In special cases, particularly in the treatment of extensive skull base tumors, the use of imaging modalities can be helpful in taking a closer look at the extent of resection (Figs. 3.25, 3.26). Intraoperative MRI is technically challenging and expensive, so the use of intraoperative CT seems to make more sense. Lee at al.\[38\] evaluated the extent of endoscopic resection for the treatment of macroadenomas and confirmed completeness of resection in 89.0% of non-invasive cases. The degree of precision afforded by intraoperative CT was satisfactory. No statistically significant difference was found compared to the results obtained by postoperative high-resolution MRI. In summary, it was found that “the extent of resection in trans-sphenoidal surgery could be reliably assessed by ioCT.”

The use of intraoperative imaging modalities is of relatively little importance in endoscopic transnasal surgery.
Endoscopic rhino-neurosurgery

Fig. 3.23
In transnasal endoscopic surgery, the use of electromagnetic navigation offers considerable advantages. The use of a rigid headrest is not required and, typically, the head is positioned on the electromagnetic field generator (a). Registration is intuitive using anatomic landmarks. The navigated suction cannula may also be used as a pointer, and the surgeon can rely on real-time navigation (b).

Fig. 3.24
Use of an optoelectronic navigation system always requires a clear line of sight to be maintained between the overhead navigation camera and the pointer. When using a bimanual 4-hand technique, the typical operational flow is prone to result in a loss of line of sight, considering that the endoscope often obscures the pointer, thereby disrupting the tracking function.
The standard protocol for endoscopic transnasal surgery typically involves the use of rigid 4-mm telescopes with a HOPKINS® rod lens system, which in conjunction with modern HD and 4K camera heads and suitable wide screen monitors provide video images in brilliant resolution and color quality. By dynamically guiding the telescope, the surgeon obtains spatial orientation, however, the videoendoscopic image provided by a standard scope remains two-dimensional.

The use of 3D endoscopes additionally affords authentic stereoscopic perception (Fig. 3.27). This helps not only at the start of the learning curve, but offers a noticeable benefit even for experienced surgeons. For instance, Fraser et al. [16] examined the use of 2D and 3D telescopes in a realistic simulation and compared the speed, efficiency, and error rate of dissection. Thirty-three experienced surgeons confirmed that 3D visualization offers compelling benefits compared to standard 2D endoscopy. The subjective and objective results were better in 87.5% of cases. They concluded: “Visualization that provides real-time, high-resolution binocular depth perception has a significant role in endoscopic skull base surgery and other neuroendoscopic procedures.”

In a preclinical randomized study, Marcus et al. [42] compared 3D and 2D visualization as well as HD and SD image quality and demonstrated that both factors significantly impacted surgical performance.

3D HD visualization permits stereoscopic orientation in the surgical field. The initial experience is largely positive, both for beginners and experienced surgeons.

**Fig. 3.25**
Patient positioning in the Hirslanden OR1™ Skull Base Suite with integrated ioCT and neuronavigation. The mobile CT scanner gantry is moved on a rail and employed intraoperatively as needed.

**Fig. 3.26**
Transnasal surgery performed in the Hirslanden PoleStar operating room with use of an intraoperative surgical MRI system. Patient positioning is a complex task and typical workflow activities require the surgeon standing on one side to cope with some ergonomic deficiencies.

**Fig. 3.27**
The TIPCAM1® endoscope with 3D high-definition technology (KARL STORZ Tuttlingen, Germany) for transnasal surgery. The endoscope features two separate rod lens systems that provide a “true” 3D image with stereoscopic viewing in HD quality. The surgical team wears passive 3D glasses.
4.1 Case 1 – XS approach

Medical history
An endocrinological examination identified high prolactin levels in a 30-year-old male patient. The MRI scans taken in response showed an intrasellar pituitary macroadenoma with compression of the glandular structure and elevation of the sellar diaphragma. There was no visual impairment.

Planning and preparation
Computed tomography of the nose and paranasal sinuses showed a normal paranasal sinus system, with minor septal deviation to the right. Accordingly, sufficient space was available on the left for a direct paraseptal approach. Transnasal endoscopic tumor resection with a uniportal paraseptal approach was therefore suggested to the patient.

Surgery
The sphenethmoidal recess was accessed using a direct paraseptal approach. After performing wide anterior sphenoidotomy, the sellar floor was drilled open with a diamond burr, and the dura was incised. The tumor capsule was exposed using semi-oblique curettes. The adenoma was dissected free from the healthy glandular tissue and resected with grasping instruments. The sellar floor was reconstructed with TachoSil®, and due to good hemostasis, nasal packing was not necessary.

Postoperative Course
No complications arose after the procedure. The pathological exam immunohistochemically verified prolactin expression of the tumor cells. The MRI showed no residual tumor, and the endocrinological follow-up revealed normal pituitary function and normal prolactin levels. The postoperative follow-up confirmed that normal nasal and olfactory function was maintained.

Fig. 4.1 a–c
The coronal T2-weighted (a) and sagittal T1-weighted contrast-enhanced (b) MRI scans show a pituitary macroadenoma in the middle of the sella. The coronal CT image of the paranasal sinuses reveals minor septal deviation to the right (c).

Fig 4.1 d–e
Postoperative imaging shows complete tumor resection and confirms integrity of the glandular substance.
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Fig 4.1 f–h
The left nasal cavity is inspected, and epinephrine-soaked swabs are placed in the olfactory cleft (f). Following cautious provisional lateralization of the middle and superior turbinates, the sphenoethmoidal recess with the sphenoid ostium on the left is visible (g). In the midline, the mucosa is elevated, dissected as a small flap in a basal direction, and the septum is exposed. The perpendicular plate of the ethmoid bone is dissected away from the vomer, followed by anterior sphenoidotomy (h).

Fig 4.1 i–k
Following sphenoidotomy, the mucosa is elevated in a targeted manner, and the sellar floor is opened with the diamond burr (i). Once the dural opening has been made using microscissors, the dura is stripped off from the tumor and from the gland using a small 90° curette (j). Following resection of the adenoma, the normal glandular tissue is revealed (k).

Fig. 4.1 l–n
The endoscope may also be used to check completeness of tumor resection in the right intrasellar section (l). Sealing of the resulting defect was achieved with a TachoSil® patch (m). The elevated mucosa is repositioned to cover the TachoSil® patch used for defect closure (n).
4.2 Case 2 – XS approach

Medical history
Due to massive headaches, the 45-year-old female patient was subjected to MR imaging of the skull revealing a left intrasellar space-occupying lesion, most suggestive of a colloid cyst. Deterioration of symptoms and an increase in the size of the lesion prompted the authors to establish the indication for surgery. No deficits were identified in the endocrinological and ophthalmological exams.

Planning and preparation
The non-enhanced CT scans showed septal deviation to the right with otherwise unremarkable paranasal sinuses. The outcome of a further rhinological exam evaluating mucosal conditions and olfactory function was normal and showed that there was a little more space available on the left. Hence, an uniporal transnasal paraseptal approach on the left was suggested to the patient for resection of the cystic pituitary lesion.

Surgery
After registration of the optical navigation system and mucosal vasoconstriction, the turbinates were lateralized to the left, the sphenoid sinus was exposed, followed by sphenoidotomy with resection of the anterior sphenoid wall and the rostrum. A paramedian intersphenoid septum was removed using a diamond burr. The left posterior part of the sellar floor was opened after prior navigation-based confirmation of the correct position. The dura was opened with a surgical knife, and the glandular substance was mobilized anteriorly. Left posteriorly, colloidal material was found and resected with a suction cannula and micro-grasping instruments. Using the endoscope, the anterior and posterior lobe of the gland was well identified. In the background, the clival bone was clearly visible, without evidence of residual lesions.

Postoperative Course
There were no complications in the postoperative course, and the severe headache subsided remarkably quickly and completely (!). The MRI did not show any signs of residual disease, and the endocrinological follow-up revealed normal pituitary function. The postoperative follow-up confirmed that normal nasal breathing and olfactory function was maintained.

Fig 4.2 a–c
The non-enhanced fat-suppressed T1-weighted MRI scans in sagittal (a) and coronal (b) planes show a posterior colloid cyst on the left side. The preoperative CT in the coronal plane reveals septal deviation to the right. The anatomy on the left exhibits a normal width (c).

Fig 4.2 d–f
Following decongestion of the nasal mucosa using epinephrine-soaked swabs (d), sufficient space is available between the nasal septum and the middle turbinate (e). Along the midline, the sphenoid ostium is then identified (f).
Fig. 4.2 m–n
The postoperative imaging confirms that the cyst was resected completely while preserving integrity of the glandular substance.

Fig. 4.2 g
Following sphenoidotomy, the sellar floor and a paramedian septum become visible. The anatomy is assessed against the navigation system (g).

Fig. 4.2 h–l
The sellar floor is then opened using a 135° punch (h). The dura is incised with a micro-knife, and typical colloidal substance is readily discharged (i). The cyst wall is resected using small grasping forceps (j).

The subsequent inspection reveals no signs of residual disease (k). At the end of the procedure, venous bleeding is stopped using a Surgifo® hemostatic matrix (l).

Fig. 4.2 m–n
The postoperative imaging confirms that the cyst was resected completely while preserving integrity of the glandular substance.
4.3 Case 3 – S approach

Medical history
In this 36-year-old female patient, we endoscopically resected a hormone-inactive macroadenoma. Following an initially complication-free course, the MRI scans taken three years later showed a recurrent tumor in the left cavernous sinus. Due to progression of the findings, another transnasal tumor resection was considered indicated. The patient had normal pituitary function and declined stereotactic or conformal radiotherapy.

Planning and preparation
Three years ago, primary pituitary adenoma resection was performed via an uniportal transethmoidal-paraseptal approach on the left. Nasal endoscopy revealed normal conditions in the area of the former access and a wide open ethmoidal space without signs of mucosal scarring. Therefore, tumor resection using an uniportal left transethmoidal approach was suggested to the patient.

Fig 4.3 a1–2
The T2-weighted coronal MRI scan shows a macroadenoma with massive chiasmal compression (a1). Follow-up assessment after endoscopic resection revealed no signs of residual tumor (a2).

Fig 4.3 b1–2
Three years later, a recurrent tumor is found in the left cavernous sinus.

Fig. 4.3 c1–2
The coronal (c2) and axial (c1) CT scans confirm that a left transethmoidal approach was adopted.
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Surgery
Revision surgery commonly mandate the use of an image-guided technique. The procedure was performed under optical navigation. On account of the patient's previous history of a left transethmoidal-paraseptal approach and the relatively wide spacious conditions resulting from it, an optimal endoscopic view through the ethmoid onto the left optico-carotid recess was obtained. After prior confirmation of the correct position by use of the navigation system, the already enlarged sellar opening was extended laterally, the anterior wall of the cavernous sinus was exposed, and the course of the internal carotid artery verified against the navigation unit as well as the micro-Doppler.

In a next step, the basal dura was further opened in a lateral direction, and the anterior carotid knee was exposed. The discharged adenomatous tissue was of fluid and fibrous consistency. The sellar diaphragma was protected with neurosurgical swabs. No CSF leak was detected during surgery. Due to good hemostasis, nasal packing was not necessary.

Postoperative Course
The course was complication-free; the laboratory follow-up revealed inconspicuous electrolytes and normal basal hormone levels. The patient exhibited virtually normal nasal breathing and was discharged on the 3rd postoperative day. The MRI scans taken 3 months after the procedure showed no residual tumor.

Fig 4.3 d–e
With regard to the patient’s history of prior resection, the left transthyroid approach shows a well-healed anterior sellar wall (d). On account of difficulties with anatomic orientation, the tumor is localized under navigation assistance, followed by assessment of the course of the carotid artery with the micro-Doppler (e).

Fig 4.3 f–g
The floor of the left cavernous sinus is opened with microscissors (f). After resection, no residual tumor tissue is found in the cavernous sinus (g).

Fig 4.3 h1–2
Postoperative MRI scans demonstrate complete tumor resection.
4.4 Case 4 – S approach

Medical history
The 58-year-old male patient with metastasized rhabdomyosarcoma presented with progressive diplopia while looking downward, which was related to the presence of a metastasis in the area of the orbital apex. His visual acuity was normal. Despite continuing chemotherapy, the intraorbital lesion showed an increase in volume, and the multidisciplinary tumor board recommended resection.

Planning and preparation
The CT and MRI scans showed intraorbital metastasis on the right. The lesion was in the medial superior orbital apex, above and slightly lateral to the medial rectus muscle and inferolaterally of the superior oblique muscle. The lesion extended all the way into the orbital apex and displaced the optic nerve, but there were no signs of encroachment. In view of tumor location, the patient was counseled to undergo transnasal endoscopic tumor resection, with access gained through a right sphenoidectomy.

Upon close examination, the CT in 3 planes showed the tumor to be located in the right orbital cavity.

The T1-weighted MRI scans clearly demonstrated the tumor, providing evidence of optic nerve displacement, and proximity of the tumor to the medial rectus muscle and superior oblique muscle.

Nasal endoscopy showed a small septal spur at the level of the middle nasal meatus. Prior to sphenoidectomy, the spur was resected endoscopically (c). Following sphenoidectomy, the medial orbital wall was exposed (d). Close-up view of the orbital apex. The suction tip indicates the course of the optic nerve in the lateral sphenoid wall (e).
Surgery
The procedure was performed under electromagnetic CT and MRI navigation. After resection of a small nasal septal spur and right sphenoethmoidectomy, the medial orbital wall was exposed. The lamina papyracea was removed, and the periorbita was incised anterior to the tumor under navigation guidance. Subsequently, the medial rectus muscle and the superior oblique muscle were exposed as landmarks. Subsequently, the lesion located lateral to these muscles in the orbital apex, was demonstrated. The tumor, which adhered to the surrounding tissue, was mobilized and resected by blunt dissection. The orbital fat, which had been cranially and caudally mobilized to enable dissection, was returned to its position and covered with absorbable hyaluronic acid gel.

Postoperative Course
The patient tolerated the surgery well. Postoperatively, the patient’s visual acuity was still normal, and there was no recurrence of orbital symptoms. The diplopia subsided considerably after a few days. The postoperative MRI scan did not exhibit any signs of an intraorbital tumor remnant.

Fig. 4.4 f–h
After periorbital incision, orbital fat prolapsed into the ethmoid (f). The medial rectus muscle and – above the suction tip – the superior oblique muscle are shown as intraorbital landmarks (g). The tumor was mobilized through blunt dissection (h).

Fig. 4.4 i–k
Mobilization of the tumor into the ethmoid cavity (i). Following resection, the orbital apex was inspected once again (j). View of the medial orbital wall following tumor resection. Subsequently, the surgical site was covered with absorbable hyaluronic acid gel (k).

Fig. 4.4 l1–3
The postoperative MRI scans, taken at 1-week follow up, showed no signs of residual tumor.
4.5 Case 5 – M approach

Medical history
The 34-year-old male patient was referred to us for subjective visual disturbances. As part of the ophthalmological diagnostic workup, an MRI of the head was obtained. The scans revealed an extensive pituitary macroadenoma more than 4 cm in size with elevation of the sellar diaphragma and compression of the optic nerve.

The ophthalmological diagnostic assessment revealed only non-specific visual disturbances, but without any objective evidence of reduced visual acuity or visual field defect. The endocrinological exam showed normal function of the anterior and posterior pituitary lobes, without any signs of pathological hormone secretion.

Planning and preparation
Despite the absence of functional deficits, the indication for surgery was established on the basis of MR imaging. Taking into account that resection of the large pituitary adenoma was expected to require a higher degree of maneuverability, the patient was suggested to undergo uniportal transnasal endoscopic resection using a combined transethmoidal-paraseptal approach. The uniportal approach on the right side was chosen because it afforded a little more space and included the option of being transformed into a biportal approach, for which an added paraseptal corridor on the left was planned.

Surgery
Surgery was performed under electromagnetic navigation. After creating the tranethmoidal-paraseptal approach on the right, the sphenoid sinus was exposed in an optimal fashion, also with regard to the tumor expanding the sellar floor. The optico-carotid recess, frontal base, and clivus around the expanded sellar floor could be well identified and assessed.

The distinctly thinned-out osseous sellar floor was opened, the basal dura was incised, and the soft adenoma tissue mobilized step-by-step, resected, and sent for histopathological examination.

The medial wall of the cavernous sinus and the pulsating internal carotid artery were identified. On the diaphragma, which descended after tumor resection, we were able to identify the thin layer of a normal-appearing pituitary gland. Endoscopic inspection revealed complete tumor resection.

The descended sellar diaphragma was supported with Spongostan™, and the sellar floor was reconstructed with TachoSil® and the thin osseous sellar floor. The patient exhibited normal wound conditions and good hemostasis, so we did not use nasal packing.
Postoperative Course
After the procedure, the patient was promptly extubated. The postoperative exam showed no visual field defect and no eye motility disorder as well as normal pituitary hormonal function. Completeness of tumor resection was confirmed by MR imaging.

Fig 4.5 e
Upon completion of right ethmoidectomy, the middle turbinate is temporarily lateralized with the MASING elevator.

Fig 4.5 f
After wide exposure of the sphenoid, the thin sellar floor is opened and the dura incised using microscissors.

Fig. 4.5 g
The large adenoma is resected step-by-step using a suction cannula and curette. The tumor is dissected away from the medial wall of the left cavernous sinus using a curette. The diaphragma and the reddish thin glandular substance are protected by swabs.

Fig 4.5 h
Condition after complete resection of the macroadenoma.

Fig 4.5 i
The diaphragma, which descended considerably after tumor resection, is supported with absorbable Spongostan to prevent rupturing the diaphragma and tearing off the pituitary stalk. The osseous sellar floor is then returned to its normal position.

Fig 4.5 j
The sellar floor is reconstructed using TachoSil® and bone as well as sphenoid mucosa, and the mucosal flap of the anterior sphenoid wall is repositioned. Integrity of the turbinates and the mucosa of the olfactory cleft is preserved.

Fig 4.5 k–l
Postoperative imaging shows complete resection of the pituitary macroadenoma.
4.6 Case 6 – M approach

Medical history
The 75-year-old female patient had a previous history of a supraorbital approach for resection of an extensive left medial sphenoid wing meningioma. Six months after primary surgery, an intracavernous residual tumor was treated by means of CyberKnife® radiosurgery. Four years later, the patient developed a progressive visual field defect; MR imaging showed a subchiasmatic intrasellar tumor recurrence.

Planning and preparation
High-resolution CT and MRI revealed a prominent high sellar tubercle and a low prefixed optic chiasm. The tumor was not accessible by another subfrontal approach. Therefore, a transnasal approach was considered indicated.

The CT showed a normal paranasal sinus system with a well-pneumatized sphenoid sinus on both sides, and slightly larger anatomical dimensions on the left. Therefore, transnasal endoscopic tumor resection with an uniportal combined transethmoidal-paraseptal approach on the left was suggested to the patient, with the option of expanding to a biportal approach through a paraseptal corridor on the right.

Surgery
The procedure was performed under optical navigational guidance. Once a left transethmoidal-paraseptal approach had been established, the sphenoid sinus was widely exposed on both sides and a nasoseptal flap was prepared for later reconstruction of the skull base.

After checking the navigation monitor, the sellar floor was opened using a micro-burr. The opening was expanded using punches to resect the sellar tubercle and planum sphenoidale. Once the basal craniotomy had been made, the dura was opened about 1 mm dorsally of the optic chiasm, and the opening was extended posteriorly to the intracavernous sinus, sparing the two carotid arteries. The intrasellar/suprasellar and subchiasmatic tumor, almost 1 cm in size, was exposed in an optimal fashion through the transnasal approach. The soft tissue tumor was dissected away from the adjacent arachnoid layers without any difficulties. The pituitary stalk was found to be displaced to the right, and the yellowish glandular substance had been compressed downward. The optic chiasm was raised by the tumor. All mentioned structures were freed from tumor tissue and spared under endoscopic control.
Next, a plug of adipose tissue was placed intradurally and the skull base was closed using rectus abdominis fascia as an underlay and small pieces of abdominal fat as an onlay. TachoSil® was placed on this layer, and the skull base was reconstructed with the previously created nasoseptal flap. Defect closure was supported with absorbable Spongostan™ packing.

**Postoperative Course**
The postoperative course was free of complications. No lumbar drain was placed. The follow-up nasal endoscopy showed normal wound healing without any signs of CSF leakage. The MRI scans demonstrated complete tumor resection. Visual disturbances had completely subsided 3 months after the procedure.
4.7 Case 7 – L approach

Medical history
The 46-year-old male patient underwent MR imaging of the head for a neurological diagnostic workup, taken because of deterioration of vision. The images revealed a suprasellar, partially solid, partially cystic space-occupying lesion with compression of the optic chiasm. Ophthalmological testing yielded a right temporal visual field defect. The endocrinological exam showed deficiency in the levels of growth hormone and gonadotropin. In view of the rapid deterioration of visual acuity and tumor growth, surgery was considered urgent.

Planning and preparation
The rhinological endoscopic examination showed narrow anatomical conditions on both sides, and the nasal septum was deviated to the left. The CT imaging did not reveal any other nasal pathologies. The patient was counseled to undergo bilateral transnasal resection, including a right combined transeptal-paraseptal and a right paraseptal approach.

![Fig 4.7 a–c](image)
Fig 4.7 a–c
The MRI (coronal T2-weighted, sagittal T1-weighted) shows a partially solid, partially cystic craniopharyngioma in the suprasellar and retrosellar area. The pituitary stalk is expanded by the tumor. A retrosellar cyst is visible (a1–2). After 2 months, massive tumor growth, as well as compression of the chiasm and thalamus is clearly demonstrated. The stalk is no longer distinguishable, the optic chiasm is fixed (b1–2). The axial CT scan shows inconspicuous anatomy of the nasal cavity and paranasal sinuses, with a well-pneumatized sphenoid sinus (c).

Surgery
In a first step, the deviated nasal septum was corrected. The nasoseptal flap used for reconstruction was prepared. The sphenoid sinus was accessed through a right transeptal-paraseptal approach. On the left side, the sphenoid sinus was exposed paraseptally. Following basal craniotomy, the dura was opened with microscissors and the chiasmatic cistern was exposed. The tumor was dissected away from the pituitary stalk and optic chiasm using sharp and blunt dissection.

The remaining portions of the cystic tumor were resected from the third ventricle. The foramina of Monro were endoscopically assessed on both sides. The dura was adapted with single sutures, and the skull base was reconstructed using abdominal fascia, TachoSil®, and a nasoseptal flap.

Postoperative Course
Postoperatively, the patient exhibited diabetes insipidus. Pituitary function returned to normal in the further postoperative course. MRI confirmed complete resection of the tumor. The visual disturbances had distinctly improved 3 months after surgery, with a minor visual field defect remaining on the right temporal side. Normal nasal function was maintained.
Fig 4.7 d–l
Following right ethmoidectomy and lateralization of the middle turbinate, a nasoseptal flap is prepared (d). Once the biportal approach has been established, the craniotomy is made at the level of the sellar tubercle. The endoscope is introduced from the left and the instruments from the right (e).

Following basal craniotomy, the dura is opened at the level of the sellar tubercle. Behind the arachnoid, the optic chiasm and the solid tumor portion are seen (f). The calcified tumor is dissected away from the pituitary stalk and resected (g). The cystic tumor portion is removed with a grasping instrument (h). Using a 45°-telescope, the third ventricle is inspected upon completion of tumor resection. Looking through the foramina of Monro into the lateral ventricles (i). As the first layer of skull base reconstruction, abdominal adipose tissue is placed in the intradural space (j). The dura is closed with single sutures (k). Subsequently, reconstruction is completed using the prepared nasoseptal flap (l).

Fig. 4.7 m–o
The procedure was performed under permanent electromagnetic navigation with a fused set of CT and MRI data. In this case, navigational assistance permitted the safe planning of the surgical trajectory and tumor resection (m). The postoperative imaging confirmed complete resection of the tumor (n, o).
4.8 Case 8 – L approach

Medical history
The 19-year-old female patient underwent MR imaging of the head as part of the neurological diagnostic workup taken because of progressive symptoms of headache and gait disorder. Imaging revealed an extensive clival tumor with considerable compression of the brain stem. The neurological exam confirmed the absence of focal deficits. The endocrinological workup revealed normal pituitary function.

In view of progression of symptoms, surgery was considered indicated.

Planning and preparation
Computed tomography showed a well-pneumatized sphenoid sinus on both sides, with adequate room for a transclival approach despite a narrow intercarotid space. The MRI clearly demonstrated an intracranial space-occupying lesion transgressing the dura and compressing the brain stem. The patient was counseled to undergo transnasal endoscopic tumor resection through a transeptal-endoscopic approach on the right, expanded to a biportal approach by adding a parasellar corridor on the left. The planned reconstruction of the defect included a nasoseptal flap to be used on the left as well as harvest of abdominal fat and rectus abdominis fascia.

Surgery
The procedure was performed under optical CT and MRI navigation as well as intraoperative electrophysiological monitoring. In a first step, a combined transeptal-paraseptal approach on the right was established. The degree of maneuverability was still limited due to the narrow anatomical conditions, prompting us to add a paraseptal approach on the left. A nasoseptal flap was prepared for later reconstruction of the skull base. The endoscope was introduced from the left and the instruments from the right.

Once the opening in the sellar floor had been made, the clivus was opened between the two carotid arteries using a high-speed burr after checking the navigation system for real-time updated anatomic information. At this point, brownish-gray fibrous tumor tissue was revealed and dissected with ease using dissectors, curettes, and an ultrasound aspirator. Proceeding in a basal direction, the tumor was gradually dissected away from the dura. A good cleavage plane was developed between the tumor surface and the basal dura. Deep dissection exposed the site of dural tumor transgression. Owing to the intradural extension of tumor tissue, the basilar artery was found to be strongly displaced to the right. The intradural tumor portions were mobilized away from the basilar artery and the branching-off anterior inferior cerebral artery. Subsequently, a 45°-telescope was introduced into the surgical site. In a lateral direction, the 5th, 6th, and 7th cranial nerves were identified. Following complete tumor resection, the skull base was closed from the left side using abdominal fat, rectus abdominis fascia, TachoSil®, and the prepared nasoseptal flap.

Postoperative Course
Intraoperative electrophysiological monitoring was uneventful. After prompt extubation, no deficits were found. The postoperative MRI confirmed complete tumor resection, and the patient recovered quickly from the procedure. Nasal function was maintained and sinonasal outcome (SNOT-22) had improved. The smell test showed normal olfactory function on both sides.

The young patient, in whom complete tumor resection was achieved while maintaining normal pituitary function, did not receive postoperative proton radiotherapy. The 5-year follow-up demonstrated that the patient is free of recurrence.
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Fig 4.8 d–l
Following right sphenoethmoidectomy, the maxillary sinus opening and the anatomy of the lateral sphenoid wall are shown (d). On the left, a nasoseptal flap is prepared after completion of the paraseptal approach (e). Following sphenoидotomy, ample space is available for tumor resection through the biportal approach (f). Once the sellar floor is exposed, a diamond burr is used to drill open the clivus between the horizontal carotid arteries (g). The solid tumor is resected using the 4-hand technique via the biportal approach (h). Once tumor resection is completed, the basilar artery and the surface of the brain stem come into view (i). With the 45° telescope, the basal cranial nerves can be visualized in the left cerebellopontine angle (j). The skull base defect is reconstructed with abdominal fat, rectus abdominis fascia, and the prepared nasoseptal flap (k). Nasal endoscopy, performed during the 3-month follow-up visit, demonstrated a well-healed and normal-appearing sphenoid sinus (l).

Fig 4.8 m–n
Postoperative imaging confirms complete tumor resection without any signs of late complications. The course of healing of the nasoseptal flap is shown in Fig. 2.25 on page 37.
4.9 Case 9 – XL approach

Medical history
Four years ago, the 47-year-old male patient received chemoradiotherapy (70.4 Gy) for nasopharyngeal carcinoma. Thereafter, the patient had progressive symptoms of diplopia and low energy, which were related to tumor recurrence despite another course of chemotherapy and adjunct immunotherapy. Imaging studies confirmed tumor recurrence in the right cavernous sinus. The carotid artery was encased by the tumor which extended intracranially to the intrasellar space. The PET-CT showed no additional tumor manifestations. The patient presented clinical symptoms of right oculomotor paresis and total loss of pituitary hormones.

Planning and preparation
The multidisciplinary tumor board recommended surgical resection of the recurring tumor because another course of radiotherapy was not feasible and immunotherapy was unable to halt the progression of disease. Accordingly, transnasal endoscopic resection was suggested to the patient. Balloon test occlusion of the right carotid artery was performed and well tolerated. Subsequently, endovascular carotid occlusion was undertaken by interventional neuroradiologists to permit radical tumor resection. To ensure a maximum degree of maneuverability, a transnasal biportal transethmoidal-paraseptal approach was planned including the option of adding a transcranial approach.

Surgery
The procedure was performed under optical navigation. After establishing a bilateral combined transethmoidal-paraseptal approach, a supra-sellar approach was used to dissect the intracranial part of the recurrent carcinoma away from the pituitary stalk, optic chiasm, and right anterior communicating artery. Subsequently, the tumor in the right cavernous sinus was exposed and resected completely with inclusion of the encased carotid artery. The resection margins of the carotid artery were secured with vascular clips for safety purposes. The defect was reconstructed using fascia of the rectus abdominis muscle, abdominal fat, and a nasoseptal flap from the left side. The reconstruction was supported by absorbable Spongostan packing. No lumbar drain was placed.

Fig 4.9 a1–2
The axial T2-weighted MRI shows a recurrent carcinoma in the right cavernous sinus. The carotid artery is completely encased by the tumor (a1). The coronal contrast-enhanced T1-weighted MRI shows intracranial extension of the carcinoma, which encases the carotid artery (a2).

Fig 4.9 b1–2
Angiography reveals good cerebral perfusion in the balloon test occlusion (b1). Subsequently, the right internal carotid artery is occluded with coils (b2).
Postoperative Course
The 11-hour procedure was completed without complications. The patient was extubated on the ICU and presented no neurological deficits. On the 6th postoperative day, heavy straining due to constipation resulted in CSF rhinorrhea, which was surgically repaired instantly. A small dehiscence at the site of the reconstructed defect was sealed with abdominal adipose tissue and TachoSil™. Coverage of the area of repair was completed by repositioning the nasoseptal flap. Despite successful closure of the CSF leak, the patient developed meningitis, which was successfully managed with antibiotics. The patient was discharged home on the 18th postoperative day. Postoperative imaging demonstrated complete tumor resection in the right cavernous sinus. One year after surgery, a tumor recurrence was found intracranially near the anterior clinoid process. After failure of radiotherapy, surgical treatment of the tumor manifestation was provided via a transcranial supraorbital approach. Two years after reoperation, no further tumor manifestations were detectable.

Fig 4.9 c–l
Following resection of the anterior sphenoid wall, the sphenoid is visible inferiorly, and the sphenoethmoidal (Onodi) cells superiorly (c). Using a suprasellar craniotomy, the intracranial tumor portion is exposed (d). The tumor is dissected away from the optic chiasm and the pituitary stalk (e). When resecting the carotid artery, the wire coils used for embolization come into view (f). Abdominal adipose tissue is placed in the intracranial resection cavity. In addition, the resected dura is closed with rectus abdominis fascia, TachoSil™, and a nasoseptal flap harvested from the left side (g). Endoscopic appearance of the sphenoid 6 months after tumor resection. Minor mucosal defect related to a viral infection of the upper respiratory tract. The vascular coils are well visible (h).

Fig 4.9 i–j
The postoperative axial T2-weighted MRI demonstrates complete resection of the tumor portion located in the cavernous sinus (i). One year after surgery, the coronal contrast-enhanced T1-weighted MRI shows an intracranial tumor recurrence in proximity to the anterior communicating artery. After refractory radiotherapy, the recurrent tumor was resected using a transcranial approach (j).
4.10  Case 10 – XL approach

Medical history
For the past year, the 48-year-old male patient suffered from progressive worsening of compromised nasal breathing on the right and from impaired olfactory function. Nasal endoscopy demonstrated a solid, well-vascularized polyp on the right, resulting in complete obstruction of the nasal cavity. CT and MR imaging revealed an extensive tumor in the nasal cavity and central skull base. The intracranial portion had a maximum size of 10 mm at the level of the right olfactory fossa. The imaging findings were suggestive of an olfactory neuroblastoma (Kadish stage C). The tentative diagnosis was later confirmed by histology. The staging exams, including a PET-CT scan, showed no additional tumor manifestations.

Planning and preparation
The multidisciplinary tumor board recommended bimodal therapy with primary tumor resection and subsequent radiotherapy of the olfactory neuroblastoma. Accordingly, transnasal endoscopic resection was suggested to the patient, including the option of transcranial expansion of the resection using a supraorbital approach. Closure of the planned defect included harvesting of abdominal adipose tissue and fascia lata from the right thigh. The endocrinological diagnostic workup confirmed normal pituitary function, as expected. The smell test provided evidence of bilateral anosmia.

Surgery
The surgical procedure was performed under electromagnetic navigation. To create sufficient space and to enable exposure of key anatomic landmarks, bilateral frontosphenoethmoidectomy was performed, including resection of the frontal sinus floor as in a Draf III median drainage procedure. The intranasal tumor was removed with inclusion of the adjacent nasal septum and the middle and superior turbinates. The median anterior skull base harboring the tumor – which was growing in an intracranial direction – was then resected, and the intracranial tumor portion along with the affected dura was dissected away from the frontal lobe. Intraoperative cryosection analysis confirmed tumor-free resection margins. The defect was reconstructed as planned using fascia lata from the right thigh. The harvested autograft was placed in the defect as an underlay and sutured in place. Apart from that, small fragments of abdominal fat were used for sealing, and the reconstructed skull base defect was secured using TachoSil® collagen sponges.

The reconstruction was supported using absorbable Spongostan™ packing. Lumbar drainage was not required.

Postoperative Course
The 9-hour procedure was completed without complications, and the patient was extubated on the ICU. The CT ruled out surgical endocranial complications, and the patient was transferred to the ward on the 2nd postoperative day. Despite standard thrombosis prevention, pulmonary embolism occurred on the 3rd postoperative day, which was treated with heparin, and consequently with phenprocoumon and healed without sequelae. As recommended by the tumor board, postoperative radiotherapy was given. The patient receives regular follow-up care with MRI control and has been cancer-free for 2 years. Nasal breathing is normal, and no crusting was noticeable.
Nasal endoscopy confirms subtotal obstruction of the right nasal cavity by a well-vascularized polypoid tumor.

Once the intranasal tumor portion including the nasal septum as well as the middle and superior turbinates has been resected, the dura of the anterior skull base is exposed. Median drainage of the frontal sinus permits surgical control of the anterior resection margin adjoining the frontal sinus (arrow).

Resection of the intracranial tumor portion with inclusion of the olfactory nerve on both sides.

Endoscopic view of the surgical site after complete tumor resection. Intraoperative cryosection analysis of resection margins was negative. The resulting dural defect had a size of 3.3 x 2 cm (g). Reconstruction of the dural defect using fascia lata from the right thigh. The fascia is secured with single sutures (h). The reconstructed defect is sealed using abdominal adipose tissue. The reconstruction is then secured with TachoSil® collagen sponges and supported using absorbable Spongostan™ packing (i).

Endoscopic view of the nasal cavity and the anterior skull base, 18 months after tumor resection and radiotherapy. Note the unremarkable appearance of the skull base lacking any clue of tumor recurrence (j).

The postoperative coronal T2-weighted MRI obtained 18 months after tumor resection and radiotherapy showed no signs of recurrence of the olfactory neuroblastoma (k). Similarly, the postoperative sagittal T1-weighted MRI scan shows normal conditions around the reconstructed anterior skull base, without signs of recurrence of the olfactory neuroblastoma (l).
4.11 Case 11 – XXL approach

Medical history
In 2001, the 49-year-old male patient underwent surgery for a skull base chondrosarcoma using a LeFort I maxillotomy. A tumor recurrence was treated by surgical resection in 2009 using a transnasal approach. In the present case, the diagnostic workup was undertaken in 2018 due to incomplete oculomotor nerve palsy. MR imaging demonstrated extensive tumor recurrence in the nasal cavity and the central skull base. Thin-slice imaging revealed tumor-related displacement without infiltration of the left cavernous sinus and concomitant transgression of the tumor into the middle cranial fossa.

Planning and preparation
A single transnasal approach does not enable adequate control of resection in the middle cranial fossa. Therefore, a combined transnasal-transcranial resection was suggested to the patient. In view of the healthy orbital content and normal visual acuity, the patient was counseled against undergoing the previously suggested orbital exenteration. With regard to the tumor-related displacement of the internal carotid artery, catheter angiography was performed preoperatively. The BTO showed sufficient collateral supply in case occlusion of the left carotid artery was needed during surgery.

Surgery
The procedure was performed under CT/MRI-based optical navigation. Following bilateral ethmoidectomy, a partial medial maxillectomy was included in the left nasal approach. Extensive tumor infiltration was found, with displacement of the pterygopalatine fossa and invasion of the inferior orbital fissure. The lamina papyracea and the orbital floor were exposed as landmarks, and the lateral tumor margin was defined. No orbital infiltration was found.
The tumor was enucleated internally, dissected from the dural sellar floor in a basal direction, and the clivus, optic nerve, and internal carotid artery were exposed. Dissecting in a basal direction, the horizontal carotid segment was skeletonized, and tumor resection was carried as far as the clivus and epipharynx. Next, the tumor was resected lateral to the carotid course in the left cavernous sinus, and the foramen rotundum was identified. At this site, the tumor was found to encroach on the middle cranial fossa with infiltration of the medial temporal fossa. It was not feasible to further extend tumor resection in a controlled manner through the transnasal approach.

Therefore, an arched skin incision and mini-pterional approach were made in the left frontotemporal area.

Fig 4.11 f–h
Nasal endoscopy on the left side reveals the ulcerated tumor surface. The posterior septum is missing. Shown is the inferior turbinate at the right lateral nasal wall (f). First, the tumor is dissected away from the skull base on the right. In the ethmoid, polypoid alterations are detected on the mucosa (g). The tumor is resected step-by-step through the nostrils (h).

Fig 4.11 i–k
In the sphenoid sinus, the anterior carotid knee is assessed with the micro-Doppler (i). The tumor is dissected away from the central skull base, internal carotid artery, cavernous sinus, nasopharynx, and pterygopalatine fossa. Continuing with dissection laterally into the middle cranial fossa is no longer feasible because the level of controllability is insufficient. Accordingly, a left pterional approach is created (j). After opening the dura, the temporal lobe is mobilized with gauze and spared. The tumor is found to transgress into the middle cranial fossa below the cavernous sinus, but without infiltrating the brain surface (k).

Fig 4.11 l–n
Inferior to the second branch of the trigeminal nerve, the skull base is opened, giving view of the transnasally inserted endoscope (l). After transnasal insertion of the endoscope, it is passed through the dural opening to visualize the mesial temporal brain surface (m). The dural opening is closed in layers from both sides. At the end of the procedure, the nasal resection cavity is unremarkable and integrity of the middle turbinates is confirmed (n).
The Sylvian fissure was opened, the temporal lobe mobilized, and the temporal skull base exposed under endoscopic guidance. The mushroom-shaped tumor was seen to protrude. The skull base was closed with a piece of the inner table of the calvaria, temporal fascia, and TachoSil® collagen sponges.

The procedure was continued using a combined transnasal-transcranial approach, and tumor resection was completed under optimal visualization. Transnasal surgery was controlled transcranially, and vice versa, transcranial dissection was controlled via the transnasal approach. As a result of the combined approach, a macroscopically complete tumor resection was achieved while preserving integrity of the cavernous sinus and orbital content.

The skull base reconstruction was performed from “inside out” with the inner cortical bone of the craniotomy and TachoSil®, and from “outside in” via the transnasal route with a free mucosal flap and TachoSil®.

Postoperative Course
The 11-hour procedure was completed without complications and the patient was extubated on the ICU. The absence of surgical complications was confirmed by CT imaging. The patient was transferred to the ward on the 2nd postoperative day and discharged on the 8th postoperative day. The MRI demonstrated complete tumor resection.

Fig 4.11 o–p
The nasal endoscopy performed at 3-month (o) and 6-month (p) follow-up shows little remaining granulation tissue in the area of the reconstructed dural defect and skull base, with optimal wound healing.

Fig 4.11 q–u
The postoperative CT shows the position of the reconstructed osseous skull base (q, r).
The MRI scan performed at 3-month follow-up shows no signs of residual tumor and gives no clues of a late surgical complication (s–u).
4.12  Case 12 – XXL approach

Medical history
The 39-year-old male patient was presented to us with a previous history of five revision surgeries for an extensive clival chordoma treated via a transnasal approach. The most up-to-date imaging demonstrated a recurrent tumor of massive proportions.

The patient’s clinical condition was rapidly deteriorating. At the time of admission, the patient presented incomplete quadriparesis, right oculomotor paresis as well as caudal cranial nerve deficits with dysphagia. At another institution, the tumor had been assessed as inoperable.

Planning and preparation
The MRI scans showed a chordoma of the middle clivus with massive brain stem compression and displacement of the vertebrobasilar vessels and basal cranial nerves. The tumor was found to extend far laterally into the skull base infiltrating the cavernous sinus and petrous apex. Signs of bone erosion in these areas were demonstrated on CT imaging.

In view of the far lateral extension of the tumor, the patient was offered resection using a combined transnasal-transcranial approach including the option of augmenting the biportal transnasal approach by a left-sided retrosigmoid craniotomy.

Fig 4.12 a–b
The axial (a) and sagittal (b) T2-weighted MRI scans show the extensive recurrent chordoma of the central skull base. The tumor is encroaching on the posterior cranial fossa causing massive brain stem compression. The vertebral arteries and basal cranial nerves are considerably displaced.

Fig 4.12 c1–2
The patient positioning permits intraoperative rotation for the planned transnasal-transcranial procedure. The patient is positioned in a way that allows to augment the transnasal approach by a left pterional approach, if necessary (c1). Through the biportal transnasal approach, the tumor is resected in a piecemeal fashion. As anticipated, complete resection is not feasible via a transnasal approach. After repositioning the head, a transcranial retrosigmoid approach is therefore prepared. (c2).
Surgery
The head was fixed in place using a carbon fiber clamp in a way that permitted rotation for the planned retrosigmoid craniotomy. The intraoperative CT data set was fused with the preoperative MRI data set, and registration of the navigation system was performed.

After bilateral ethmoidectomy, the tumor was enucleated internally until a tumor-free layer was reached in frontobasal and clival planes. Dissection was particularly difficult because of the far lateral extension of the tumor. The dural layer was reached by dissecting in the center of the tumor, but due to adhesions with the brain stem surface, a continued resection could not be justified.

The head was rotated far to the right, and a retrosigmoid keyhole approach was made. The cerebellum was carefully mobilized, and after CSF drainage, the tumor surface was reached. Using endoscope-assisted microsurgery, the tumor was dissected and detached from the pontomedullary surface, while sparing the vertebrobasilar junction and all of the cranial nerves.

The operation was then continued using a combined transnasal-transcranial approach. The transnasal surgical maneuvers were visually controlled using the transcranial approach. Macroscopically complete resection was achieved and the skull base was closed from “inside out” with a fascia layer and TachoSil® collagen sponges, whereas an “inside out” technique was used to reposition the nasoseptal flap over the surface area of resection. A final CT scan performed on the operating table confirmed the absence of any signs of surgical complications.

**Fig. 4.12 d–f**
The tumor is resected piecemeal via the biportal transnasal approach. Achieving a complete resection is not feasible using the transnasal approach. After repositioning the head, a transcranial retrosigmoid approach is therefore prepared.

**Fig. 4.12 g–i**
View of the pontomedullary and vertebrobasilar junction, offered via the transnasal approach after complete tumor resection.
Postoperative Course
The patient had tolerated the 16-hour surgery well and was extubated on the first postoperative day. The postoperative MR imaging did not show any significant signs of residual tumor. Following proton radiotherapy, the patient was discharged from hospital presenting a distinctly improved status.

Fig. 4.12 j
Shown is the operating room setup with the rhino-surgeon standing on the patient's right side while the neurosurgeon is operating from the left.

Fig. 4.12 k–l
Axial (k) and sagittal (l) MRI scans taken at the 6-week follow-up before planned proton radiotherapy do not show any relevant signs of residual tumor.

Fig. 4.12 m
The patient after completion of proton radiotherapy, surrounded by the team of the Neurosurgery Department of Hirslanden Clinic, Zurich, Switzerland. Photograph by kind permission of the patient.
## Key to anatomical acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Latin Terminology</th>
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<tr>
<td>AC</td>
<td>Arteria carotis interna</td>
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<td>BE</td>
<td>Bulla ethmoidalis</td>
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<td>CH</td>
<td>Choana</td>
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<tr>
<td>CI</td>
<td>Concha inferior</td>
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<td>CL</td>
<td>Clivus</td>
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<td>CM</td>
<td>Concha media</td>
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<td>CO</td>
<td>Canalis opticus</td>
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<td>CS</td>
<td>Concha superior</td>
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<td>DM</td>
<td>Dura mater</td>
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<td>DN</td>
<td>Ductus nasolacrimalis</td>
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<td>EP</td>
<td>Epipharynx</td>
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<td>FS</td>
<td>Foramen sphenopalatinum</td>
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<td>HY</td>
<td>Hypophysis</td>
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<tr>
<td>LB</td>
<td>Lamella basilaris</td>
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<tr>
<td>PO</td>
<td>Pons</td>
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<td>Processus uncinatus</td>
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<td>SM</td>
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<td>SN</td>
<td>Septum nasi</td>
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<tr>
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<td>Sinus sphenoidalis</td>
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<td>ST</td>
<td>Sella turcica</td>
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<td>TT</td>
<td>Torus tubarius</td>
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<td>VO</td>
<td>Vomer</td>
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<td>n. VIII.</td>
<td>Nervus vestibulocochlearis</td>
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<tr>
<td>n. II.</td>
<td>Nervus opticus</td>
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Bibliography


[40] Lund, VJ; Stammberger, H; Fokkens, WJ; Beale, T; Bernal-Sprekelsen, M; Eloy, P; Georgalas, C; Gerstenberger, C; Helling, P; Herman, P; Hosemann, WG; Jankowski, R; Jones, N; Jorissen, M; Leuning, A; Onercin, M; Rimmer, J; Rombaux, P; Simmen, D; Tomazic, PV; Tshabalitscher, M; Welge-Luessen, A; (2014): European Position Paper on the Anatomical Terminology of the Internal Nose and Parasellar Sinuses. Rhinology. 2014; 50(24):3–+++.


Recommended sets of telescopes, instruments and video equipment for minimally invasive, tailored transnasal skull base surgery
Endoscopic Pituitary and Skull Base Surgery
Basic Set
The concept of minimally invasive, tailored transnasal skull base surgery

**Endoscopic Pituitary and Skull Base Surgery**

**Basic Set – REISCH / BRINER Recommended Set**

**BASIC Set for ENT Surgery**

**Telescopes**

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**Instruments**

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Endoscopic Pituitary and Skull Base Surgery
Basic Set – REISCH / BRINER Recommended Set

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Extended Set
Endoscopic Pituitary and Skull Base Surgery
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EXTENDED Set for ENT Surgery

Telescopes
1 7230 AE ENDOCA MELEON® ENT HOPKINS® Telescope, diameter 4 mm, length 18 cm, autoclavable, variable direction of view from 15° - 90°, adjustment knob with Fin for selecting the desired direction of view, fiber optic light transmission incorporated, color code: gold
2 7230 BA HOPKINS® Forward-Oblique Telescope 30°, enlarged view, diameter 4 mm, length 18 cm, autoclavable, fiber optic light transmission incorporated, color code: red
3 7230 CA HOPKINS® Lateral Telescope 70°, enlarged view, diameter 4 mm, length 18 cm, autoclavable, fiber optic light transmission incorporated, color code: yellow

Instruments
4 629824 CASTELNUOVO Frontal ostium seeker curved, double ended
5 651521 Frontal Sinus Punch, with link chain sheath 70° upturned, backward cutting, to reduce the spina nasalis superior, small, jaws 2.5 x 2 mm, working length 13 cm
6 459052 STAMMBERGER Antrum Punch, left side downward and forward cutting, with cleaning connector, working length 10 cm
7 459051 Same, right side downward and forward cutting
8 651020 STAMMBERGER RHINOFORCE® II Double Spoon Forceps, horizontal opening, 65° upturned, spoon diameter 3 mm, with cleaning connector, working length 12 cm
9 651010 Same, vertical opening
10 459030 STAMMBERGER RHINOFORCE® II Antrum Punch, small pediatric size, slender, upward backward cutting, with cleaning connector, working length 10 cm
11 452001 B MACKAY-GRUNWALD RHINOFORCE® II Nasal Forceps, straight, through-cutting, extra delicate, tissue-sparing, 8 x 3 mm, size 1, with cleaning connector, working length 13 cm
12 649100 B BLAKESLEY RHINOFORCE® II Ethmoid Forceps, straight, size 0, with cleaning connector, working length 16 cm
13 28164 XD Suction Tube, with cut-off hole, drop-shaped, with distance markings, LUER, conical distal end, malleable, 8 Fr., working length 15 cm
14 28164 XC Suction Tube, with cut-off hole, drop-shaped, with distance markings, LUER, conical distal end, malleable, 8 Fr., working length 15 cm
15 28164 RR CAPPABIANCA-de DIVITIIS Curette, stirrup-shape, blunt, with round handle, length 25 cm
16 28164 RM CAPPABIANCA-de DIVITIIS Ring Curette, round wire, horizontal, inner diameter 5 mm, tip angled 45°, with round handle, length 25 cm
17 28164 RF CAPPABIANCA-de DIVITIIS Ring Curette, round wire, vertical, inner diameter 5 mm, tip angled 45°, with round handle, length 25 cm
18 28164 RW CAPPABIANCA-de DIVITIIS Ring Curette, round wire, inner diameter 7 mm, tip laterally angled 90°, with round handle, length 25 cm
19 28164 RD Same, inner diameter 5 mm
20 28164 RV Same, inner diameter 3 mm
21 28164 RC CAPPABIANCA-de DIVITIIS Curette, round wire, inner diameter 7 mm, distally curved shaft, with round handle, length 25 cm
22 28164 RA Same, inner diameter 5 mm
23 28164 RB Same, inner diameter 3 mm
24 28164 RH de DIVITIIS-CAPPABIANCA Curette, round wire, inner diameter 7 mm, tip angled 90°, with round handle, length 25 cm
25 28164 RG Same, inner diameter 5 mm
26 28164 RI Same, inner diameter 3 mm
The concept of minimally invasive, tailored transnasal skull base surgery

27  28164 RP  De DIVITIIS-CAPPABIANCA Curette, round wire, inner diameter 7 mm, tip angled 45°, with round handle, length 25 cm
28  28164 RK  Same, ductile
29  28164 RO  De DIVITIIS-CAPPABIANCA Curette, round wire, inner diameter 5 mm, tip angled 45°, with round handle, length 25 cm
30  28164 RJ  Same, ductile
31  28164 RN  De DIVITIIS-CAPPABIANCA Curette, round wire, inner diameter 3 mm, tip angled 45°, with round handle, length 25 cm
32  28164 RE  Same, ductile
33  28164 NBC  Micro Needle Holder, bayonet-shaped, jaws curved to left, 1 x 6 mm, working length 10 cm
34  28164 PBG  Forceps, bayonet shaped, 2 mm, spoon horizontal, working length 10 cm
35  28164 PBH  Same, 4 mm
36  28164 PBI  Same, 6 mm
37  28164 SBA  Micro Scissors, bayonet-shaped, sharp / sharp, cutting edges straight, working length 10 cm
38  28164 SBE  Same, cutting edges horizontal
39  28164 SBB  Same, cutting edges curved to left
40  28164 SBD  Same, cutting edges curved to right
41  28164 PBA  Micro Grasping Forceps, bayonet-shaped, straight jaws, smooth, 0.5 mm, working length 10 cm
42  28164 GS  Miniature Forceps, through-cutting, with fine flat jaws, bite 1 mm, straight, working length 18 cm
43  28164 TF  Forceps, oval cupped jaws, 0.6 mm, extra delicate, curved to left, working length 18 cm
44  28164 TE  Same, curved to right
45  28164 TD  Same, straight
46  28164 BDK  TAKE-APART® Bipolar Forceps, width 4 mm, distally angled 45°, horizontal closing, outer diameter 3.4 mm, working length 20 cm, including:
   Bipolar Ring Handle
   Outer Sheath
   Inner Sheath
   Forceps Insert
47  28164 BDD  TAKE-APART® Bipolar Forceps, width 2 mm distally angled 45°, horizontal closing, outer diameter 3.4 mm, working length 20 cm, including:
   Handle
   Outer Tube
   Inner Tube
   Bipolar Insert
48  28164 BDM  TAKE-APART® Bipolar Forceps, width 1 mm delicate jaws, distally angled 45°, horizontal closing, outer diameter 3.4 mm, working length 20 cm, including:
   Handle
   Outer Tube
   Inner Tube
   Bipolar Insert
49  28164 BDL  Same, vertical closing
Intraoperative Visualization and Orientation

HOPKINS® Telescopes

**HOPKINS® Straight Forward Telescope 0°**, enlarged view, diameter 4 mm, length 18 cm, **autoclavable**, fiber optic light transmission incorporated, color code: green

**HOPKINS® Forward-Oblique Telescope 30°**, enlarged view, diameter 4 mm, length 18 cm, **autoclavable**, fiber optic light transmission incorporated, color code: red

**HOPKINS® Forward-Oblique Telescope 45°**, enlarged view, diameter 4 mm, length 18 cm, **autoclavable**, fiber optic light transmission incorporated, color code: black

**HOPKINS® Lateral Telescope 70°**, enlarged view, diameter 4 mm, length 18 cm, **autoclavable**, fiber optic light transmission incorporated, color code: yellow

**ENDOCAMELEON® ENT HOPKINS® Telescope**

**7230 AE**  
**ENDOCAMELEON® ENT HOPKINS® Telescope**, diameter 4 mm, length 18 cm, **autoclavable**, variable direction of view from 15° - 90°, adjustment knob with Fin for selecting the desired direction of view, fiber optic light transmission incorporated, color code: gold
The concept of minimally invasive, tailored transnasal skull base surgery

Intraoperative Visualization and Orientation
TIPCAM®1 S 3D Telescopes

**TIPCAM®1 S 3D**, diameter 4 mm, length 18 cm, two FULL HD image sensors, **autoclavable**, S-Technologies available, freely programmable camera head buttons, including video connecting cable, for use with IMAGE1 S™

<table>
<thead>
<tr>
<th>Angle</th>
<th>Code</th>
<th>Description</th>
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<tr>
<td>0°</td>
<td>7230 AA 3D</td>
<td><strong>Same</strong>, direction of view 0°</td>
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<tr>
<td>30°</td>
<td>7230 BA 3D</td>
<td><strong>Same</strong>, direction of view 30°</td>
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<tr>
<td>45°</td>
<td>7230 FA 3D</td>
<td><strong>Same</strong>, direction of view 45°</td>
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</tbody>
</table>
Management of Bleeding
Bipolar Forceps

844524  **Bipolar Forceps**, bayonet-shaped, with bar, tip 0.7 mm, length 23 cm

844525  **Bipolar Forceps**, bayonet-shaped, angled, with bar, tip 0.7 mm, length 23 cm

**TAKE-APART® Bipolar Forceps**

*28164 BDM  **TAKE-APART® Bipolar Forceps**, with fine jaws, width 1 mm, distally angled 45°, horizontal closing, outer diameter 3.4 mm, length 20 cm

*28164 BDD  **Same**, width 2 mm

*28164 BDK  **Same**, width 4 mm

*28164 BDL  **Same**, width 1 mm, vertical closing

* For use with Bipolar High Frequency Cords 26176 LE/LM/L/LA/LV
### Management of Bleeding

#### Suction Tubes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tr>
<td>839310 N</td>
<td>Suction Cannula, for nose, straight, outer diameter 3 mm, working length 10 cm</td>
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<tr>
<td>839312</td>
<td>SIMMEN Insulated Suction Cannula, for nose and epistaxis, angular, malleable, distal with uninsulated horn, outer diameter 3.5 mm, with cut-off hole, working length 12 cm, for use with Unipolar High Frequency Cords 26005 M, 26004 M, 26002 M, 26006 M</td>
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<tr>
<td>839313</td>
<td>Same, outer diameter 4.5 mm</td>
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<tr>
<td>839325</td>
<td>BRINER Bipolar Coagulation Suction Cannula, angular, insulated, length of electrodes 3.2 mm, with cut-off hole, outer diameter 3.5 mm, working length 11 cm, for use with Bipolar High Frequency Cords 847000 or 847000 A / E / M / V</td>
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<tr>
<td>839330</td>
<td>Same, outer diameter 4.5 mm</td>
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</table>
Access, Fine Dissection and Decompression
Osteotome, Mallet, Elevator and Knives

486103  WALTER Osteotome, flat, double-edged grinding, width 3 mm, length 19 cm

174200  COTTLE Metal Mallet, length 18 cm

479000  MASING Elevator, double-ended, graduated, sharp and blunt, length 22.5 cm

628001  Sickle Knife, pointed, length 19 cm

28164 KK  de DIVITIIS-CAPPABIANCA Scalpel, with retractable blade consisting of:
Handle
Outer Sheath
Micro Knife, sickle-shaped

28164 M  Same,
including: Micro Knife, pointed
Access, Fine Dissection and Decompression

Antrum Punches

STAMMBERGER Antrum Punches

459051 STAMMBERGER Antrum Punch, right side downward and forward cutting, with cleaning connector, working length 10 cm

459052 Same, left side downward and forward cutting

RHINOFORCE® II STAMMBERGER Antrum Punches

459030 STAMMBERGER RHINOFORCE® II Antrum Punch, small pediatric size, slender, upward backward cutting, with cleaning connector, working length 10 cm
Access, Fine Dissection and Decompression
KERRISON Bone Punches

KERRISON Bone Punch, detachable, rigid, 90° upbiting, not through-cutting, size 2 mm, working length 17 cm

662102

Same, size 3 mm
662103
Same, size 4 mm
662104

KERRISON Bone Punch, detachable, rigid, 90° downbiting, not through-cutting, size 2 mm, working length 17 cm

662112

Same, size 3 mm
662113

KERRISON Bone Punch, detachable, rigid, upbiting 60° forward, size 1 mm, working length 17 cm

28164 MKA

Same, size 2 mm
28164 MKB
Same, size 3 mm
28164 MKC

KERRISON Bone Punch, detachable, rigid, downbiting 60° forward, size 2 mm, working length 17 cm

28164 MKE

Same, size 3 mm
28164 MKF
Access, Fine Dissection and Decompression

**Forceps**

<table>
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<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>451001B</td>
<td>GRÜNWALD-HENKE RHINOFORCE® II Nasal Cutting Forceps, straight, through-cutting, tissue-sparing, BLAKESLEY shape, size 1, width 3.5 mm, with cleaning connector, working length 13 cm</td>
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<tr>
<td>451002B</td>
<td>Same, size 2, width 4 mm</td>
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<tr>
<td>451501B</td>
<td>GRÜNWALD-HENKE RHINOFORCE® II Nasal Cutting Forceps, 45° upturned, through-cutting, tissue-sparing, BLAKESLEY shape, size 1, width 3.5 mm, with cleaning connector, working length 13 cm</td>
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<tr>
<td>451502B</td>
<td>Same, size 2, width 4 mm</td>
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<tr>
<td>663231</td>
<td>Forceps, detachable, straight, with round cupped jaws, diameter 2.5 mm, working length 18 cm</td>
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<tr>
<td>663241</td>
<td>Same, diameter 4 mm</td>
</tr>
<tr>
<td>663237</td>
<td>Same, 45° upturned</td>
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</tbody>
</table>
Access, Fine Dissection and Decompression

Micro Forceps

28164 PBG  Micro Forceps, bayonet-shaped, spoon horizontal, working length 10 cm

28164 PBH  Same, 4 mm

28164 PBI  Same, 6 mm

28164 PBA  Micro Grasping Forceps, bayonet-shaped, straight jaws, smooth, 0.5 mm, working length 10 cm
**Access, Fine Dissection and Decompression**

*Scissors*

449250  **Nasal Scissors**, ZÜRICH model, detachable, straight, large model, cutting length 18 mm, working length 14 cm

449251  ZÜRICH **Nasal Scissors**, detachable, small model straight, 12 mm blade, working length 12 cm

28164 MZD  **Micro Scissors**, bayonet-shaped, sharp/sharp, cutting edges straight, working length 10 cm

28164 MZB  **Scissors**, straight, with small handle, with cleaning connector, working length 18 cm

28164 MZE  **Same**, curved upwards

28164 MZD  **Same**, curved to left

28164 MZC  **Same**, curved to right

28164 SBD  **Same**, cutting edges curved to right

28164 SBE  **Same**, cutting edges horizontal
Access, Fine Dissection and Decompression
CAPPABIANCA-de DIVITIIS Ring Curettes

28164 RN  CAPPABIANCA-de DIVITIIS Ring Curette, round wire, inner diameter 3 mm, tip angled 45°, with round handle, length 25 cm
28164 RO  Same, inner diameter 5 mm
28164 RP  Same, inner diameter 7 mm

28164 RE  CAPPABIANCA-de DIVITIIS Ring Curette, round wire, ductile, inner diameter 3 mm, tip angled 45°, with round handle, length 25 cm
28164 RJ  Same, inner diameter 5 mm
28164 RK  Same, inner diameter 7 mm

28164 RI  CAPPABIANCA-de DIVITIIS Ring Curette, round wire, inner diameter 3 mm, tip angled 90°, with round handle, length 25 cm
28164 RG  Same, inner diameter 5 mm
28164 RH  Same, inner diameter 7 mm

28164 RB  CAPPABIANCA-de DIVITIIS Ring Curette, round wire, inner diameter 3 mm, distally curved shaft, with round handle, length 25 cm
28164 RA  Same, inner diameter 5 mm
28164 RC  Same, inner diameter 7 mm

28164 RV  CAPPABIANCA-de DIVITIIS Ring Curette, round wire, inner diameter 3 mm, tip laterally angled 90°, with round handle, length 25 cm
28164 RD  Same, inner diameter 5 mm
28164 RW  Same, inner diameter 7 mm

28164 RR  CAPPABIANCA-de DIVITIIS Curette, blunt, stirrup-shaped, with round handle, length 25 cm
Access, Fine Dissection and Decompression

Ring Curettes

28164 RF  De DIVITIIS-CAPPABIANCA Ring Curette, round wire, vertical, inner diameter 5 mm, tip angled 45°, with round handle, length 25 cm

28164 RM  Same, horizontal

28164 GGO  Ring Curette, bayonet-shaped, round wire, inner diameter 5 mm, tip angled 90° upwards, with round handle, length 25 cm

28164 GGU  Same, tip angled 90° downwards

28164 GLL  Ring Curette, bayonet-shaped, blunt, tip angled to left 90°, outer diameter 3.3 mm, with round handle, working length 25 cm

28164 GLR  Same, tip angled to right 90°
UNIDRIVE® S III ENT SCB
UNIDRIVE® S III NEURO SCB
System Components

**System Components**

- **Two-Pedal Footswitch**
  - 200166-30
- **Tubing Set, for single use**
  - 031131-10

**Unilateral (UNIT SIDE)**

- **UNIDRIVE® S III NEURO**
  - 407017-01-1

- **UNIDRIVE® S III ENT**
  - 407016-20-1

**Components**

- **High-Speed Micro Motor**
  - 20712033
- **High-Speed Handpiece**
  - 60,000 rpm
  - 252661 - 252663
- **High-Speed Handpiece**
  - 60,000 rpm
  - 252671 - 252672
- **INTRA Handpiece**
  - 252571 - 252592
- **High-Performance EC Micro Motor II**
  - 20711033
  - 20711173
- **DRILLCUT-X® II Shaver Handpiece**
  - DRILLCUT-X® II-35 Shaver Handpiece
  - 40712050
  - 40712055
  - 40712535
- **DRILLCUT-X® II-35 Shaver Handpiece**
  - 40712055
  - 40712535
- **Suction Shaver Blade**
  - 41201KN
- **Shaver Blade, curved**
  - 41302KN
- **Sinus Burr**
  - 41305DN
- **Sinus Burr 35k**
  - 41335W
The concept of minimally invasive, tailored transnasal skull base surgery

UNIDRIVE® S III ENT SCB
UNIDRIVE® S III NEURO SCB
Recommended Standard Set Configurations

UNIDRIVE® S III ENT SCB

40 7016 20-1
UNIDRIVE® S III ENT with KARL STORZ-SCB,
motor control unit with color display, touch screen,
two motor outputs, integrated irrigation pump and integrated SCB
module, power supply 100-240 VAC, 50/60 Hz
including:
UNIDRIVE® S III NEURO with KARL STORZ-SCB
Mains Cord
Irrigator Rod
Two-Pedal Footswitch, two-stage, with proportional function
SCB Connecting Cable, length 100 cm
Single Use Tubing Set, sterile, package of 3

UNIDRIVE® S III NEURO SCB

40 7017 01-1
UNIDRIVE® S III NEURO, motor system with color display,
touch screen, two motor outputs, integrated irrigation pump and
integrated SCB module, 100-240 VAC, 50/60 Hz
including:
UNIDRIVE® S III NEURO with KARL STORZ-SCB
Mains Cord
Irrigator Rod
Two-Pedal Footswitch, two-stage, with proportional function
SCB Connecting Cable, length 100 cm
Single Use Tubing Set, sterile, package of 3

Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
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<tbody>
<tr>
<td>Touch Screen</td>
<td>UNIDRIVE® S III SCB: 6.4’’ / 300 cd / m²</td>
</tr>
<tr>
<td>Flow</td>
<td>9 steps</td>
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<tr>
<td>Power supply</td>
<td>100-240 VAC, 50 / 60 Hz</td>
</tr>
<tr>
<td>Dimensions w x h x d</td>
<td>300 x 165 x 265 mm</td>
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<tr>
<td>Weight</td>
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<tr>
<td>Certified to</td>
<td>IEC 601-1, CE acc. to MDD</td>
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</tbody>
</table>
Optional Accessories
for use with UNIDRIVE® S III ENT SCB and UNIDRIVE® S III NEURO

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Details</th>
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<tr>
<td>280053</td>
<td>Universal Spray, 500 ml bottle, HAZARDOUS GOODS</td>
<td>UN 1950 consisting of:</td>
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<td>Spray Nozzle</td>
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<tr>
<td>031131-10*</td>
<td>Tubing Set, for irrigation, sterile, for single use, package of 10</td>
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</tbody>
</table>
The concept of minimally invasive, tailored transnasal skull base surgery

Motor Systems

Special Features:

• Self-cooling, brushless high-performance EC micro motor
• Smallest possible dimensions
• **Autoclavable**
• Can be processed in a cleaning machine
• Detachable connecting cable

• INTRA coupling enables a wide variety of applications
• Maximum torque 4 Ncm
• Number of revolutions can be continuously adjusted from 0–40,000 rpm
• Possible to adjust the number of revolutions to 80,000 rpm with the appropriate handle

![Image of the High-Performance EC Micro Motor II](20711033)

**20711033**  
**High-Performance EC Micro Motor II,** for use with UNIDRIVE® II / UNIDRIVE® ENT / OMFS / NEURO / ECO and Connecting Cable **20711033**, or for use with UNIDRIVE® S III ENT / ECO / NEURO and Connecting Cable **20711173**

**20711173**  
**Connecting Cable,** to connect High-Performance EC Micro Motor **20711033** to UNIDRIVE® S III ENT / ECO / NEURO

Special Features:

• Self-cooling and brushless high-speed micro motor
• The smallest possible dimensions
• **Autoclavable**
• Can be processed in a cleaning machine

• Maximum torque 6 Ncm
• Number of revolutions can be continuously adjusted from 1000–60,000 rpm
• Possible to adjust the number of revolutions to 100,000 rpm with the appropriate handle

![Image of the High-Speed Micro Motor](20712033)

**20712033**  
**High-Speed Micro Motor,** max. speed 60,000 rpm, including connecting cable, for use with UNIDRIVE® S III ENT / NEURO
INTRA Drill Handpieces
for surgery in the ethmoid area and the skull base

Special Features:
- Tool-free closing and opening of the drill possible
- Clockwise/counterclockwise rotation
- Max. rotating speed up to 40,000 or 80,000 rpm
- Detachable irrigation tubes
- Lightweight construction
- Low-vibration operation
- Low maintenance
- Can be reprocessed in a washer
- Safe grip

INTRA Drill Handpiece, angled, length 15 cm, transmission 1:1 (40,000 rpm), for use with high-performance EC Micro Motor II and straight shaft burrs

**Same**, transmission 1:2 (80,000 rpm)

**649600 - 649770 G**

<table>
<thead>
<tr>
<th>Detail</th>
<th>Size</th>
<th>Diameter in mm</th>
<th>Standard</th>
<th>Diamond</th>
<th>Diamond coarse</th>
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</table>

649600  **Standard Straight Shaft Burr**, stainless, size 014-070, length 9.5 cm, set of 11
649700  **Diamond Straight Shaft Burr**, stainless, size 014-070, length 9.5 cm, set of 11
649700 G **Rapid Diamond Straight Shaft Burr**, stainless, with coarse diamond coating for precise drilling and abrasion without hand pressure and generating minimal heat, size 023-070, length 9.5 cm, set of 9, color code: gold
280033  **Rack**, for 36 straight shaft burrs with a length of 9.5 cm, foldable, sterilizable, size 22 x 14 x 2 cm
The concept of minimally invasive, tailored transnasal skull base surgery

INTRA Drill Handpieces
for surgery in the ethmoid area and the skull base

Special Features:
• Tool-free closing and opening of the drill possible
• Clockwise/counterclockwise rotation
• Max. rotating speed up to 40,000 or 80,000 rpm
• Detachable irrigation tubes
• Lightweight construction
• Low-vibration operation
• Low maintenance
• Can be reprocessed in a washer
• Safe grip

INTRA Drill Handpiece, angled,
length 18 cm, transmission 1:1 (40,000 rpm), for use with highperformance EC Micro Motor II and straight shaft burrs

Same, transmission 1:2 (80,000 rpm)

<table>
<thead>
<tr>
<th>Detail Size Diameter in mm</th>
<th>Standard</th>
<th>Diamond</th>
<th>Diamond coarse</th>
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<tr>
<td>070</td>
<td>7</td>
<td>649670 L</td>
<td>649770</td>
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649600 L  Standard Straight Shaft Burr, stainless, size 014-070, length 12.5 cm, set of 11
649700 L  Diamond Straight Shaft Burr, stainless, size 014-070, length 12.5 cm, set of 11
649700 GL Rapid Diamond Straight Shaft Burr, stainless, with coarse diamond coating for precise drilling and abrasion without hand pressure and generating minimal heat, sizes 023-070, length 12.5 cm, set of 9, color code: gold
280034 Rack, for 36 straight shaft burrs with a length of 12.5 cm, foldable, sterilizable, size 22 x 17 x 2 cm
UNIDRIVE® S III NEURO SCB
High-Speed Handpieces, angled, 60,000 rpm

For use with High-Speed drills, shaft diameter 2.35 mm,
with High-Speed Micro Motor 20 7120 33

252661  High-Speed Handpiece, short, angled, 60,000 rpm,
for use with High-Speed Micro Motor 20 7120 33

252662  High-Speed Handpiece, medium, angled, 60,000 rpm,
for use with High-Speed Micro Motor 20 7120 33

252663  High-Speed Handpiece, long, angled, 60,000 rpm,
for use with High-Speed Micro Motor 20 7120 33
The concept of minimally invasive, tailored transnasal skull base surgery

UNIDRIVE® S III NEURO SCB
High-Speed Handpieces, malleable, slim, angled, 60,000 rpm

For use with High-Speed drills, shaft diameter 1 mm,
with High-Speed Micro Motor 20 7120 33

The handpieces have malleable shafts that can be bent up to 20° according to user requirements.

High-Speed Handpiece,
extra long, malleable, slim, angled, 60,000 rpm,
for use with High-Speed Micro Motor 20 7120 33

High-Speed Handpiece,
super long, malleable, slim, angled, 60,000 rpm,
for use with High-Speed Micro Motor 20 7120 33
UNIDRIVE® S III NEURO SCB
High-Speed Standard Burrs, High-Speed Diamond Burrs

For use with High-Speed Handpieces, 60,000 rpm

<table>
<thead>
<tr>
<th>Diameter in mm</th>
<th>short</th>
<th>medium</th>
<th>long</th>
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<tr>
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<td>330110 M</td>
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<td>3</td>
<td>330130 S</td>
<td>330130 M</td>
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<td>330140 S</td>
<td>330140 M</td>
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<td>330150 M</td>
<td>330150 L</td>
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<td>330170 M</td>
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<table>
<thead>
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<th>Diameter in mm</th>
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<td>330240 S</td>
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</tr>
<tr>
<td>5</td>
<td>330250 S</td>
<td>330250 M</td>
<td>330250 L</td>
</tr>
<tr>
<td>6</td>
<td>330260 S</td>
<td>330260 M</td>
<td>330260 L</td>
</tr>
<tr>
<td>7</td>
<td>330270 S</td>
<td>330270 M</td>
<td>330270 L</td>
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</table>
The concept of minimally invasive, tailored transnasal skull base surgery

**UNIDRIVE® S III NEURO SCB**
High-Speed Diamond Burrs, High-Speed Barrel Burrs,
LINDEMANN High-Speed Fluted Burrs

For use with High-Speed Handpieces, 60,000 rpm

<table>
<thead>
<tr>
<th>Diameter in mm</th>
<th>short</th>
<th>medium</th>
<th>long</th>
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<tbody>
<tr>
<td>3</td>
<td>330330 S</td>
<td>330330 M</td>
<td>330330 L</td>
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<td>330340 M</td>
<td>330340 L</td>
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<tr>
<td>7</td>
<td>330370 S</td>
<td>330370 M</td>
<td>330370 L</td>
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UNIDRIVE® S III NEURO SCB
High-Speed Diamond Burrs

For use with High-Speed Handpieces, 60,000 rpm

<table>
<thead>
<tr>
<th>Diameter in mm</th>
<th>extra long</th>
<th>super long</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<td>320220 SL</td>
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<tr>
<td>3</td>
<td>320230 EL</td>
<td>320230 SL</td>
</tr>
<tr>
<td>4</td>
<td>320240 EL</td>
<td>320240 SL</td>
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</table>

<table>
<thead>
<tr>
<th>Diameter in mm</th>
<th>extra long</th>
<th>super long</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<td>320320 SL</td>
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<tr>
<td>4</td>
<td>320340 EL</td>
<td>320340 SL</td>
</tr>
</tbody>
</table>
The concept of minimally invasive, tailored transnasal skull base surgery

**DRILLCUT-X® II-35 Shaver Handpiece**

**Special Features:**
- Powerful motor
- Absolutely silent running
- Fast and precise work
- Enhanced ergonomics
- Reduced-weight design
- Rotation mode for sinus shavers, max. 35,000 rpm
- Straight suction channel and integrated irrigation
- Variable handle allows connection with various handpiece models and enables more comfortable work
- Easy hygienic processing, suitable for use in washer and autoclavable at 134 °C
- Quick coupling mechanism facilitates more rapid exchange of working inserts
- Proven DRILLCUT-X® blade portfolios can be used

![DRILLCUT-X® II-35 Shaver Handpiece](image)

**40712035**

**DRILLCUT-X® II-35 Shaver Handpiece,** for use with UNIDRIVE® S III ECO / ENT / NEURO / OMFS

![Handle](image)

**40712090**

**Handle,** adjustable, for use with all DRILLCUT-X® II shaver handpieces

**Optional Accessory**

![Cleaning Adaptor](image)

**41250 RA**

**Cleaning Adaptor,** LUER-Lock, for cleaning DRILLCUT-X® / DRILLCUT-X® II shaver handpieces
## Sinus Burrs, curved
for Nasal Sinuses and Skull Base Surgery

For use with DRILLCUT-X® II-35 and DRILLCUT-X® II-35 N

<table>
<thead>
<tr>
<th>Detail</th>
<th>Sinus Burrs 35k, with integrated irrigation, length 12 cm, sterile, for single use, package of 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="41335_W.png" alt="Image" /></td>
<td>41335 W, curved 40°, cylindrical, burr diameter 3 mm, shaft diameter 4 mm, color code: red</td>
</tr>
<tr>
<td><img src="41335_RN.png" alt="Image" /></td>
<td>41335 RN, curved 15°, bud drill, burr diameter 4 mm, shaft diameter 4 mm, color code: red</td>
</tr>
<tr>
<td><img src="41335_DW.png" alt="Image" /></td>
<td>41335 DW, curved 40°, diamond head, burr diameter 5 mm, shaft diameter 4 mm, color code: red</td>
</tr>
<tr>
<td><img src="41335_DT.png" alt="Image" /></td>
<td>41335 DT, curved 70°, diamond head, burr diameter 3.6 mm, shaft diameter 4 mm, color code: red</td>
</tr>
<tr>
<td><img src="41335_DS.png" alt="Image" /></td>
<td>41335 DS, curved 40°, diamond-shaped cutting, burr diameter 4 mm, shaft diameter 4 mm, color code: red</td>
</tr>
</tbody>
</table>
The concept of minimally invasive, tailored transnasal skull base surgery

**DRILLCUT-X® II and DRILLCUT-X® II N Shaver Handpieces**

- **40712050** DRILLCUT-X® II Shaver Handpiece, for use with UNIDRIVE® S III ECO / ENT / NEURO
- **40712055** DRILLCUT-X® II N Shaver Handpiece, with adaptation possibilities for Optical Shaver Tracker 40 8001 22, for use with NAV1® OPTICAL, NAV1® PICO and UNIDRIVE® S III ECO / ENT / NEURO
- **40712090** Handle, adjustable, for use with all DRILLCUT-X® II shaver handpieces

**Optional Accessory**

- **41250 RA** Cleaning Adaptor, LUER-Lock, for cleaning DRILLCUT-X® / DRILLCUT-X® II shaver handpieces
Shaver Blades, straight
for Nasal Sinuses and Skull Base Surgery

For use with DRILLCUT-X® II and DRILLCUT-X® II N

Shaver Blades, straight, sterile, for single use, package of 5

<table>
<thead>
<tr>
<th>Detail</th>
<th>for use with DRILLCUT-X® II Handpiece 40712050 DRILLCUT-X® II N Handpiece</th>
<th>Shaver Blade length 12 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>41301 KN</td>
<td>serrated cutting edge, diameter 4 mm, color code: blue-red</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>41301 KK</td>
<td>double serrated cutting edge, diameter 4 mm, color code: blue-yellow</td>
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<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>41301 GN</td>
<td>concave cutting edge, oval cutting window, diameter 4 mm, color code: blue-green</td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td>41301 LN</td>
<td>concave cutting edge, oblique cutting window, diameter 4 mm, color code: blue-black</td>
</tr>
<tr>
<td><img src="image5.png" alt="Image" /></td>
<td>41301 SN</td>
<td>straight cutting edge, diameter 4 mm, color code: blue-blue</td>
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<tr>
<td><img src="image6.png" alt="Image" /></td>
<td>41301 KSA</td>
<td>serrated cutting edge, diameter 3 mm, color code: blue-red</td>
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<tr>
<td><img src="image7.png" alt="Image" /></td>
<td>41301 KKSA</td>
<td>double serrated cutting edge, diameter 3 mm, color code: blue-yellow</td>
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<tr>
<td><img src="image8.png" alt="Image" /></td>
<td>41301 KKSB</td>
<td>double serrated cutting edge, diameter 2 mm, color code: blue-yellow</td>
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<tr>
<td><img src="image9.png" alt="Image" /></td>
<td>41301 LSA</td>
<td>concave cutting edge, oblique cutting window, diameter 3 mm, color code: blue-black</td>
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Shaver Blades, curved
for Nasal Sinuses and Skull Base Surgery

For use with DRILLCUT-X® II and DRILLCUT-X® II N

Shaver Blades, curved 35°/40°, sterile, for single use, package of 5

<table>
<thead>
<tr>
<th>Detail</th>
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<th>Shaver Blade length 12 cm</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>40 712050 DRILLCUT-X® II Handpiece</td>
<td>curved 35°, cutting edge serrated backwards, diameter 4 mm, color code: blue-red</td>
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<tr>
<td>41302 KN</td>
<td>40 712055 DRILLCUT-X® II N Handpiece</td>
<td>curved 35°, cutting edge serrated backwards, diameter 4 mm, color code: blue-red</td>
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<tr>
<td>41304 KKF</td>
<td></td>
<td>curved 40°, cutting edge serrated forwards, double serrated, diameter 4 mm, color code: blue-yellow</td>
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<tr>
<td>41304 KKB</td>
<td></td>
<td>curved 40°, cutting edge serrated backwards, double serrated, diameter 4 mm, color code: blue-yellow</td>
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<tr>
<td>41304 KKFA</td>
<td></td>
<td>curved 40°, cutting edge serrated forwards, double serrated, diameter 3 mm, color code: blue-yellow</td>
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<tr>
<td>41304 KKBA</td>
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<td>curved 40°, cutting edge serrated backwards, double serrated, diameter 3 mm, color code: blue-yellow</td>
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Shaver Blades, curved
for Nasal Sinuses and Skull Base Surgery

For use with DRILLCUT-X® II and DRILLCUT-X® II N

<table>
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<th>Detail</th>
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<tbody>
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<td></td>
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<td>40712055 DRILLCUT-X® II N Handpiece</td>
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<tr>
<td>41303 KNB</td>
<td></td>
<td>curved 65°, cutting edge serrated forwards, double serrated, diameter 4 mm, color code: blue-yellow</td>
</tr>
<tr>
<td>41303 KKF</td>
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<td>41303 KKB</td>
<td></td>
<td>curved 65°, cutting edge serrated forwards, double serrated, diameter 3 mm, color code: blue-yellow</td>
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<td>41303 KKFA</td>
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<td>curved 65°, cutting edge serrated backwards, double serrated, diameter 3 mm, color code: blue-yellow</td>
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<tr>
<td>41303 KKBA</td>
<td></td>
<td>curved 65°, cutting edge concave forwards, oval cutting window, diameter 4 mm, color code: blue-green</td>
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<tr>
<td>41303 GNF</td>
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<td>curved 65°, cutting edge concave backwards, oval cutting window, diameter 4 mm, color code: blue-green</td>
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<tr>
<td>41303 GNB</td>
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</table>
Shaver Blades, curved
for Nasal Sinuses and Skull Base Surgery

For use with DRILLCUT-X® II and DRILLCUT-X® II N

Sinus Burrs, curved 70°/55°/40°/15°, sterile, for single use, package of 5

<table>
<thead>
<tr>
<th>Detail</th>
<th>for use with</th>
<th>Shaver Blade length 12 cm</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>40712050 DRILLCUT-X® II Handpiece</td>
<td>curved 40°, cylindrical, drill diameter 3 mm, shaft diameter 4 mm, color code: red-blue</td>
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<tr>
<td></td>
<td>40712055 DRILLCUT-X® II N Handpiece</td>
<td>curved 55°, cylindrical, drill diameter 3.6 mm, shaft diameter 4 mm, color code: red-blue</td>
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<td>41304 W</td>
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<td>curved 15°, bud drill, drill diameter 3 mm, shaft diameter 4 mm, color code: red-black</td>
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<tr>
<td>41303 WN</td>
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<td>curved 15°, diamond head, drill diameter 3 mm, shaft diameter 4 mm, color code: red-yellow</td>
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<td>41305 RN</td>
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<td>curved 15°, diamond head, drill diameter 5 mm, shaft diameter 4 mm, color code: red-yellow</td>
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<td>41305 DN</td>
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<tr>
<td>41305 DW</td>
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</tr>
<tr>
<td>41303 DT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IMAGE1 S™ Camera System

**Economical and future-proof**
- Modular concept for flexible, rigid and 3D endoscopy as well as new technologies
- Forward and backward compatibility with video endoscopes and FULL HD camera heads
- Sustainable investment
- Compatible with all light sources

**Innovative Design**
- Dashboard: Complete overview with intuitive menu guidance
- Live menu: User-friendly and customizable
- Intelligent icons: Graphic representation changes when settings of connected devices or the entire system are adjusted
- Automatic light source control
- Side-by-side view: Parallel display of standard image and the Visualization mode
- Multiple source control: IMAGE1 S™ allows the simultaneous display, processing and documentation of image information from two connected image sources, e.g., for hybrid operations
The concept of minimally invasive, tailored transnasal skull base surgery

**IMAGE1 S™ Camera System**

**Brilliant Imaging**
- Clear and razor-sharp endoscopic images in FULL HD
- Natural color rendition
- Reflection is minimized

- Multiple IMAGE1 S™ technologies for homogeneous illumination, contrast enhancement and color shifting

* SPECTRA A and B: Not for sale in the U.S.
IMAGE1 S™ Camera System

TC 200EN*

IMAGE1 S CONNECT®, connect module, for use with up to 3 link modules, resolution 1920 x 1080 pixels, with integrated KARL STORZ-SCB and digital Image Processing Module, power supply 100-120 VAC/200-240 VAC, 50/60 Hz

including:

Mains Cord, length 300 cm
DVI-D Connecting Cable, length 300 cm
SCB Connecting Cable, length 100 cm
USB Flash Drive, 32 GB
USB silicone keyboard, with touchpad, US

*Available in the following languages: DE, ES, FR, IT, PT, RU

For use with IMAGE1 S™

IMAGE1 S CONNECT® Module TC 200EN

TC 300

IMAGE1 S™ H3-LINK, link module, for use with IMAGE1 FULL HD three-chip camera heads, power supply 100-120 VAC/200-240 VAC, 50/60 Hz,

for use with IMAGE1 S CONNECT® TC 200EN

including:

Mains Cord, length 300 cm
Link Cable, length 20 cm

TC 302

IMAGE1 S D3-LINK®, link module, for use with 3D TIPCAM®, power supply 100-120 VAC/200-240 VAC, 50/60 Hz,

for use with IMAGE1 S CONNECT® TC 200EN

including:

Mains Cord, length 300 cm
Link Cable, length 20 cm

* SPECTRA A und B: Not for sale in the U.S.
The concept of minimally invasive, tailored transnasal skull base surgery

IMAGE1 S™ Camera Heads

For use with IMAGE1 S™ Camera System
IMAGE1 S CONNECT® Module TC 200EN, IMAGE1 S™ H3-LINK Module TC 300
and with all IMAGE1 HUB™ HD Camera Control Units

<table>
<thead>
<tr>
<th>Specifications:</th>
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<tbody>
<tr>
<td><strong>IMAGE1 FULL HD Camera Heads</strong></td>
<td><strong>IMAGE1 S™ H3-Z</strong></td>
</tr>
<tr>
<td>Product no.</td>
<td>TH 100</td>
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<tr>
<td>Image sensor</td>
<td>3 x 1 / 3’’ CCD chip</td>
</tr>
<tr>
<td>Dimensions (w x h x d)</td>
<td>39 x 49 x 114 mm</td>
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<tr>
<td>Weight</td>
<td>270 g</td>
</tr>
<tr>
<td>Optical interface</td>
<td>integrated Parfocal Zoom Lens, f = 15-31 mm (2 x)</td>
</tr>
<tr>
<td>Min. sensitivity</td>
<td>F 1.4 / 1.17 Lux</td>
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<tr>
<td>Grip mechanism</td>
<td>standard eyepiece adaptor</td>
</tr>
<tr>
<td>Cable</td>
<td>non-detachable</td>
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<tr>
<td>Cable length</td>
<td>300 cm</td>
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</tbody>
</table>

**IMAGE1 S™ H3-Z Three-Chip FULL HD Camera Head,**
S-Technologies available, progressive scan, soakable, gas- and plasma-sterilizable, with integrated Parfocal Zoom Lens, focal length f = 15-31 mm (2x), 2 freely programmable camera head buttons, for use with IMAGE1 S™ and IMAGE1 HUB™ HD / IMAGE1 HD, S-Technologies only available for IMAGE1 S™

<table>
<thead>
<tr>
<th>Specifications:</th>
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<tr>
<td><strong>IMAGE1 FULL HD Camera Heads</strong></td>
<td><strong>IMAGE1 S™ H3-ZA</strong></td>
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<td>Image sensor</td>
<td>3 x 1 / 3’’ CCD-Chip</td>
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<td>Dimensions (w x h x d)</td>
<td>39 x 49 x 100 mm</td>
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<tr>
<td>Weight</td>
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<tr>
<td>Optical interface</td>
<td>integrated Parfocal Zoom Lens, f = 15-31 mm</td>
</tr>
<tr>
<td>Min. sensitivity</td>
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<td>standard eyepiece adaptor</td>
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<td>non-detachable</td>
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<tr>
<td>Cable length</td>
<td>300 cm</td>
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</tbody>
</table>
The name AIDA® stands for the comprehensive implementation of all documentation requirements arising in surgical procedures: A tailored solution that flexibly adapts to the needs of every specialty and thereby allows for the greatest degree of customization. This customization is achieved in accordance with existing clinical standards to guarantee a reliable and safe solution. Proven functionalities merge with the latest trends and developments in medicine to create a fully new documentation experience – AIDA®. AIDA® seamlessly integrates into existing infrastructures and exchanges data with other systems using common standard interfaces.

**WD 300-XX**  
**AIDA® Documentation system,**  
for recording of images and videos,  
two channel, 4K, Full HD, 2D / 3D

**WD 350-XX**  
**AIDA® with SMARTSCREEN® Documentation system,**  
for recording of images and videos,  
two channel, 4K, Full HD, 2D / 3D

*XX  Please indicate the relevant country code (DE, EN, ES, FR, IT, PT, RU) when placing your order.*
Workflow-oriented use

**Patient**
The procedure data input can be done manually or via a DICOM worklist.

**Checklist**
You have the option of digitizing a wide range of OR safety checklists.

**Record**
Still images and video sequences can be recorded in Full HD, 4K and 3D quality.

**Edit**
Simple adjustments to recorded still images and videos can be very rapidly completed with the Edit module.

**Complete**
A procedure can be completed with just one click. The Intelligent Export Manager (IEM) allows the automatic transmission of all data to configured storage locations in the background.

**Reference**
Allows you direct and easy access to previously recorded data at all times.
KARL STORZ NAV1® ELECTROMAGNETIC
KARL STORZ navigation system with advanced tracking technology

The new KARL STORZ navigation system NAV1® ELECTROMAGNETIC supports surgeons in otorhinolaryngology and skull base surgery. It uses a sophisticated electromagnetic tracking system. Experience the excellent quality and precision of the KARL STORZ navigation system NAV1® ELECTROMAGNETIC.

Benefits of KARL STORZ NAV1® ELECTROMAGNETIC

- High precision thanks to sensor location in instrument tip
- Navigated instruments can be autoclaved 30x
- Wide range of instruments; simultaneous tracking of up to 3 instruments possible
- Display of complete instrument geometry in the patient’s radiology data
- Planning and monitoring of high-risk structures with intraoperative distance control
- Better orientation through waypoint navigation
- Automatic and reliable documentation of the navigated procedure
- Infinitely adjustable CT-MRI fusion
- Import of patient data via USB, CD or PACS
The concept of minimally invasive, tailored transnasal skull base surgery

KARL STORZ NAV1® ELECTROMAGNETIC
Components of NAV1® ELECTROMAGNETIC

40 8200 01  NAV1® ELECTROMAGNETIC
including:
NAV1® Module
NAV1® ELECTROMAGNETIC Module
NAV1® ELECTROMAGNETIC Field Generator
Headband for Navigation, for single use*
EM Patient Tracker
EM Probe
Optical Mouse
Mains Cord, length 300 cm
Module Connecting Cable, length 250 cm
DVI Connecting Cable, length 300 cm

* A headrest with integrated EM field generator is included in the scope of delivery.
Instruments for use with NAV1® ELECTROMAGNETIC

**40820086**  
**EM Patient Tracker,**  
with verification adaptor and fixation screw, cable length 250 cm,  
dimensions (w x h x d): 55 x 30 x 8 mm,  
**autoclavable,** reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820105**  
**EM Probe,**  
with atraumatic tip, bayonet-shaped, for patient registration,  
tip diameter 1.9 mm, working length 10.5 cm, cable length 250 cm,  
**autoclavable,** reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820110**  
**EM Palpation Probe,**  
with atraumatic tip, malleable, straight, tip diameter 1.7 mm,  
working length 8.5 cm, cable length 250 cm,  
**autoclavable,** reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820111**  
**EM Frontal Sinus Probe,**  
with atraumatic tip, curved 77°, tip diameter 1.2 mm,  
working length 7 cm, cable length 250 cm,  
**autoclavable,** reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820112**  
**EM Palpation Probe,**  
with atraumatic tip, malleable, curved 63°, tip diameter 1.7 mm,  
working length 8.5 cm, cable length 250 cm,  
**autoclavable,** reusable 30 times, for use with NAV1® ELECTROMAGNETIC
The concept of minimally invasive, tailored transnasal skull base surgery

Instruments for use with NAV1® ELECTROMAGNETIC

**40820130**  **EM Frontal Sinus Curette**, curved 90°, oval, forward cutting, length 18 cm, cable length 250 cm, **autoclavable**, reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820131**  **EM Antrum Curette**, oblong, small, length 19 cm, cable length 250 cm, **autoclavable**, reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820145**  **EM Suction Tube**, straight, with cut-off hole, Luer, outer diameter 3.5 mm, working length 10 cm, cable length 250 cm, **autoclavable**, reusable 30 times, for use with NAV1® ELECTROMAGNETIC

**40820165**  **EM Suction Tube**, curved 60°, with cut-off hole, Luer, outer diameter 3.5 mm, working length 10 cm, cable length 250 cm, **autoclavable**, reusable 30 times, for use with NAV1® ELECTROMAGNETIC
**EM Shaver Tracker**

The **EM Shaver Tracker 408201.23** allows the electromagnetic navigation of motorized Shaver Blades (41201 KK, 41204 KKB) and Sinus Burrs (41305 D, 41305 DW and 41303 DT) as of software version 6.1.1.

**Benefits of EM-navigated shaver blades and sinus burrs**
- Customary handling of the shaver blades and sinus burrs by attaching the Shaver Tracker to the rotary wheel of the blade or burr
- Reusable tracker (up to 30 applications guaranteed)
- Automatic detection of rotation
- Visualized geometry and ablation radius of the shaver attachments

Shown above is the **EM Shaver Tracker 408201.23** with the DRILLCUT-X® II handpiece.

Shown above are the EM-navigated Shaver Blade 41204 KKB (left) and EM-navigated Sinus Burr 41305 DW (right).

**EM Shaver Tracker**, reusable
cable length 200 cm, autoclavable, reusable 30 times, for use with NAV1® ELECTROMAGNETIC, DRILLCUT-X® II, DRILLCUT-X® II N and DRILLCUT-X® II-35 N handpieces.
The concept of minimally invasive, tailored transnasal skull base surgery

NAV1® SINUSTRACKER™
The innovative planning software for new routes in FESS surgery

The NAV1® SINUSTRACKER™ planning software enhances the KARL STORZ NAV1® ELECTROMAGNETIC system with the automatic planning of access paths in paranasal sinus and skull base surgery. On the basis of a preoperatively set starting and destination point in the patient’s radiological data, the software allows the surgeon to determine a precise access path that is specially adapted to the individual anatomic structures of the patient. The physician then reviews and modifies the suggested access path at their discretion. Intraoperatively, the selected route is visualized on the navigation screen so that the actual position in the site is under constant control.

Benefits of the NAV1® SINUSTRACKER™

- Multiple path planning enables the preoperative planning and naming of up to 8 different access paths and alternatives
- Intraoperative visualization and control of access paths
- Less preoperative planning required thanks to automatic preplanning
- Flexible, pre- and intraoperative adaptation of the access path possible

40 810600  SINUSTRACKER™, additional software module for the NAV1® family, compatible with software version 6.0.0 or higher
Endoscopic rhino-neurosurgery

**NAV1® EM Endoscope Tracker**

Augmented FESS endoscopy with EM-navigated endoscope adaptor

Using augmented endoscopy, which was specially developed for the NAV1® SINUSTRACKER™, the real-time endoscopic image can be enhanced with information obtained from preoperative virtual planning of the access route. Adaptor 40 8201 50 is used in conjunction with KARL STORZ HOPKINS® telescopes with 0° (7230 AA), 30° (7230 BA) or 45° (7230 FA) directions of view for augmentation. Both the position and direction of view of the telescope are displayed in real-time on the radiologic sectional images allowing the actual in-situ location to be identified and tracked precisely throughout the procedure.

**Benefits of augmented endoscopy**
- Provides the option to superimpose planning elements onto the standard endoscopic image
- Visual navigation of non-navigated instruments along the preoperatively planned route
- Spatial mapping of both direction of view and the exact in-situ location of the telescope

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**40 8201 50**  
EM Endoscope Tracker, universal, cable length 250 cm, for use with NAV1® ELECTROMAGNETIC, HOPKINS® Telescope 0°, diameter 4 mm, 18 cm  
HOPKINS® Telescope 30°, diameter 4 mm, 18 cm  
HOPKINS® Telescope 45°, diameter 4 mm, 18 cm and NAV1® SINUSTRACKER™

The telescope shown above is not included in the scope of delivery.
The concept of minimally invasive, tailored transnasal skull base surgery

Notes:

Please note that the described products in this medium may not be available yet in all countries due to different regulatory requirements.
Notes:
with the compliments of
KARL STORZ — ENDOSKOPE