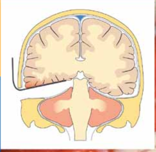
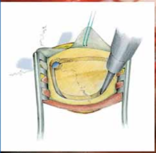
A. Perneczky · R. Reisch

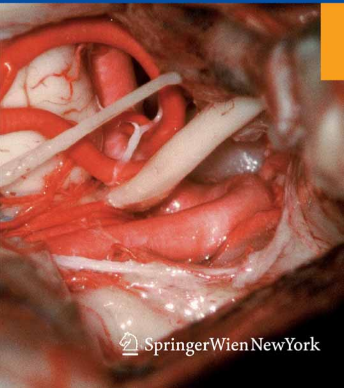
in collaboration with M. Tschabitscher
illustrated by S. Kindel

Keyhole Approaches in Neurosurgery

Volume 1: Concept and Surgical Technique







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With a foreword by
Tetsuo Kanno

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Foreword

Recent advances in neurosurgery have been characterized by a constant improvement in surgical precision. The detailed study of microanatomy yielded information essential for the development of precision techniques; however, it was the anatomy studied for centuries that has been re-visited many times with the aim of serving the innovative ideas of neurosurgeons. One of these innovative basic concepts is that of minimal invasiveness – a most important hallmark of contemporary neurosurgery. Minimal invasiveness conforms completely with the desire of both patients and surgeons to reduce surgically induced trauma to a minimum. A rapid return to normal life is the highest aim of every patient and his/her surgeon.

Professor Perneczky's work as a whole is the perfect illustration of this dedicated creative neurosurgical approach. Among his many achievements, the concept of "keyhole" surgery is of essential importance as a main tool of minimal invasiveness. Summarizing his vast experience makes this book valuable for every neurosurgeon and serves as an indicator of the direction of progress in neurosurgical techniques.

The authors have stimulated and contributed to the training of many neurosurgeons in minimal invasiveness. By demonstrating the benefits and training, Professor Perneczky is probably making the greatest contribution a surgeon can provide – distributing his knowledge and techniques to many surgeons around the world for the benefit of greater numbers of patients. I admire him for his dedication and his achievements.

Tetsuo Kanno

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Contents

Abbreviations

ACA (A1, A2, A3, A4)	anterior cerebral artery (segments)
AChA	anterior choroidal artery
ACoA	anterior communicating artery
ACP	anterior clinoid process
APcL	anterior petroclinoid ligament
BA	basilar artery
CN I	olfactory nerve
CN II	optic nerve
CN III	oculomotor nerve
CN IV	trochlear nerve
CN V	trigeminal nerve
CN V/1–3	branches of the trigeminal nerve
CN VI	abducent nerve
CN VII	facial nerve
CN VIII	vestibulocochlear nerve
CN IX	glossopharyngeal nerve
CN X	vagus nerve
CN XI	accessory nerve
CN XII	hypoglossal nerve
CS	cavernous sinus
CSF	cerebrospinal fluid
EAC	external auditory canal
GSPN	greater superficial petrosal nerve
IAC	internal auditory canal
ICA	internal carotid artery
ICP	intracranial pressure
INOP	intraoptic window
MCA (M1, M2, M3, M4)	middle cerebral artery (segments)
MMA	middle meningeal artery
OPCA	opto-carotid window
OphtA	ophthalmic artery
PCA (P1, P2)	posterior cerebellar artery (segments)
PCoA	posterior communicating artery
PCP	posterior clinoid process
PICA	posterior inferior cerebellar artery
PPcL	posterior petroclinoid ligament
PSC	posterior semicircular canal
SCA	superior cerebellar artery
SSC	superior semicircular canal
SSS	superior sagittal sinus
VA	vertebral artery

In his article entitled "Limited Exposure in Cerebral Surgery", published in 1971, Donald H. Wilson quoted the famous neurosurgeon William Halsted, who, in 1924, expressed his belief "*that the tendency will always be in the direction of exercising greater care and refinement in operating*" [Wilson 1971]. Today, on the threshold of the third millennium, this fundamental philosophy of minimally invasive therapy should be emphasized more than even before, operating with a minimum of iatrogenic trauma and achieving a maximum of efficiency.

In this first volume of our publication, we intend to demonstrate different keyhole approaches for the surgical treatment of intracranial and skull base lesions. Each chapter describes the historical development of the craniotomy, the anatomical construction of the target region and, most importantly, the surgical approach. Concentrating on surgical practice, patient positioning and orientation based on superficial anatomical landmarks, the stages of the craniotomy, intradural dissection, and wound closure are described in detail. Dealing with different approaches, a consequent way, patient's positioning and the extradural stages of the craniotomy are illustrated with artistic drawings and the intradural dissection with fresh human cadavers. Potential errors, their consequences and important tips and tricks are also given, providing instructions for everyday use.

In the second volume of the book, scheduled to appear in 2008, we will present demonstrative operative cases treated via keyhole approaches. Patient history, medical reports and neurological appearance will be described; special attention will be given to preoperative neuroradiological diagnostics, e.g., computed tomography (CT), magnetic resonance (MR) tomography including MR angiography and functional imaging, and, if performed, digital subtraction angiography (DSA). Three-dimensional preoperative approach planning will be discussed, in particular using stereoscopic evaluation of the radiological data in virtual reality. Of course, minimally invasive keyhole surgery with well documented intra- and postoperative course of each patient will be presented in detail.

1.0 Introduction

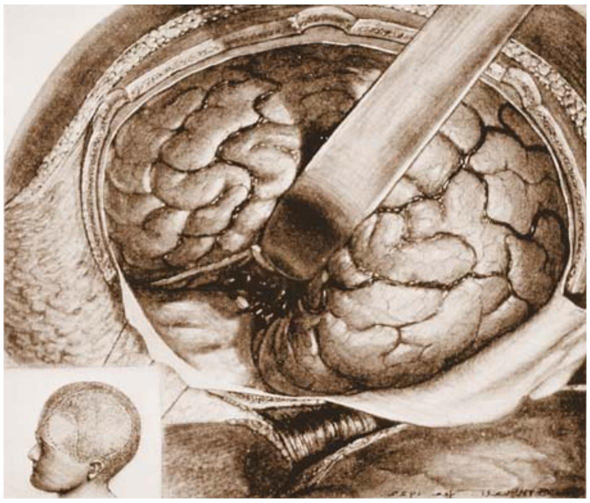


Fig. 1.0.1 *Dandy's frontotemporal craniotomy exposing sellar and parasellar lesions. Note the extensive exploration causing unavoidable injury to the cortical surface. In the 1920s and 1930s, craniotomies of this size were necessary to bring enough light into deep-seated areas for manipulation with macrosurgical instruments. Note that approaching a pituitary tumor, Dandy severed the left CN II to obtain optical monitoring of tumor removal.*

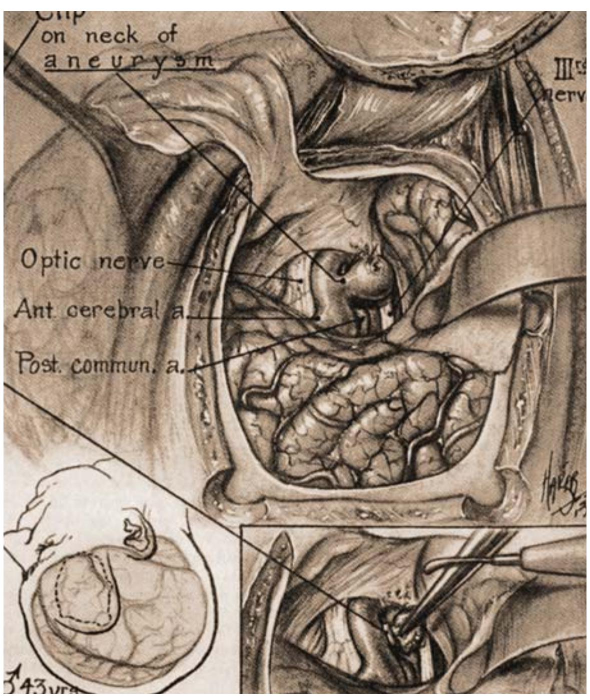


Fig. 1.0.2 *In 1938, Dandy described the so-called hypophyseal approach, exposing the suprasellar area. Note the significant limitation of skin incision and cranial opening, documenting Dandy's learning process in reducing surgical trauma. The illustration shows the first clipping of an intracranial aneurysm, causing oculomotor palsy due to local compression of the CN III.*

Evolution of neurosurgical techniques: from macrosurgery to the minimally invasive keyhole surgery

Approximately one hundred years ago, neurosurgical therapy of intracranial lesions was performed with extended craniotomies (Fig. 1.0.1). At that time, such large approaches were necessary for several reasons. First, on account of sparse and simple diagnostic techniques, the size and site of pathological lesions could not be accurately determined; therefore, the craniotomy had to be large enough to find the lesion within the intracranial space. Second, because of the undeveloped attitude toward health problems, intracranial lesions were only diagnosed when they had reached immense sizes; therefore, the craniotomy had to be large enough to remove these large, space-occupying tumors. Third, illumination in operating theaters was poor; therefore, the cranial opening had to be large enough to bring light into the surgical field. Fourth, instruments at that time were not designed for neurosurgery but for general surgery and they were too large to be used within narrow openings. In addition, neurosurgical teams consisted of at least three members, thus, six hands and their large instruments obscured the surgical field and the craniotomy had to be large enough to allow sufficient observation of the site.

With the evolution of preoperative diagnostic tools, intraoperative illumination devices and neurosurgical instruments, the discovery of fundamental anatomical and physiological principles have allowed a tremendous development in neurosurgical techniques making such interventions less dangerous and less traumatizing (Fig. 1.0.2).

The first important factor in the development of neurosurgical techniques was the evolution of preoperative diagnostic imaging. In 1918, radiographic techniques were introduced into neurosurgery by Walter E. Dandy [Dandy 1913]. With the help of air injection and fluoroscopy of the ventricle system during the so-called ventriculography, he was able to demonstrate the deformed and dilated ventricles and verify the diagnosis (Fig. 1.0.3). A further milestone was achieved when Edgar Moniz described the technique of cerebral angiography which he called "arterial encephalography" (Fig. 1.0.4). In 1927, after experiments on animal models and cadavers, he was able to show intracranial vessels of a 20-year-old patient [Moniz 1927].

In 1932, Norman M. Dott demonstrated the first picture of an intracranial aneurysm and Herbert Olivecrona published his experience on the angiographic appearance of parasagittal meningeomas [Dott 1932, Olivecrona 1943]. The method of direct arterial puncture was improved by Sven-Ivar Seldinger with a catheter replacement technique which was later refined by René Djindjian resulting in the technique of superselective angiography [Seldinger 1953, Djindjian 1975]. However, Dandy's ventriculography and Moniz' angiography allowed only an indirect observation of the brain with its ventricular chambers and vessels. The first direct visualization of brain tissue increased the further development of diagnostic facilities using "computerized axial tomography" (CT), described by Allen M. Cormack, Godfrey N. Hounsfield and James Ambrose in the early 1970s (Fig. 1.0.5). After much development, magnetic resonance imaging (MRI) enabled not only the precise diagnosis but also the accurate determination of topographic relations of specific lesions to individual anatomical structures [Hounsfield & Ambrose 1973, Lauterbur 1973, Damadian 1977, Goldsmith 1977].

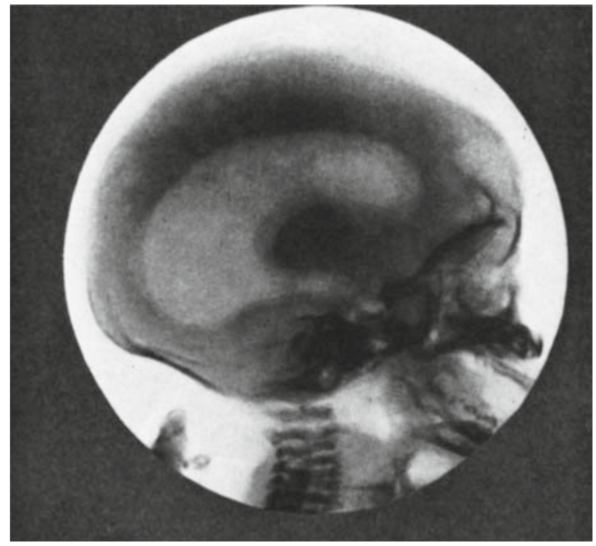


Fig. 1.0.3 *Ventriculogram of a child suffering from severe hydrocephalus. This photograph was published by Dandy in 1913 in his ground-breaking paper "Ventriculography following the injection of air into the cerebral ventricles".*

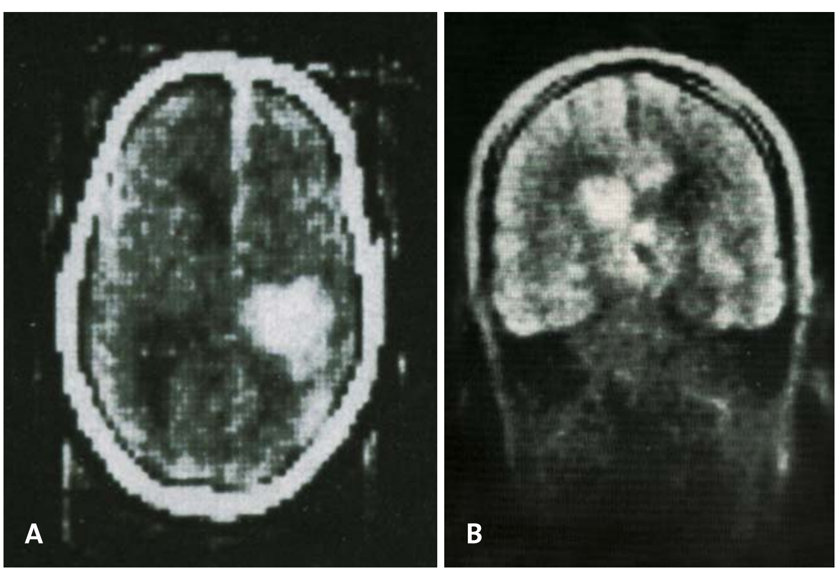


Fig. 1.0.5 *One of the first CT scans published by Hounsfield in his fundamental article "Computerized transverse axial scanning tomography" in 1973 (A). Note the displacement of the ventricles according to a space-occupying bleeding of the left basal ganglia. An early coronar MRI scan of a craniopharyngeoma from the Nottingham facility in 1980 (B).*

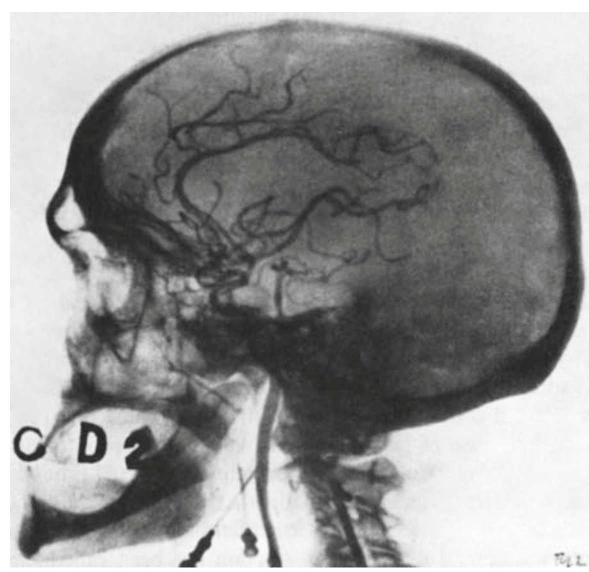


Fig. 1.0.4 *In 1927, Moniz published in his article "Arterial encephalography, its importance in the localization of cerebral tumors" the arterial network of the internal carotid artery in 20-year-old men. He injected a 30% solution of sodium iodide directly into the carotid, which was well tolerated by the patients.*

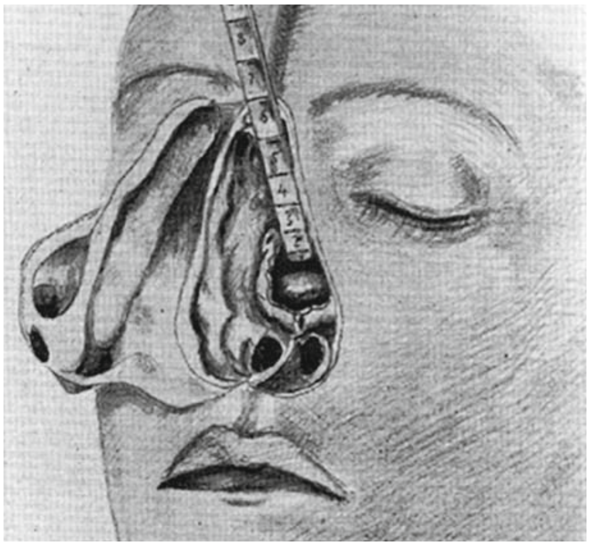


Fig. 1.0.6 *Schloffer carried out the first transsphenoidal pituitary operation on 16 March 1897. The patient was a 30-year-old man who suffered from hypopituitarism, visual disturbance and progressive signs of elevated intracranial pressure. Despite an invasive approach with removal of the septum, nasal turbinates, ethmoid cells, and the medial wall of the left orbit, the intraoperative orientation was complicated. Schloffer therefore measured the distance from the glabella to the anterior aspect of the sella on a preoperative radiograph and used the measurement to "sound out" the surgical cavity with a "dipstick".*

The second important factor in the evolution of neurosurgical techniques was the development of intraoperative illumination devices. Today it is almost impossible to imagine that Hermann Schloffer, director of the neurosurgical department in Innsbruck, Austria, performed his first transsphenoidal surgery in 1907 without any illumination or magnification tools (Fig. 1.0.6). Some years later, Harvey Cushing used a head-mounted lamp for his transsphenoidal macrosurgical approach (Fig. 1.0.7). At about this time, Paul C. Bucy wrote in his publication "Neurosurgery in darkness", describing a surgical procedure of Otfrid Foerster: *"The scene was a primitive one. The only source of illumination of the operating field was a student lamp with a brass reflector. It was held in my hand, which soon became unsteady much to Foerster's disgust"* (Fig. 1.0.8) [Schloffer 1907, Cushing 1914, Bucy 1930].

Fig. 1.0.7 *Cushing's sublabial transseptal approach for pituitary tumors. Note the head-mounted lamp allowing sufficient illumination of the deep-seated surgical field.*

Fig. 1.0.8 *Foerster's operating theater for transcranial surgery in the autumn of 1930. Paul C. Bucy is on the left side of the photograph in street clothes holding a student lamp.*

Of course, the real revolution in illumination of the surgical field was the use of operating microscopes which enabled inauguration of the microsurgical area in the 1960s and early 1970s.

While other surgical fields such as gynecology, urology, and, especially otology adopted the microscope for daily routine procedures very quickly, most neurosurgeons were reluctant to use it. However, Dwight Parkinson, one of the real pioneers of microneurosurgery pointed very clearly the advantages of this new device: *"Early in 1960 the neurosurgical section borrowed an operative microscope from the otolaryngology department. The microscope provided us with the enormous advantages of coaxial illumination, magnification, and simultaneous viewing for the surgeon and resident"* [Parkinson 1995]. The first neurosurgeon who used a surgical microscope was Theodore Kurze for treating an acoustic neurinoma on 1 August 1957. Kurze published his experiences in several publications amongst others in an article entitled "Microtechniques in neurological surgery" [Kurze 1957, 1964]. In 1968, Robert W. Rand and Peter J. Jannetta made an important contribution to the evolving field of neurosurgery with the article "Microneurosurgery: application of the binocular surgical microscope in brain tumors, intracranial aneurysms, spinal cord disease, and nerve reconstruction" [Rand & Jannetta 1968]. After experimental studies, M. Gazi Yasargil demonstrated the utility of the operating microscope for the treatment of brain tumors and vascular malformations (Fig. 1.0.9). Jannetta reported the advantage of the surgical microscope for microvascular decompression of cranial nerves [Yasargil 1966, 1969, 1970, Jannetta 1970].

The introduction of microscopic visualization of the surgical field was followed by the invention of adequate surgical instruments (Figs. 1.0.10, 1.0.11). The technique of bipolar coagulation was successfully adopted for microneurosurgery by James Greenwood and Leonard Malis, and fine microinstruments were developed for intracranial and spinal use [Kurze 1963, Malis 1967, 1979, Yasargil 1969].

Despite the above mentioned development of preoperative diagnostics, illumination devices and microneurosurgical techniques, intracranial neurosurgery was characterized in the 1970s and 1980s, and also in the 1990s by large, extended craniotomies.

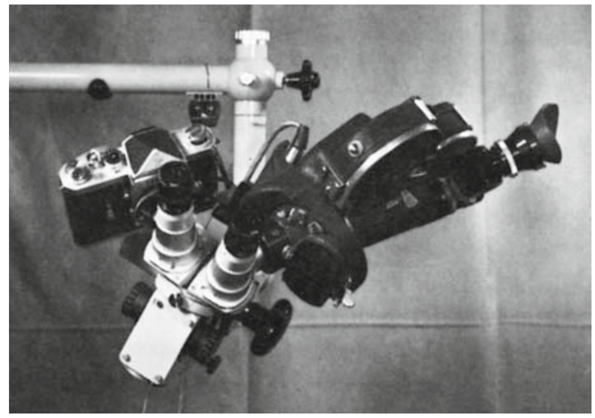


Fig. 1.0.9 *An early OPMI I Zeiss operating microscope with camera units in place used by Yasargil in the 1970s.*

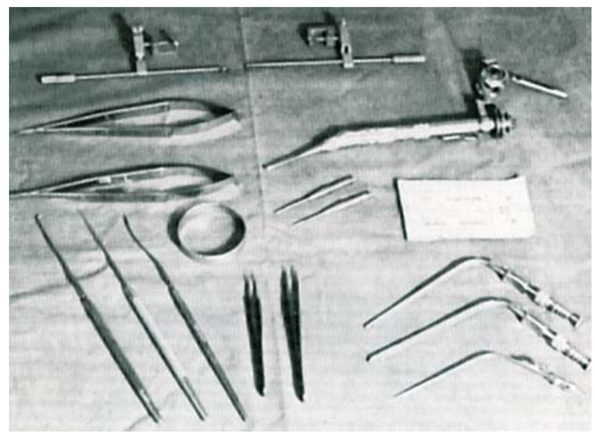


Fig. 1.0.10 *Kurze's microsurgical equipment published in his pioneering article "Microtechniques in neurological surgery" in 1964.*

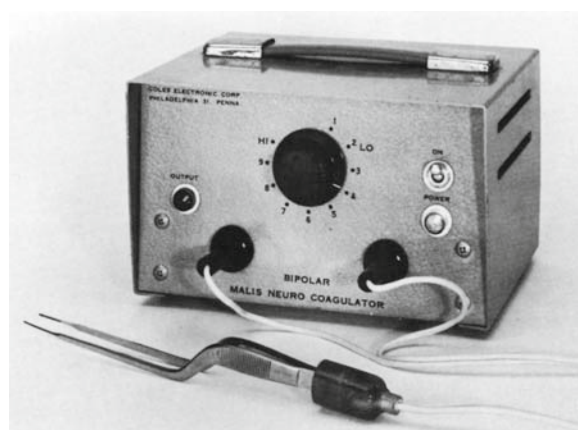


Fig. 1.0.11 *A Malis bipolar coagulator for neurosurgical use. Note the attached forceps allowing careful surgical dissection.*

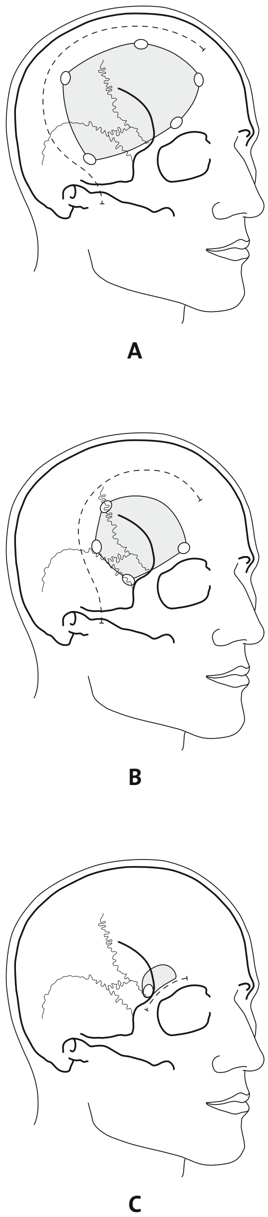


Fig. 1.0.12 *Schematic drawing demonstrating the stepwise development of the frontotemporal subfrontal approach. Note the reduction in size of the skin incision and craniotomy compared to Dandy's macrosurgical frontotemporal approach (A) and to Yasargil's pterional craniotomy using microsurgical techniques (B). The supraorbital keyhole craniotomy, representing the frontobasal part of Yasargil's pterional approach, allows a markedly reduced extension of the craniotomy with subsequently less surgical damage to the extra- and intracranial structures (C).*

However, since the very onset of neurosurgery there has been a widely accepted fact that exposure of brain tissue for several hours during surgery using these extended approaches always means injury to the brain surface by nonphysiological surroundings such as room air, irrigation, cover material, or spatula pressure. Note that these cortical microinjuries were possibly the reason for the previous necessity of routine postoperative anticonvulsive medication in all patients undergoing intracranial surgery. In order to gain an impression of dimensions of cortical exploration and surgical trauma, the area of brain surface exposed for a limited craniotomy of approximately 2 cm should be compared with the area exposed during a conventional craniotomy with a bone flap diameter of approximately 8 cm. Using the equation $r^2 \times \pi$ for the calculation of the area of a circle in which r is the radius of a circular bone flap, the following results could be obtained: area of brain surface exposed during conventional craniotomy with 8 cm diameter: $r^2 \times \pi = 4\ cm^2 \times \pi = 50.27\ cm^2$; area of surface approached during limited craniotomy with 2 cm diameter: $r^2 \times \pi = 1\ cm^2 \times \pi = 3.14\ cm^2$. We can see that in choosing a limited approach to specific lesions, it becomes possible to dramatically reduce injury to the cortical surface.

At the same time, limited craniotomy reduces the necessity of rough brain retraction. Since Eugene M. Landis in 1934 described the physiological range of capillary pressure, it has been shown in a number of experimental and clinical studies and has become a widely accepted fact that brain retraction exceeding certain limits causes significant intraoperative trauma to brain tissue and may cause permanent neurological deficits [Landis 1934, Albin 1975, 1977, Miller 1973, Yokoh 1983, 1987, Rosenorn 1985, Hongo 1987, Andrews 1993, Fries 1996, Yundt 1997]. In order to minimize brain retraction, various methods have been proposed, e.g., application of special anesthetic techniques to achieve brain relaxation, special brain retractor systems, and special patient positioning techniques. However, the best retraction is no retraction. Careful choice of an adequate, less invasive surgical approach with minimal brain exploration and retraction results in a significant reduction of damage to intracranial structures (Fig. 1.0.12).

In 1971, Donald H. Wilson mentioned that *"we make no fetish of keyhole surgery. A large arteriovenous malformation, hemispherectomy, and some epilepsy surgery would certainly require large standard craniotomies"*. He was one of the first neurosurgeons to use the term keyhole surgery describing the extension of limited trephinations [Wilson 1971].

However, it is important to note that with the expression "keyhole" not only the extension of the craniotomy should be described. The term keyhole should explain moreover a concept approaching pathological lesions in definite intracranial areas. The aim of keyhole neurosurgery is not the limited craniotomy, but the limited brain exploration and minimal brain retraction. In this way, the limited craniotomy is not the goal but the result of the philosophy of minimal invasiveness in neurosurgery. The craniotomy should be as limited as possible to offer minimal brain trauma, although as large as necessary to achieve a safe surgical dissection.

Here it is essential to notice that all large sized approaches in neurosurgery can be imagined as a side-by-side combination of several small approaches (Fig. 1.0.13). Therefore, in the planning and performance stages of any microsurgical approach, the surgeon's own critical reflection on the necessary and unavoidable manipulations and exposures during a given surgical access will be one of the most important steps in the development of his personal comprehension of the keyhole concept in microneurosurgery. The goal of keyhole surgery is to choose and perform the most ideal approach according to this critical reflection depending on the individual pathoanatomy of the patient as well as on individual personal experience, attitude, and capability.

In choosing the correct keyhole approach to a specific lesion, it becomes possible to dramatically reduce the size of the craniotomy with less need for dura opening and less brain exposure and retraction. These advantages of minimally invasive keyhole microsurgery may contribute to improved postoperative results including shorter hospitalization time because of reduction in the risk of complications such as bleeding or re-bleeding with neurological deterioration, leakage of CSF, infection, scarification, and cosmetic disturbances.

However, the use of limited approaches causes different shortcomings during the procedure such as the predefined surgical corridor, decreased intraoperative orientation, narrow viewing angles with an almost coaxial control of the microinstruments, and reduction of light intensity in the deep-seated operating field.

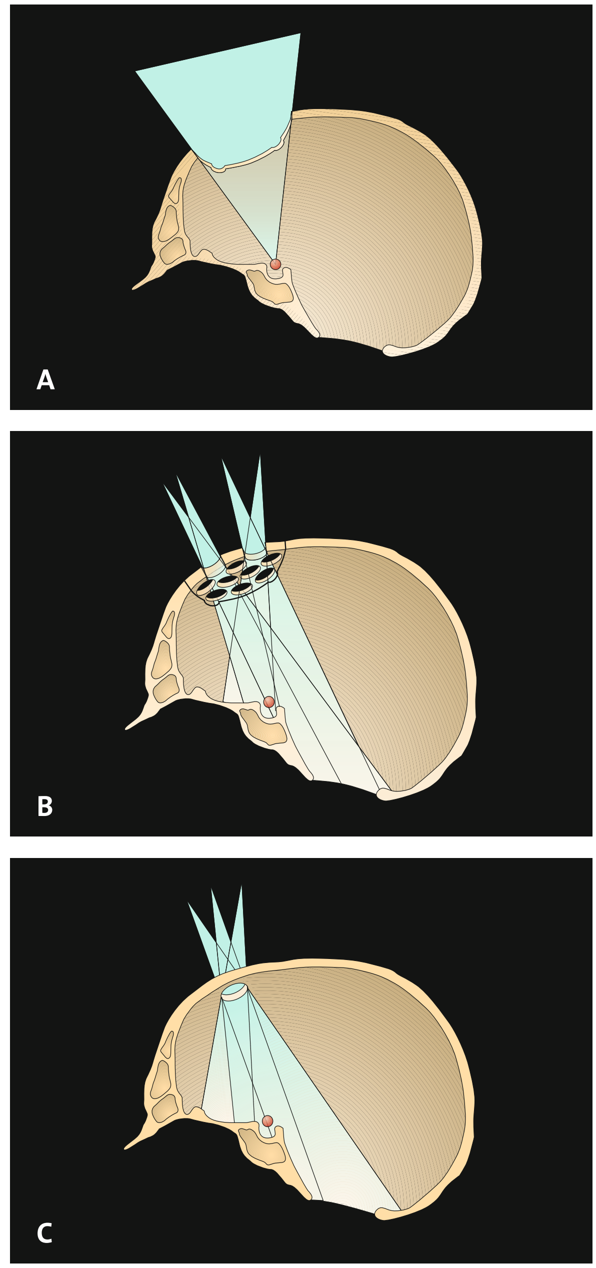


Fig. 1.0.13 *Schematic drawing of a large sized standard approach with funnel-like narrowing of the surgical field exposing deep-seated lesions (A). Extended craniotomies can be considered as a combination of several limited keyhole approaches (B). Entering the intracranial chamber through a correctly performed limited opening, the visual field shows a sector-like widening (C). A short distance allows a limited overview; in contrast, a long surgical corridor to a deep-seated surgical field often provides a better monitoring of the surgical dissection. In many cases, this consideration may result in the employment of contralateral approaches.*

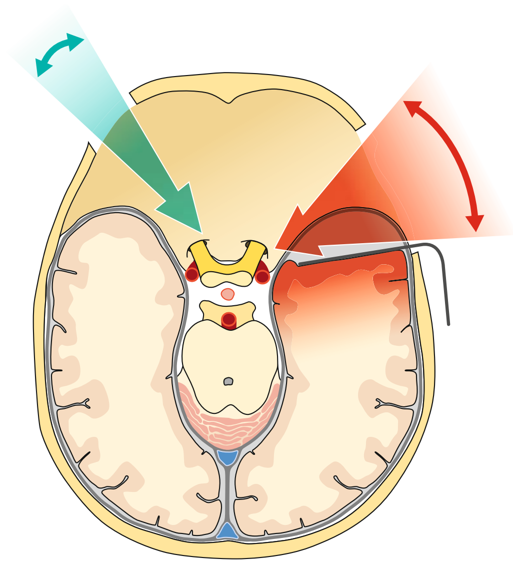


Fig. 1.0.14

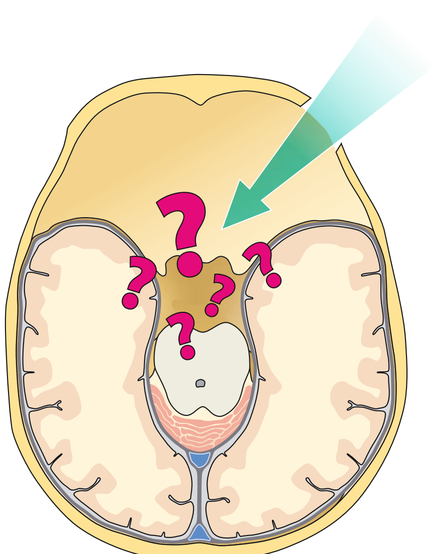


Fig. 1.0.15

Problem I Because of the predefined surgical pathway, the corridor of dissection cannot be changed during surgery; therefore, the craniotomy should be tailored exactly according to the pathoanatomical situation of the individual patient. In this way, the keyhole concept is based on a careful preoperative study of diagnostic images. Using modern tools, the exact anatomy and pathology of the patient can be precisely described. Anatomical pathways and corridors can be determined, providing optimal access to the pathological processes. According to the individual pathoanatomical situation and to the individual experience of the surgeon, a tailored, individual approach can be carried out. This individual least damaging and therefore minimally invasive approach to the target region helps to avoid retraction of sensitive structures and unnecessary exploration of the cortical surface.

The consequence of the concept of the individual surgical therapy is that after meticulous overview of the preoperative diagnostics and planning of the procedure, the surgeon should perform the surgical approach himself. Self-made surgery includes self-made positioning of the patient, self-made skin incision, self-made craniotomy and self-made surgical exposure of the target region. The individual, minimally invasive and maximally effective surgical approach to the intracranial lesion is the central question of keyhole neurosurgery; therefore exploring the pathology is the task of the operating neurosurgeon himself and not an assistant! This principle of the tailored minimally invasive keyhole neurosurgery is in direct contrast to a standard surgical therapy via extended standard surgical approaches.

In this way, preoperative planning and self-made performing of the tailored surgical approach is the most important part of keyhole neurosurgery (Fig. 1.0.14).

Problem II The second drawback of keyhole procedures is the decreased intraoperative orientation. In our experience, the individual preoperative planning according to the individual pathoanatomical situation and the individually performed exposure according to the surgeons experience offer safe dissection despite limited approaches. In addition, the use of navigation devices, ultrasound units, intraoperative CT and MRI may be helpful if the limited cranial opening has caused a confused and poorly overviewed situation (Fig. 1.0.15). Nevertheless, these technical tools can never replace the precise and particular anatomical knowledge of the target region!

Problem III The narrow viewing angle and almost coaxial control of dissection causes an additional problem. According to our experience, if the craniotomy is smaller than 15 mm, the intraoperative use of conventional microinstruments becomes very limited. For this reason, the development and intraoperative use of new tube-shaft microinstruments, e.g., scissors, grasping and coagulating forceps, clip applicators, is mandatory for performing keyhole surgery (Fig. 1.0.16).

Problem IV The eyes of the neurosurgeon must be able to see anatomical structures to save them and to recognize pathologies to attack them. The fourth main difficulty of keyhole approaches is the loss of intraoperative light and sight through the limited craniotomy, causing significantly reduced optical control during surgery. For the purpose of bringing light into the surgical field and controlling deep-seated microinstruments with an adequate magnification, surgical microscopes can be effectively supplemented by the optical properties of modern endoscopes (Fig. 1.0.17). The three advantages of endoscopes are as follows: 1) increased light intensity, 2) extended viewing angle, and 3) clear depiction of details in close-up positions. The first surgeons who realized the limitations of surgical microscopes were Werner Prott in 1974 when he performed diagnostic endoscopic cisternoscopy of the cerebellopontine angle, Michael L. J. Apuzzo in 1977 when he introduced the so-called side-viewing telescope, and Falk Oppel in 1981 when he applied intraoperative endoscopy during procedures of microvascular trigeminal decompression [Prott 1974, Apuzzo 1977, Oppel 1981]. All of these descriptions can be regarded as the initiation of endoscope-assisted microneurosurgery, which, along with other neuroendoscopic techniques, experienced a revival in the 1990s.

Modern three-chip microcameras with separate transmission of the red, green, and blue video signals provide excellent image quality. The endoscopic video signal is recorded and displayed on a video monitor which should be ideally placed in front of the surgeon. Recently, the evolution of camera technology has enabled replacement of the operating microscope. The so-called exoscope enables neurosurgeons to perform complicated cranial surgeries without using the microscope: the exoscope offers visualization of the surgical field “from outside”, the endoscope “from inside” (Figs. 1.0.19, 1.0.20). A futuristic opportunity is currently being developed with head-mounted LCD screens which allow the surgeon to take his eyes off the microscope oculars (Figs. 1.0.18, 1.0.19). Moreover, this

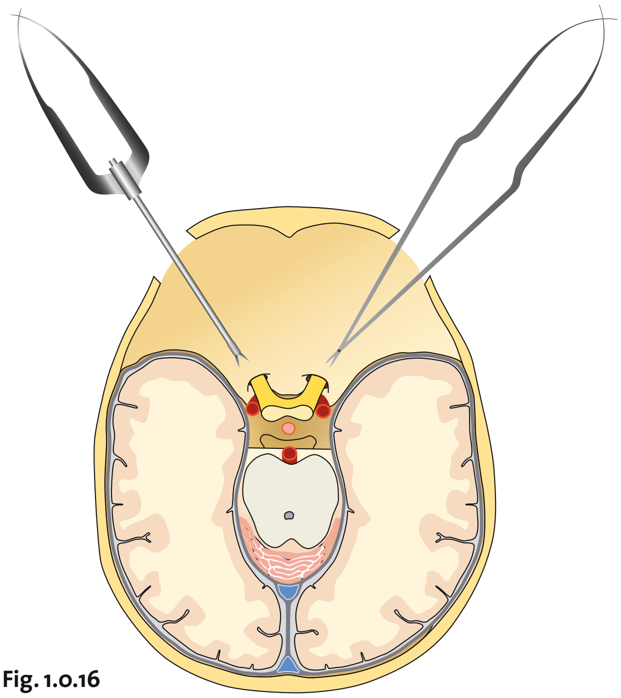


Fig. 1.0.16

narrow surgical corridor

↓

special instrumentation

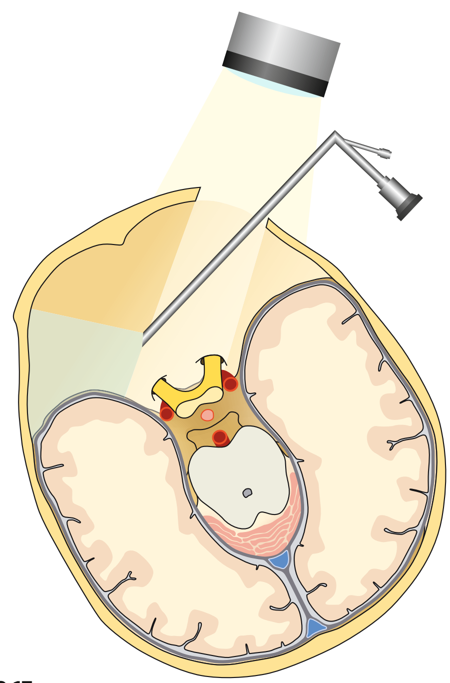


Fig. 1.0.17

limited visual control

↓

endoscope-assisted microneurosurgery

display system allows importing of different digital images such as diagnostic pictures and information of navigation devices, directly into the head-mounted LCD screens. The use of the picture-in-picture mode may result in an efficient visualization during the surgical procedure.

Fig. 1.0.18 *Photograph from the operating theatre showing the intraoperative use of an endoscope, designed for intraventricular procedures (Aesculap AG, Tuttlingen, Germany). Note the intraoperative application of a head-mounted LCD screen, manufactured by Vista Medical Technologies, Carlsbad, California, USA. The photograph clearly shows that the surgeon has a comfortable and ergonomic working position during the whole procedure.*

Fig. 1.0.19 *Photograph illustrating the intraoperative use of an exoscope (Olympus Company, Tokyo, Japan) and a head-mounted LCD screen during a keyhole procedure. The superior image quality of the exoscope enables to perform minimally invasive keyhole surgery without intraoperative use of a surgical microscope.*

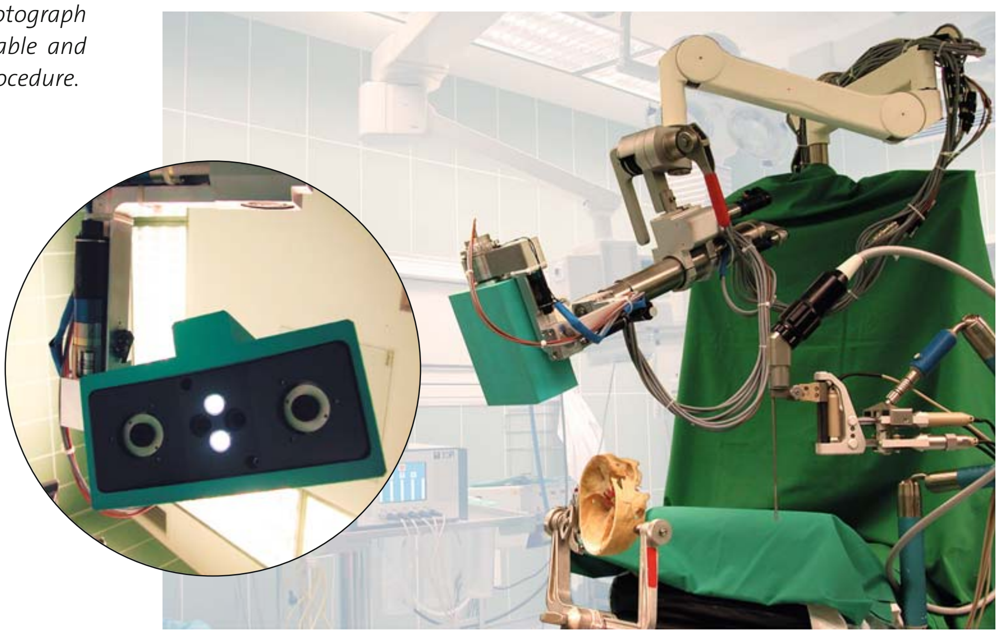


Fig. 1.0.20 *Prototype demonstrating a binocular exoscope which will be developed in the "MINOP II Study" in cooperation with Aesculap AG, Tuttlingen, Germany.*

General techniques for keyhole neurosurgery

Personnel, operating theater ergonomics, and instrumentation

Operating theater personnel

Operating theater personnel play a vital role when performing keyhole procedures. The proper education and training of surgical assistants, nurses and technical assistants are mandatory for safe intraoperative care.

The assistant should have training in neurosurgical anatomy and be familiar with general microsurgical techniques. Due to the limitation of approaches, an assistant's direct participation in performing surgical maneuvres becomes very restricted. However, in several situations the assistant can help in various ways, including suctioning, coagulating, cutting and gently retracting. The new generation of microscopes gives the assistant binocular vision which allows the associate to work and assist at ease. In our department, the assistant is in charge of bipolar coagulation according to the surgeon's advice. A device with voice control will be developed in the future.

The scrub nurse should understand the basic goal of the surgical event and be able to follow the procedure on the monitor. The nurse should be familiar with the neurosurgical equipment and deliver instruments to the surgeon's hands ready for use without requiring the surgeon to look away from the surgical field and the microscope.

The circulating nurse obtains necessary instruments and solutions and works closely with the scrub nurse. In addition, the circulating nurse should be able to set up microsurgical equipment, e.g., microscopes, endoscopes, navigation devices, bipolar units, C-arm fluoroscope tools. As a technical assistant, the circulating nurse should be trained and able to deal with any malfunctioning equipment.

Operating theater layout

Today's neurosurgical operating theaters must be large enough to accommodate the patient, the operating personnel and highly sophisticated neurosurgical equipment.

The basic organization of the operating theater in our department is shown in Fig. 1.0.20. The patient is brought on the operating table in

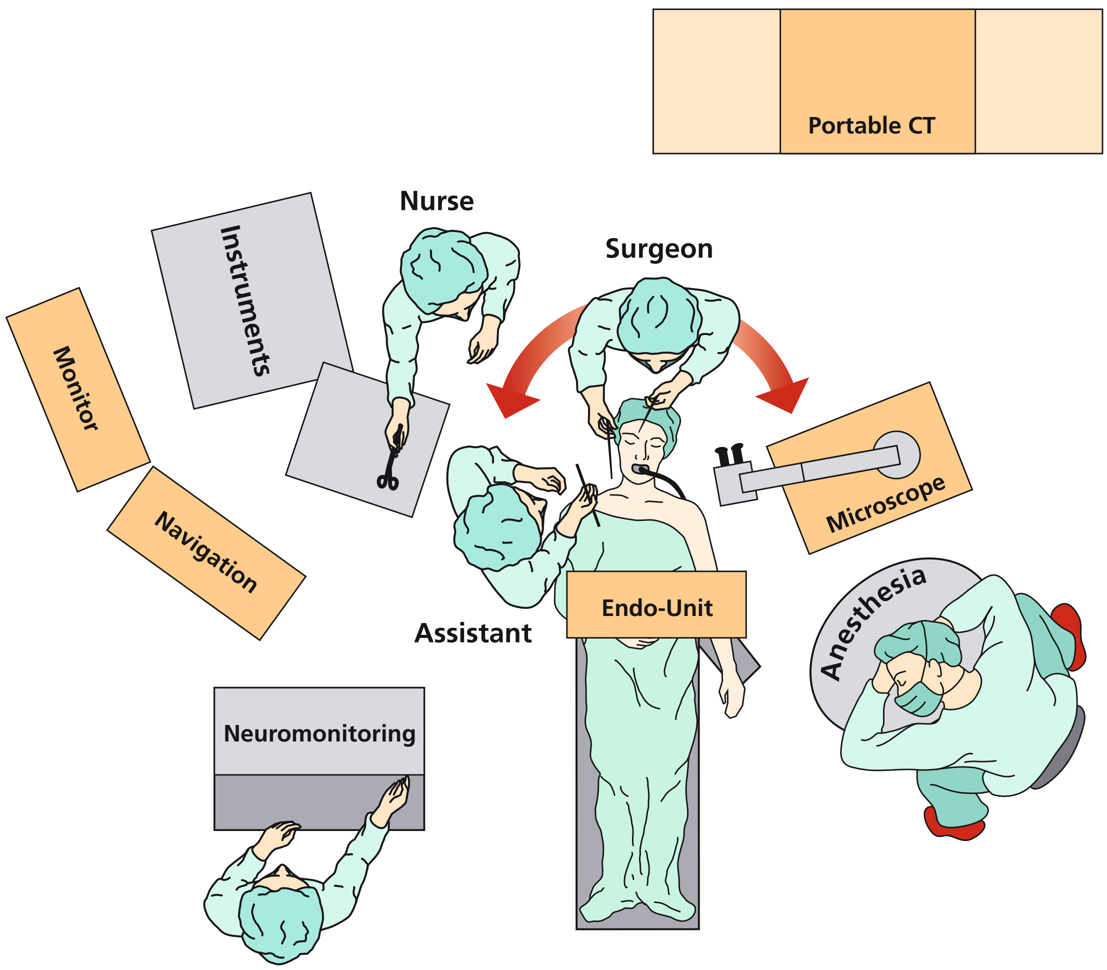


Fig. 1.0.21 *Schematic picture showing operating theater layout when performing keyhole surgery.*

the supine or prone position according to the surgical target region. The surgeon stands directly at the head with his assistant on the right side. The scrub nurse sits or stands between the surgeon and the assistant, allowing precise assistance. The anesthesiologist with his equipment is on the left side of the patient. This organization allows frequent changes in the surgeon's position when performing keyhole exposures.

The microscope is on the left side of the surgeon and the video monitor is in such a position that the nurse and the anesthesiologist can both follow the procedure. If used, the monitor for endoscopic visualization is placed directly in front of the surgeon. Frequently, additional equipment is also used during keyhole surgery. Intraoperative CT or MR scan, navigation devices and ultrasound units are used in several tumor cases and a C-arm fluoroscope in neurovascular surgery. However, the relation between the neurosurgeon's position and that of the patient is a sensitive one that is often impaired during surgery. The large number of highly sophisticated tools should not hamper efficiency in the operating theater.

Standing vs. sitting?

Basically, operating theater layout and patient positioning should offer a physiologically acceptable ergonomy for the surgeon, operating through a limited approach. However, surgical dissection through these limited keyhole craniotomies frequently requires changes in the surgeon's position when visualizing an extended intracranial area according to a sector-like widening of the surgical field (Fig. 1.0.22). In our experience, this "dancing around the table" is more relaxing for the surgeon while standing, even when performing long and time-consuming procedures. For this reason, we prefer to perform the entire surgical procedure in a standing position without the need for complicated, specially designed and therefore expensive operating chairs (Fig. 1.0.23).

Of course, the height of the operating table should be adjusted to avoid excessive bending of surgeon's body and neck; the optimal table height is usually at the level of surgeons elbow. However, it can be variable according to the focus distance of the microscope and to the specific case.

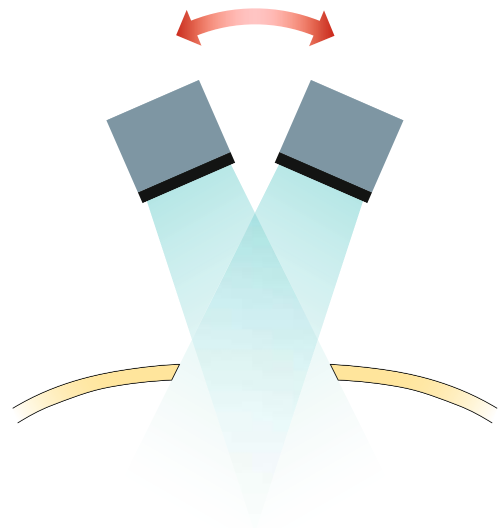
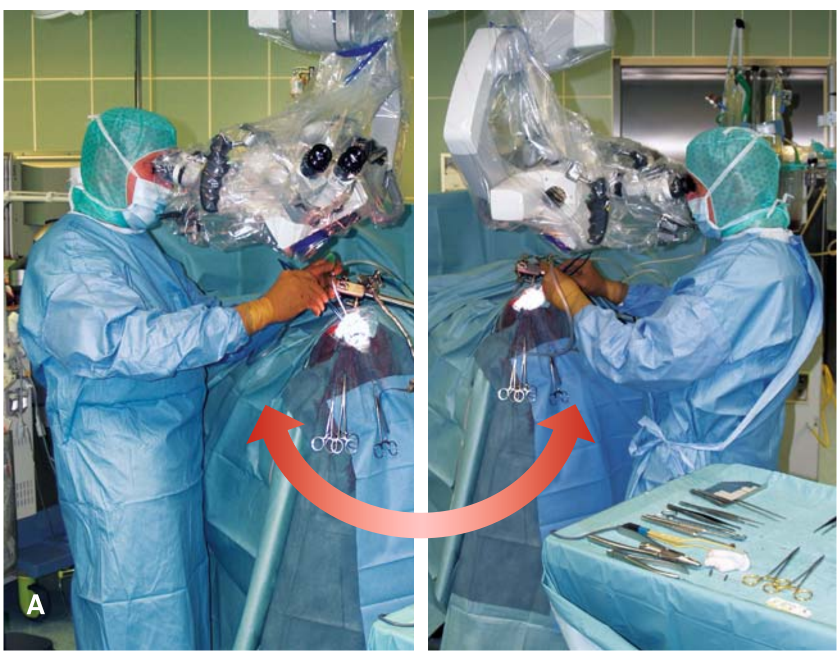


Fig. 1.0.22 *Frequent changes in the position of the operating microscope are necessary when visualizing extended deep-seated areas through a keyhole craniotomy. This offers a sector-like widening of the surgical field.*

A



B

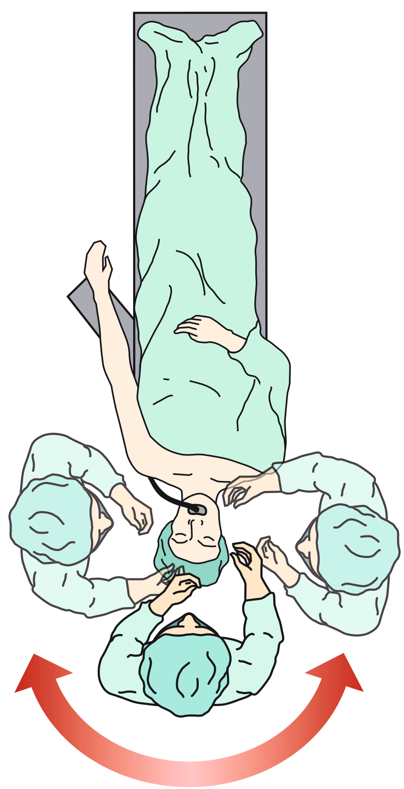


Fig. 1.0.23 *Frequent changes in position of the microscope mean that the surgeon also has to change position frequently as shown on the intraoperative photographs (A) and schematic drawing (B). However, in our experience, this "dancing around the table" while standing allows minimally invasive procedures to be performed in a more relaxed manner.*

Fig. 1.0.24 *Photographs from the operating theater illustrating the intraoperative use of a surgical microscope (A) and endoscope (B). Note the application of a Zeiss Pentero microscope (Carl Zeiss Surgical GmbH, Oberkochen, Germany) and highly sophisticated endoscopic equipment (Aesculap AG, Tuttlingen, Germany).*

The operating table

Present-generation operating tables allow adequate and safe positioning of the patient offering optimal surgical access of the target region without positioning-related risks. In addition, modern electric operating tables allow a great amount of variation in patient position during the procedure. Operating through limited approaches with frequent changes in the direction of surgical dissection, this possibility of intraoperative remodelling is especially significant.

The operating microscope, intraoperative use of endoscopes

The intraoperative use of microscopes is mandatory in keyhole neurosurgery. In our department, we prefer the Zeiss NC 4 and Zeiss Pentero microscopes (Carl Zeiss Surgical GmbH, Oberkochen, Germany), which allow perfect optical visualization with a high-quality digital photo and video documentation.

The operating microscope offers adequate magnification of the operative field in a stereoscopic manner and allows illumination of the surgical field. However, as above mentioned, the loss of light intensity in the deep-seated surgical field is a fundamental problem. For the purpose of bringing light into the site, operating microscopes can effectively be supplemented with the intraoperative use of modern endoscopes (Fig. 1.0.24).

The advantages of the endoscopic image are the increased light concentration, extended viewing angle and clear representation of anatomical details in a close-up position (Fig. 1.0.25).

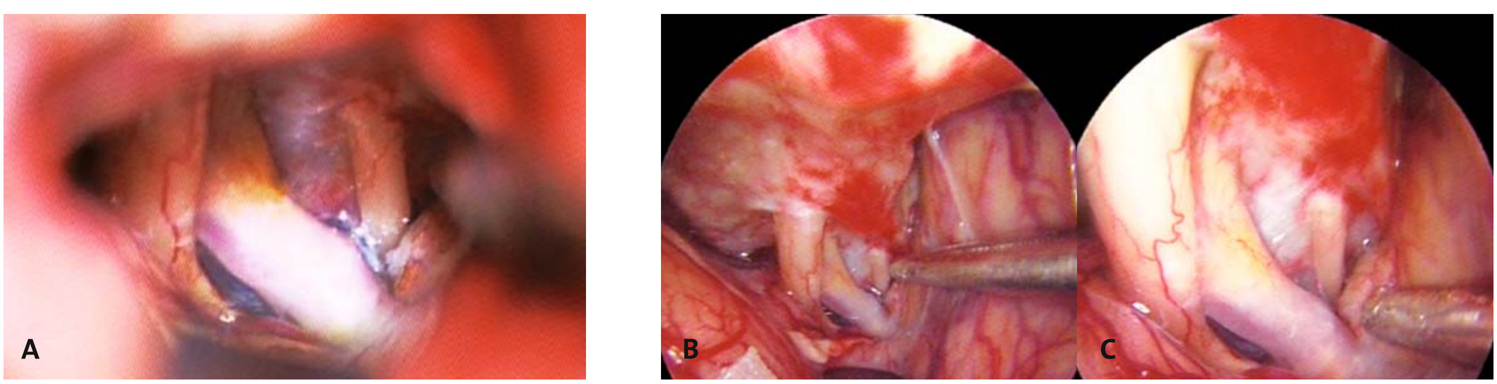


Fig. 1.0.25 *Intraoperative photographs showing exposure of the suprasellar area with the CN II, ICA and CN III through a right-sided supraorbital approach. Note the increased light intensity and extended viewing angle using a rigid endoscope (B) compared with the visualization of the surgical microscope (A). In close-up position, the endoscope gives a clear view of the anatomical details (C).*

The endoscope is especially ideal for obtaining a detailed view of structures in the shadow of the microscope beam. Thus, in situations during microsurgical dissection when additional visual information of the target area is desired or when avoidance of retraction of superficial structures is recommended, an endoscope is introduced into the surgical site. Both devices, microscope and endoscope, supplement each other due to their different optical properties.

Rigid lens scopes are recommended for *Endoscope-Assisted Microsurgery* (EAM) because only the position of instruments with rigid shafts can be controlled precisely and because, at present, only lens scopes offer acceptable image quality. Endoscopes with angled shafts are preferred for endoscope-assisted neurosurgery as the camera attached to the eyepiece does not interfere with the visual field of the microscope and does not disturb surgical manipulation (Figs. 1.0.26–30). Different degrees of inclination of the front lens offer different viewing angles of 0°, 30°, 45° and 70°. In addition, modern digital video technology is necessary to achieve full use of endoscope-assisted microsurgery.

Here it is important to notice that there are two different ways of performing endoscope-assisted techniques in keyhole neurosurgery. *Endoscope-Controlled Microneurosurgery* (ECM) offers endoscopic visualization of the surgical field according to a free-hand technique. In the case of limited visualization through the surgical microscope, the surgeon introduces the endoscope into the surgical site. For immediate optical control of the pathoanatomical situation, e.g., for allowing precise tumor removal or clip application, the endoscope is usually used only for a few minutes. The endoscope is grasped in one hand; in the other hand is a sucker for continuous cleaning of the scope (Fig. 1.0.26 A). Using pure *Endoscopic Microneurosurgey* (EM), the endoscope is fixed with a special holding device, offering bi-manual dissection under an endoscopic image. In this way, the "two-handed" surgeon is able to dissect without limitation in surgical manipulation. Without a microscope, the fixed endoscope is permanently used for a longer time during keyhole surgery (Fig. 1.0.26 B).

The use of endoscope-assisted technology in the course of microsurgical procedures with significantly improved visual control may contribute to the criteria of the keyhole concept with minimum iatrogenic trauma and maximum efficiency.

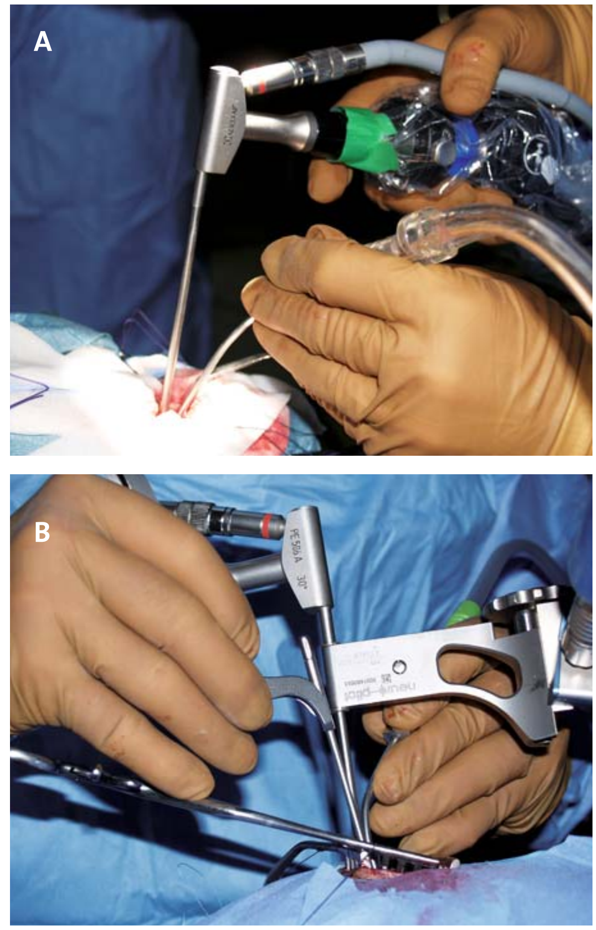


Fig. 1.0.26 *Intraoperative performance of endoscope-assisted microsurgery (EAM). Note the "one-handed" surgeon using an endoscope-controlled microneurosurgical technique (ECM). The endoscope is grasped in one hand, with the other hand a sucker is introduced for continuous cleaning of the tip of the endoscope (A). Using pure endoscopic microneurosurgery (EM), the endoscope is fixed in a special holding arm, allowing bi-manual dissection. The "two-handed" surgeon is able to work without limitation in surgical manipulation (B).*

Fig. 1.0.27 *Pure endoscopic microsurgical dissection using a holding arm, holding device and angled endoscope. The surgeon concentrates on the video-monitor; the highly sophisticated system allows free bi-manual surgical dissection without using a surgical microscope.*

Fig. 1.0.28 *Holding arm used for stable intraoperative fixation of the endoscope (UNITRAC arm, Aesculap AG, Tuttlingen, Germany).*

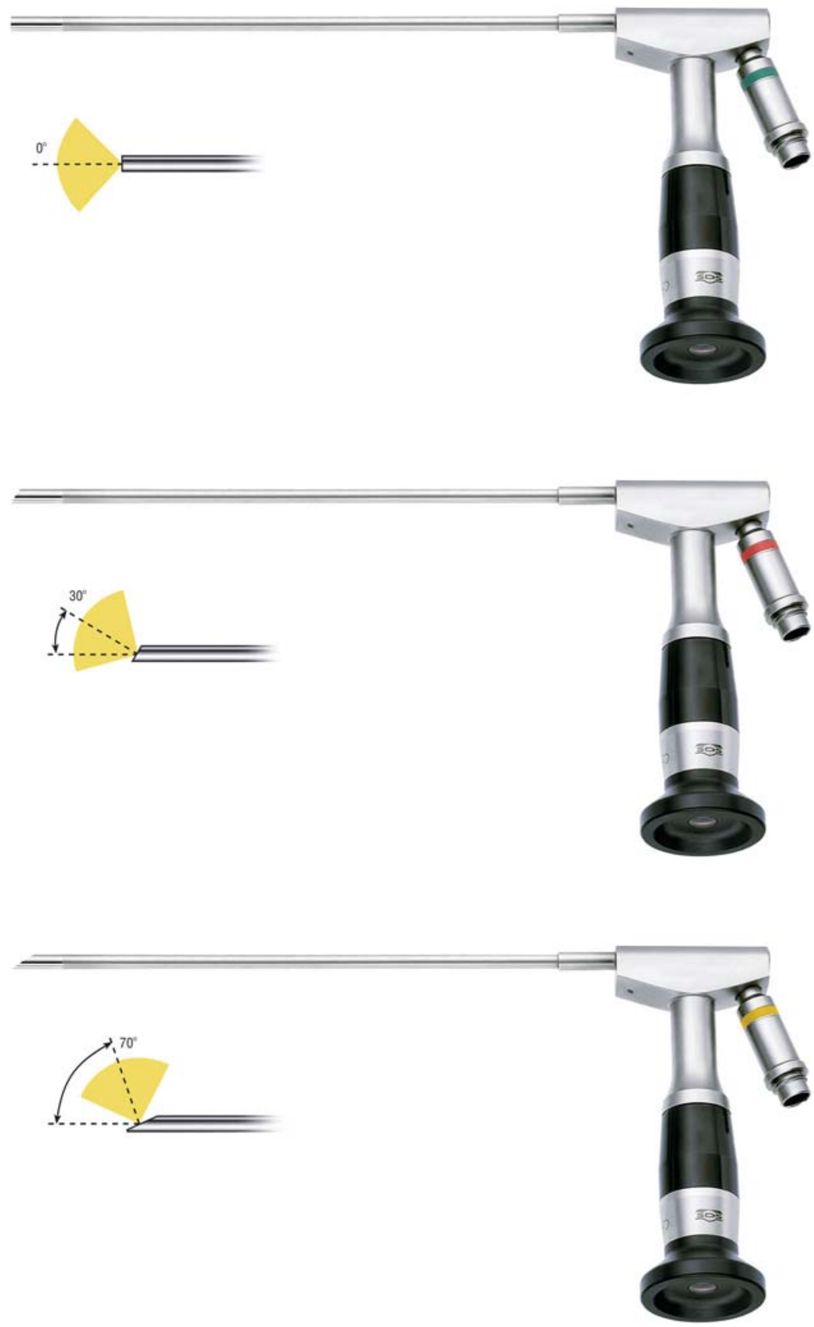


Fig. 1.0.29 *Rigid lens endosopes with 0°, 30° and 70° viewing angles, especially considered for endoscope-assisted microneurosurgery (Aesculap AG, Tuttlingen, Germany). Note the angled shaft of the tools, allowing free surgical manipulation around and along the endoscope.*

Fig. 1.0.30 *Specially designed endoscope holding device (Neuro-Pilot, Aesculap AG, Tuttlingen, Germany). The system offers adequate fixation, and the position of the endoscope can be mechanically remodelled with precise driving wheels (note blue, red and yellow arrows).*

Microsurgical instruments

The use of microneurosurgical instruments is obligatory in treating intracranial lesions. Highly sophisticated instrumentation including self-retaining retractors, microdrills, Kerrison micropunches, suction tubes, fine bipolar forceps, microscissors, diamond knives, diamond hooks, microforceps, microdissectors, microcurettes, and clip appliers allows adequate microsurgical dissection under microscopic or endoscopic control.

Nevertheless, when approaching deep-seated areas through a limited craniotomy with a diameter of ca. 15 to 20 mm, the intraoperative use of conventional microinstruments may be a problem because of the narrow surgical corridor. For example, a bipolar forceps or a microscissor will be closed at its tip when the target is reached because it has already been pushed together by the edges of the small craniotomy opening. For this reason as previously described, the invention and intraoperative use of recently developed microinstuments is mandatory for keyhole surgery.

Keyhole microinstruments are specially designed with a tube shaft allowing unhindered introduction of the tool through the limited craniotomy (Fig. 1.0.31). Tube-shaft instruments can be used in a much reduced operating corridor offering safe manipulation within the narrow surgical corridor and obvious visualization of the surgical field. By noticing that usually only the last 2–3 millimeters of a scissor blade are actually used, their blade size was hence reduced producing improved vision, range of motion and access. In several cases, the application of tube-shaft microinstruments is obligatory when operating through keyhole approaches (Figs. 1.0.32, 1.0.33).

Keyhole instruments should be carefully cleaned at the end of the operation, protecting sharp tips, and kept in special trays that separate the different types of instruments. Careful handling by the operating theater staff can eliminate the wear and tear of sensitive microdevices.

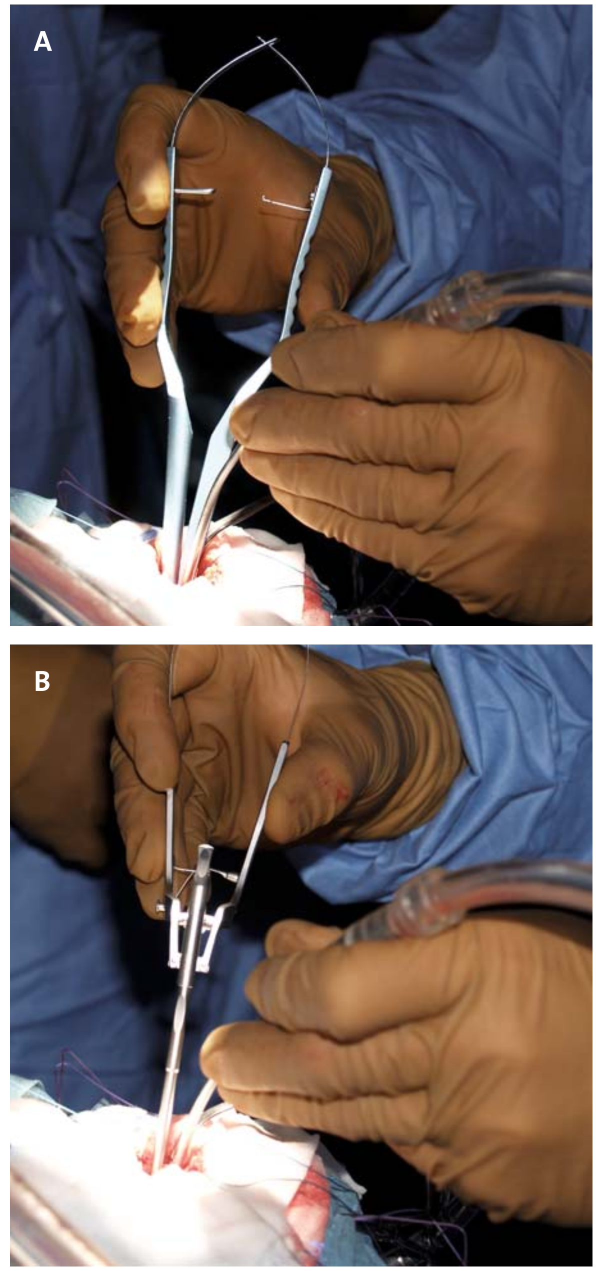


Fig. 1.0.31 *Intraoperative use of a conventional bayonet-shaped clip applier (A) compared with a tube-shaft device (B). Note that the conventional microinstruments require significantly more space within the narrow surgical corridor. Tube-shaft keyhole instruments are designed especially for unhindered introduction of the tool through the limited craniotomy.*

Fig. 1.0.32 *Photograph showing a conventional bayonet-shaped clip applier (A) and a tube-shaft instrument (B) especially considered for minimally invasive keyhole neurosurgery. Using limited craniotomies with a diameter of ca. 15–20 mm, tube-shaft instruments allow unhindered visualization of the deep-seated site and safe manipulation within the narrow surgical corridor.*

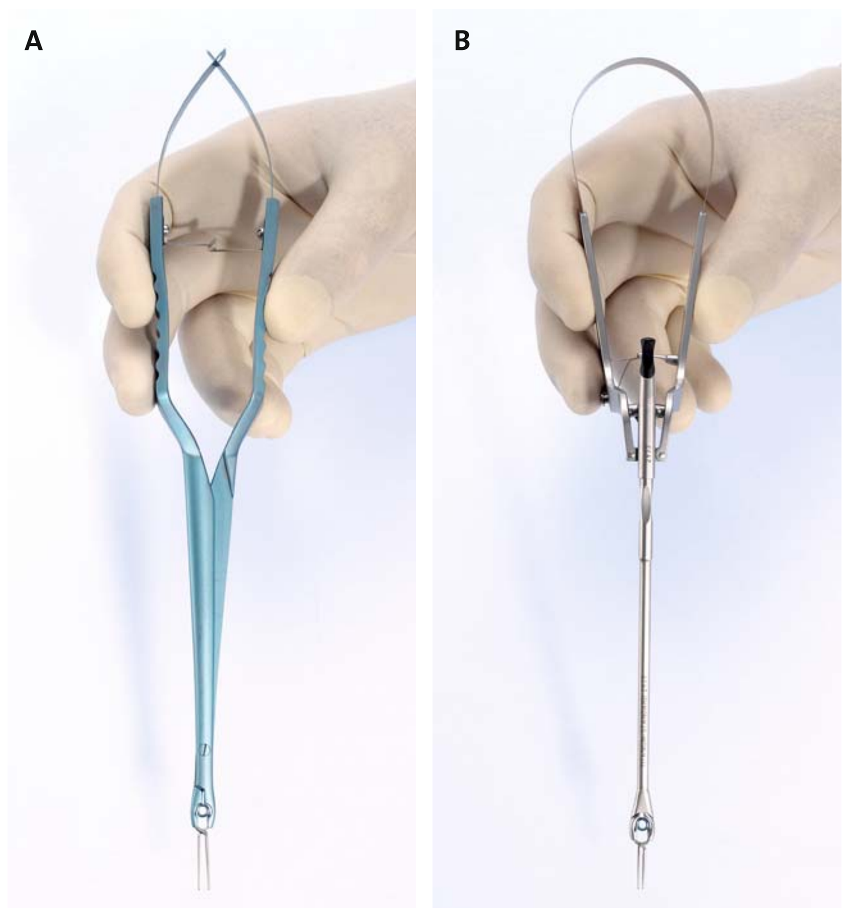


Fig. 1.0.33 *Comparison of a conventional (A) and a tube-shaft (B) clip applier showing impressively the difference in instrument design. When operating through keyhole craniotomies, the use of tube-shaft instruments is often obligatory for safe intraoperative dissection.*

Performance and technique of keyhole neurosurgery

Preoperative planning

The goal of preoperative planning is to choose the correct and accurate way, operating with a minimum of iatrogenic trauma and achieving a maximum of surgical efficiency without missing the target or causing injury to sensitive intracranial structures.

The planning and execution of the approach play a critical role in performing minimally invasive keyhole approaches. The smaller the craniotomy the greater the need for precise planning and self-made completion of the approach because the corridor of surgical dissection cannot be changed during the procedure.

The preoperative planning is based on the precise and particular anatomical knowledge of the target region and on a careful preoperative study of diagnostic images. Not only the diagnosis gains a principal interest, the task of modern neuroradiology should not end with the definition of the suspected pathology. The goal is to describe additional information concerning anatomical details, not only of the lesion itself but of its vicinity and of neighboring bony, dural, nervous and vascular structures. Using the excellent diagnostic facilities of CT, MRI and digital subtraction angiography (DSA), one has today the possibility to demonstrate the special anatomical situation of the patient including small details and elucidate preoperatively the precise individual anatomy and pathology. It is especially important to determine anatomical windows of the subarachnoidal spaces that provide access to the pathological processes. These anatomical paths for surgical dissection should be described preoperatively and be included in the planning of the surgical procedure. According to these windows and surgical paths, the least traumatizing approach to the target region should be defined, which helps to avoid retraction and unnecessary surface exploration.

Computers have been used increasingly to help surgeons to analyze preoperative imaging data. Various computer programs have been developed to generate three-dimensional representations of tomographic imaging data in order to plan neurosurgical approaches and most nowadays available image guidance systems offer surgical planning tools. Conceptually, the planning of a surgical procedure with three-dimensional computer-generated

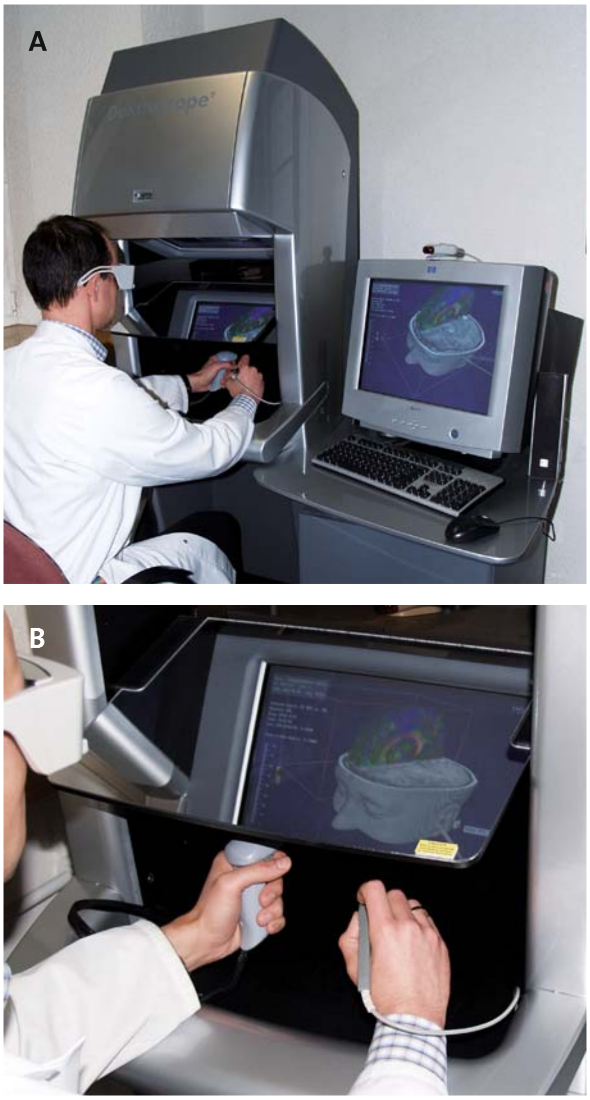


Fig. 1.0.34 *Computer analysis of the preoperative imaging data with three-dimensional representation of the pathoanatomical situation offers a useful tool for planning of the surgical approach. Photograph shows the application of the Dextroscope (Volume Interactions Pte. Ltd., Singapore), for which liquid display shutter glasses are worn (A). The user works with both hands inside the stereoscopic virtual workspace; one hand holds an ergonomically designed handle to move the three-dimensional data, the other hand holds a pen-shaped instrument which can be used to perform detailed data manipulations (B).*

data should reflect the three-dimensionality of the real procedure. In our department, we use the Dextroscope system (Volume Interactions Pte. Ltd., Singapore), which allows a stereoscopic display of the preoperative data and virtual manipulation with three-dimensional tools instead of mouse and keyboard (Fig. 1.0.34).

In the Dextroscope, the user works with both hands inside a stereoscopic virtual workspace. This is achieved by reflecting a computer-generated 3-D scenario via a mirror into the user's eyes. Wearing liquid display shutter glasses synchronized with the time split display, the user reaches with both hands behind the mirror into the "floating" 3-D data. Electromagnetic sensors in both hands convey the interaction and allow manipulation of the 3-D data in real time. One hand holds an ergonomically shaped handle to move the 3-D data freely as if it were an object held in real space. The other hand holds a pen-shaped instrument which appears inside the virtual reality workspace as a computer-generated instrument and which can be used to perform detailed data manipulations (Fig. 1.0.34B).

With the three-dimensional individual anatomical details of a specific patient, it is possible to perform a specific and tailored surgical procedure reducing the surgical traumatization to a necessary minimum limit.

In this way, preoperative planning is the most important part of the minimally invasive and maximally effective keyhole neurosurgery.

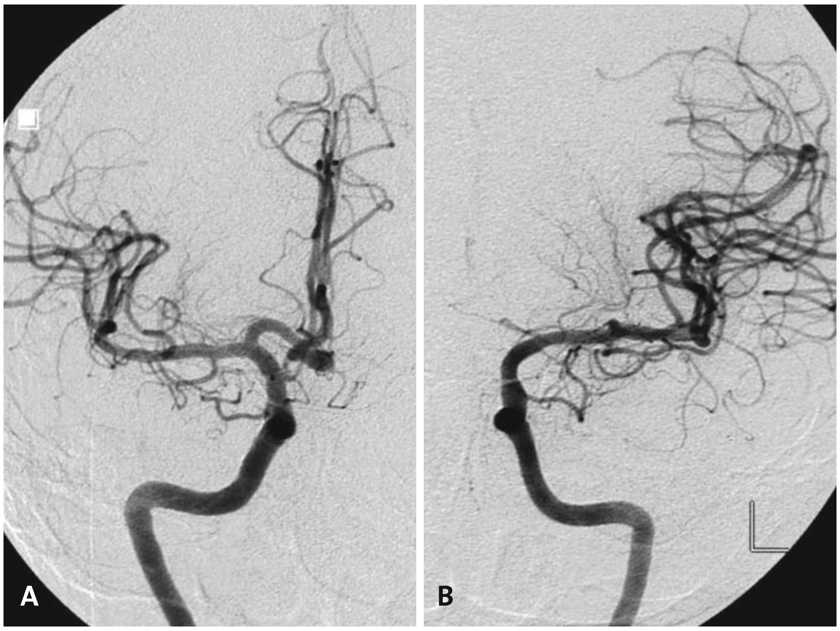
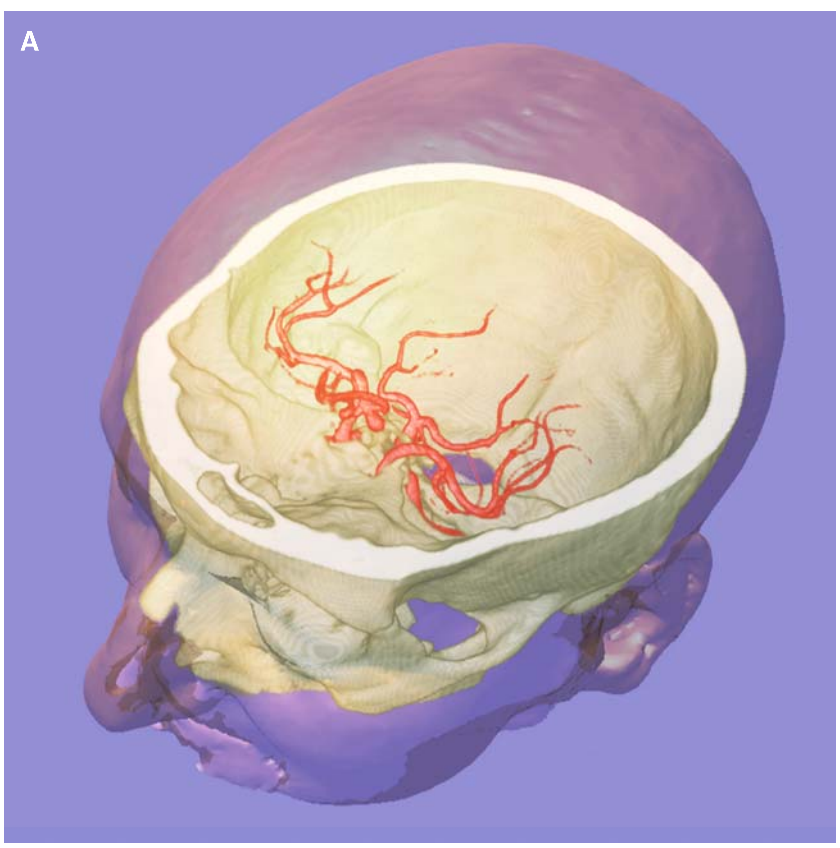


Fig. 1.0.35 A, B *Illustrative case of a patient with an unruptured aneurysm of the ACoA. Conventional DSA of the right (A) and left (B) carotid arteries in antero-posterior view demonstrates the aneurysm, with the dome directed to left. Note that the A1 segment of the left ACA appears hypoplastic, making interventional therapy with reconstruction of the ACoA more difficult.*

Fig. 1.0.35 C *3-D angiography of the right ICA showing the neck region and the dome of the aneurysm, directed to the left side.*



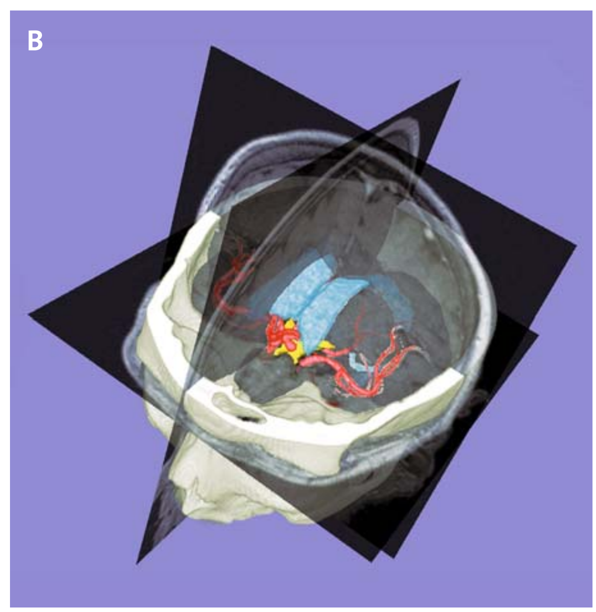


Fig. 1.0.36 *Three-dimensional dextroscope reconstruction of the preoperative CT and MRI data showing the skull base structures, vessels of the anterior circulation with the ACoA aneurysm, and important anatomical structures of the neighborhoods. Note the relationship of the vessels to the appearance of the skin surface (A) and to the triplanar MR imaging (B).*

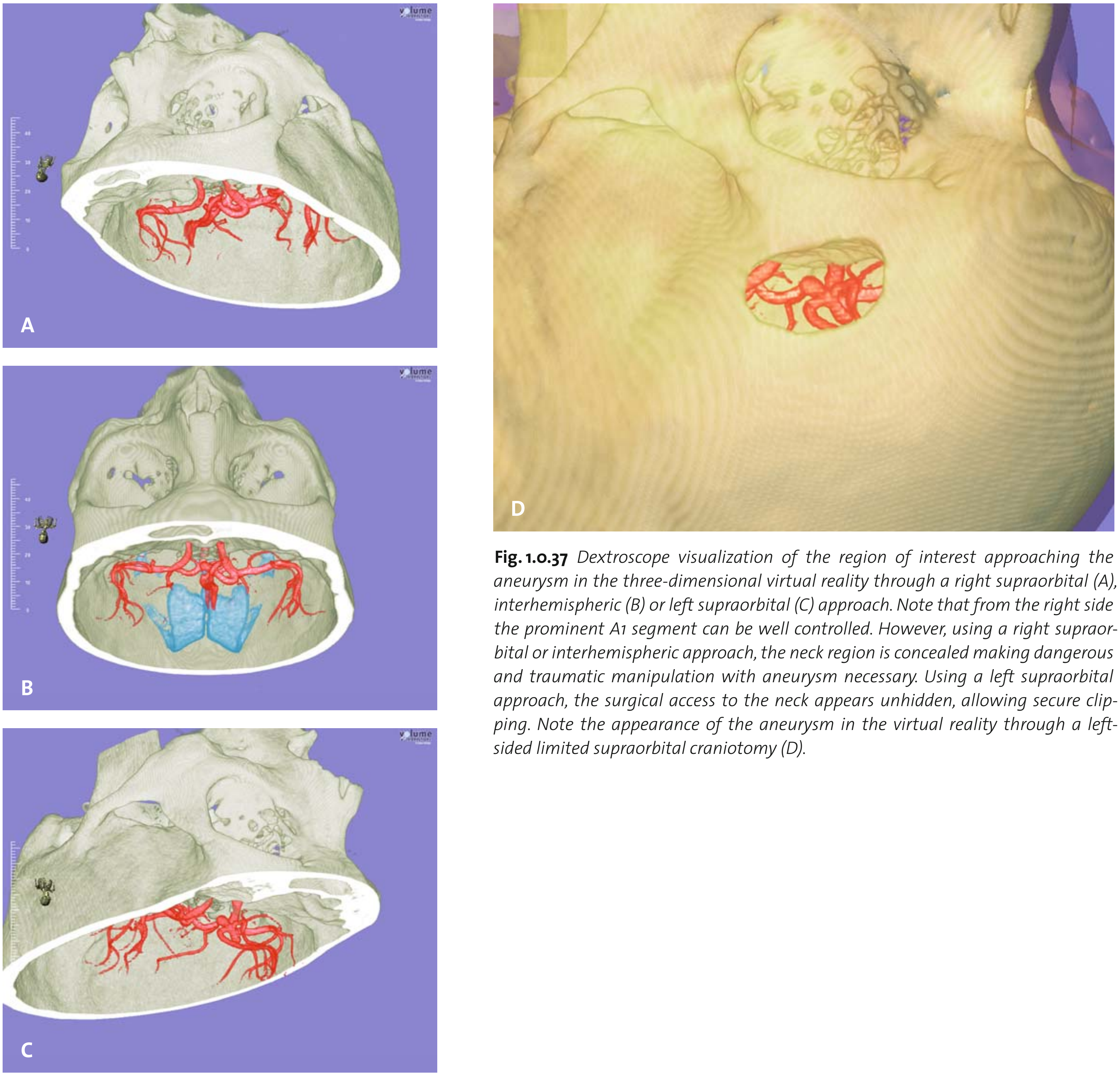


Fig. 1.0.37 *Dextroscope visualization of the region of interest approaching the aneurysm in the three-dimensional virtual reality through a right supraorbital (A), interhemispheric (B) or left supraorbital (C) approach. Note that from the right side the prominent A1 segment can be well controlled. However, using a right supraorbital or interhemispheric approach, the neck region is concealed making dangerous and traumatic manipulation with aneurysm necessary. Using a left supraorbital approach, the surgical access to the neck appears unhidden, allowing secure clipping. Note the appearance of the aneurysm in the virtual reality through a left-sided limited supraorbital craniotomy (D).*

Patient positioning

The neurosurgeon must plan and perform the proper positioning of the patient's body and head himself before starting the surgical procedure. This self-made preparation including planning and positioning is essential for creating keyhole craniotomies. The goal of patient positioning is to achieve optimal surgical access to the target region without positioning-related dangers for the patient. In addition, position should offer ergonomic conditions for the surgeon and make the operation physiologically acceptable during the often long, time-consuming procedures. The use of a modern operating table, which can be manipulated electrically, also facilitates optimal patient positioning during surgery (Fig. 1.0.38).

Almost every intracranial target region can be successfully approached using the supine or prone position. In our opinion, making use of complex positioning techniques, e.g., the lateral park bench position, semiprone position, sitting or semisitting position, does not offer additional advantages in intracranial visualization. Surgical approaches performed using these complicated, time-consuming positioning maneuvres can be done equally well with the patient in the simple supine or prone position. In addition, particularly the sitting and semisitting positions cause several surgical and anesthesiological disadvantages and make the operation physiologically very difficult for the surgeon.

The supine position

The majority of neurosurgical operations take place with the patient in the supine position (Figs. 1.0.38, 1.0.39). This position enables the surgeon to access the anterior and middle cranial fossa, the frontal and temporal skull base and the cerebellopontine region.

Approaching these target regions, other neurosurgeons frequently use the lateral park bench position. However, the lateral position is time-consuming and difficult to use for an inexperienced surgical team without adversely affecting pressure points. Using the simple supine position, the patient is placed on the table, well padded but with the shoulder some centimeters above the edge of the table; the ipsilateral shoulder can be elevated with a cushion to facilitate the head rotation. In several cases, the use of skull clamps is not necessary, offering simple and brief preparation of the patient (Fig. 1.0.38 B). If used, the single pin of the head fixator should be placed in the opposite frontal area behind the hairline to allow free manipulation of the ipsilateral side during the procedure. The pin

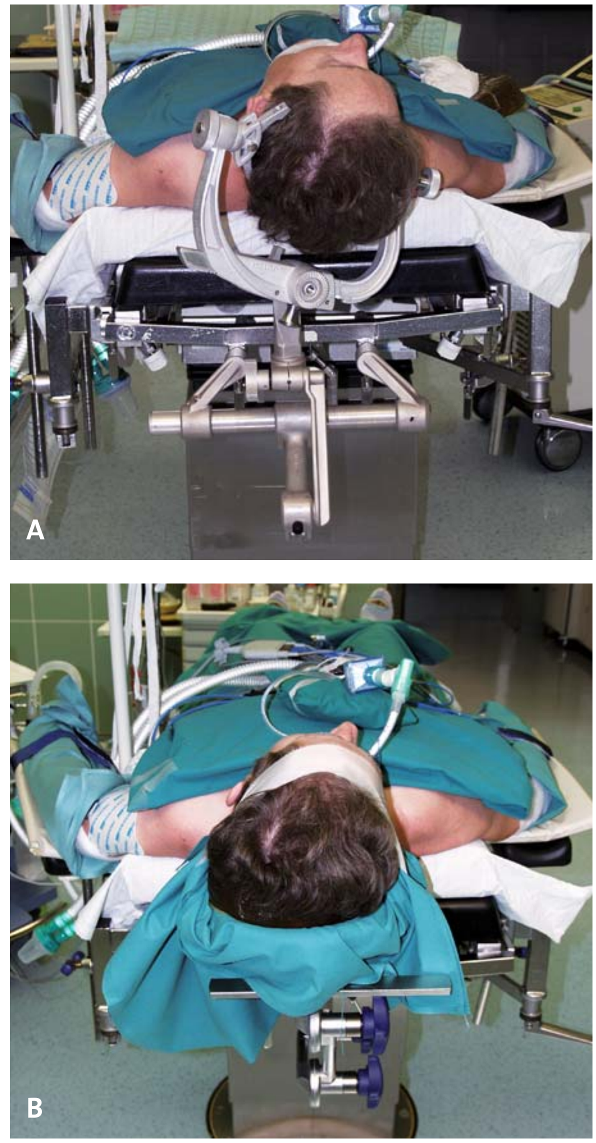


Fig. 1.0.38 *Supine positioning of the patient prepared for supraorbital craniomy using a modern operating table. The head is secured in a three-pin clamp (A). In several cases, the use of skull clamps is not necessary, offering a simple and brief preparation of the patient. The head is positioned in a soft cushion and fixed with a simple tape (B).*

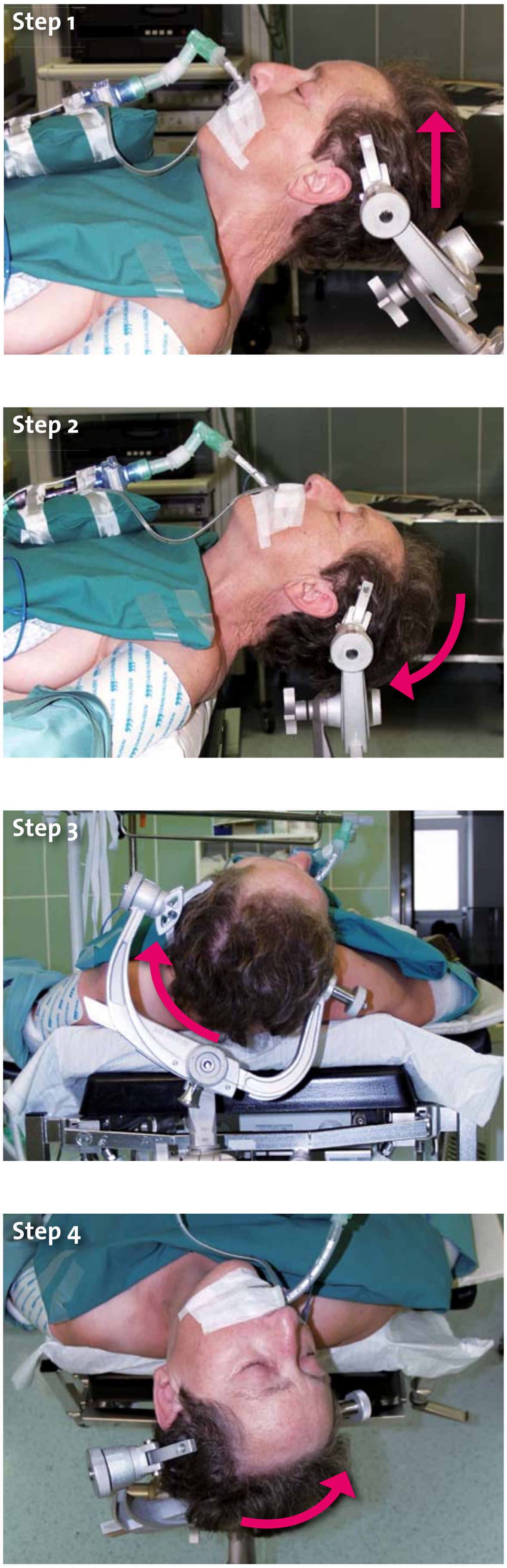


Fig. 1.0.39 *Approaching the frontal skull base, and the anterior or middle cranial fossa through a subfrontal supraorbital approach, the next steps of positioning should be followed:*

Step 1. *Initially, the head is elevated above the level of the thorax to facilitate venous drainage of the intracranial space. In addition, elevation offers effective decompression of the main cervical vessels, larynx and the ventilation tube.*

Step 2. *As a second step, the head should be retroflected ca. 15°. This gentle retroflexion supports not only gravity-related self-retraction of the frontal or temporal lobe, but also depends upon the precise anatomical and pathological situation. Generally, lesions with close proximity to the skull base require less retroflexion; structures situated more cranially can be optimally approached with more head retroflexion.*

Step 3. *Thereafter, the head is rotated according to the target region. Performing a supraorbital approach through an eyebrow skin incision, the ipsilateral temporomesial area and Sylvian fissure can be best approached with a rotation of ca. 15°. Approaching the lateral suprasellar and retrosellar area, a rotation of ca. 20° is necessary. For the anterior suprasellar region, a rotation of 30° and for the olfactory groove, a 45° to 60° rotation is required. By choosing the correct angle between 30° and 60°, one can also make contralateral lesions visible. Note that right-handed surgeons using a left-sided craniotomy need more rotation to provide an efficient working position.*

Step 4. *The last positioning step using the supraorbital approach is lateroflexion of ca. 10°, providing an ergonomic working position during surgery.*

should not be placed into the temporalis muscle as this diminishes the stability of the system (Figs. 1.0.38 A, 1.0.39).

The prone position

The prone position is best for the torcular region, pineal region, midline posterior fossa and the craniocervical junction.

Some outstanding neurosurgeons still use the sitting or semisitting position to approach the same target regions. As a main advantage, the sitting position improves venous drainage of the posterior fossa. Blood, CSF and irrigating fluids drain away from operative site making viewing of the anatomy easier. However, the sitting position requires enormous anesthesiological monitoring because of the danger of air embolism and cardiopulmonary instability. In addition, severe pneumocephalus or ventricular collapse because of the large loss of CSF can appear as postoperative surgical complications.

In our department, we utilize the prone position for the above mentioned target regions. Advantages of this positioning are the simplicity of the technique and comfort for the patient undergoing long, time-consuming procedures. In addition, the perpendicular direction of surgical dissection provides an ergonomic working position for the surgeon with optimal visualization of the operating field. The patient's shoulder and hips must be well supported by heavy rolls. The head is placed in pins allowing optimum positioning. We do not require the use of a horseshoe headrest to avoid severe compression of the skin during long surgical procedures.

Orientation according to anatomical landmarks
After preoperative planning of the approach according to the individual pathoanatomical situation and after patient positioning according to the target region, the placement and size of the craniotomy should be individually tailored (Fig. 1.0.40).

For this reason, palpable structures of the patient's anatomical surface should be determined and drawn on the skin with sterile markers (A). For example, when using the supraorbital craniotomy, the important anatomical landmarks of the frontotemporal osseous skull, such as the supraorbital foramen (1), temporal line (2), frontobasis with impression of the Sylvian fissure (3) and the zygomatic arch (4) are palpated precisely. Special attention must be given to the course of the superficial neurovascular structures of the frontotemporal region such as the supraorbital nerves and artery (5) and the frontal branch of the facial nerve (6). Only thereafter should the borders of the craniotomy be marked, taking into consideration the position of the lesion and the landmarks drawn on the skin (B). After defining the craniotomy, the individual optimum line of the skin incision is marked with the pen (C).

Recently, the optimal placement of the craniotomy can be effectively controlled with the use of modern navigation tools. However, the approach must be determined after surgical orientation according to the accurate anatomical knowledge and the navigation device should play only the role of a precise control!

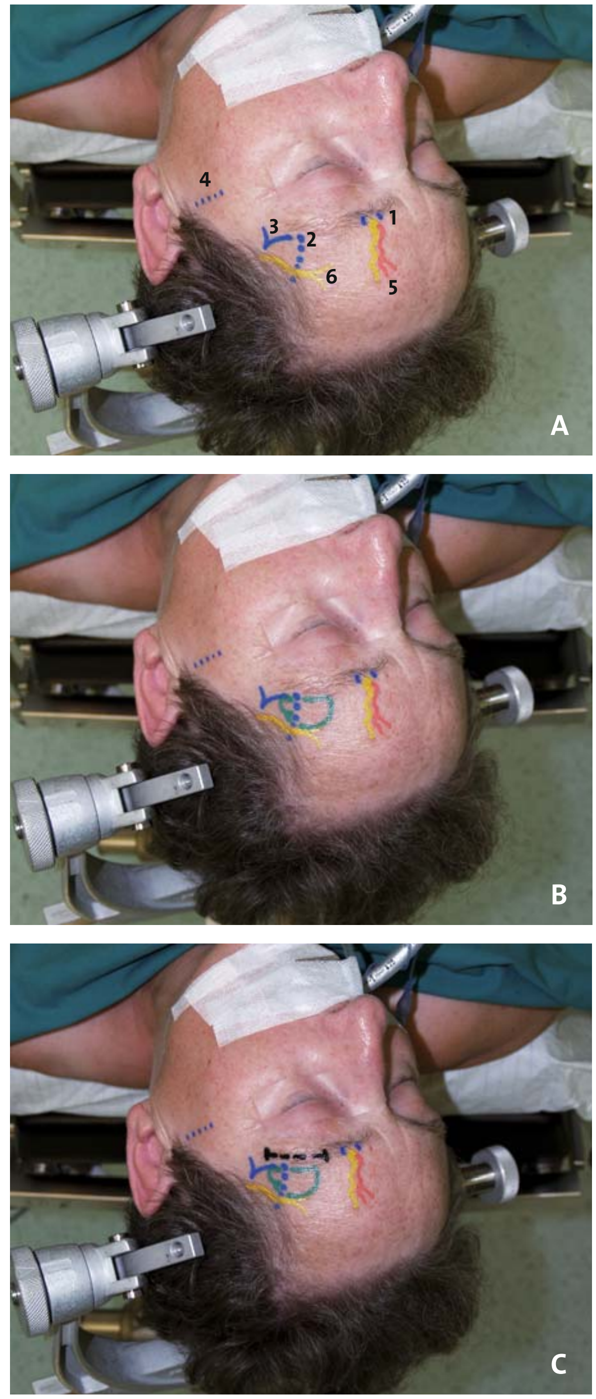


Fig. 1.0.40 *Illustrative case performing supraorbital craniotomy. For the appropriate skin incision, the important anatomical landmarks (A) of the osseous skull are palpated precisely and marked with a sterile pen (blue lines). Special attention must be given to the course of the superficial neurovascular structures of the frontotemporal region (yellow and red lines). Only thereafter should the borders of the craniotomy be marked (green line), taking into consideration the position of the lesion and the landmarks drawn on the skin (B). After defining the craniotomy, the individual, optimum line of the skin incision is marked with a black pen (C).*

Surgical dissection

Skin incision and soft tissue dissection
The skin incision is made according to the preoperative planning and anatomical orientation. The dissection should offer adequate inspection of the osseous surface whilst minimizing soft tissue trauma. An additional important factor is to achieve cosmetically favorable postoperative results with subsequent satisfaction among patients (Steps 1–3, Figs. 1.0.41–43).

Performing a supraorbital craniotomy through an eyebrow skin incision, shaving of the eyebrow is not necessary; for a pleasing cosmetic outcome, the incision line must be placed exactly in the haired area. Performing an approach within the haired area, we usually use a minimal 10 mm shaving according to the exact line of the skin incision.

Craniotomy, dural opening

The aim of keyhole neurosurgery is not the limited craniotomy, but the limited brain exploration and minimal brain retraction. In this way, the limited craniotomy is not the goal but the result of the philosophy of minimal invasiveness in neurosurgery.

After performing a limited keyhole craniotomy, removal of the inner edge of the craniotomy under protection of the dura can be very helpful. Careful drilling of this inner bone edge significantly increases the angle for visualization and manipulation; small osseous extensions of the skull base should also be carefully removed to provide an excellent overview and to allow free microsurgical access to deep-seated sites. These maneuvres greatly facilitate the use of the operating microscope and microsurgical instruments in the further course of the operation (Steps 4–7, Figs. 1.0.44–47).

The dural opening should offer optimal intracranial exposure and facilitate the dural closure thereafter. The dura should be opened in a curved or "Y" shaped fashion with its base toward to the skull base or to the midline. The free dural flap is fixed with sutures; other dural elevation sutures are not required (Step 8, Fig. 1.0.48).

Intradural dissection

The intracranial dissection should be performed after exact planning of every step of the procedure. The surgeon should be able to "run through" each step of the operation in his or her mind according to mandatory anatomical and surgical experience. This offers safe manipulation within the surgical field and will help to prevent intraoperative complications.

First step of the intracranial procedure should be the sufficient drainage of CSF. Due to the marked intracranial relaxation, cortical retraction can be effectively minimized. With full employment of techniques such as endoscope-assisted keyhole microneurosurgery the intracranial procedure can be successfully completed (Steps 9–15, Figs. 1.0.49–55).

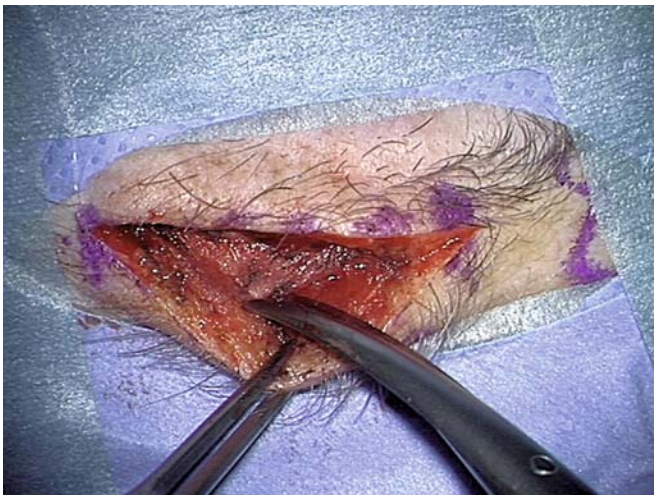


Fig. 1.0.41

Step 1

The skin incision begins laterally from the supraorbital incisura and is made within the eyebrow. For a cosmetically optimal result, the incision should follow the orbital rim. Note careful dissection of the skin flap using non-damaging forceps. The subcutaneous tissue is dissected upwards in a frontal direction to achieve optimal exposure; however, the skin flap should be gently mobilized downwards in an orbital direction to avoid periorbital hematoma (Fig. 1.0.41).

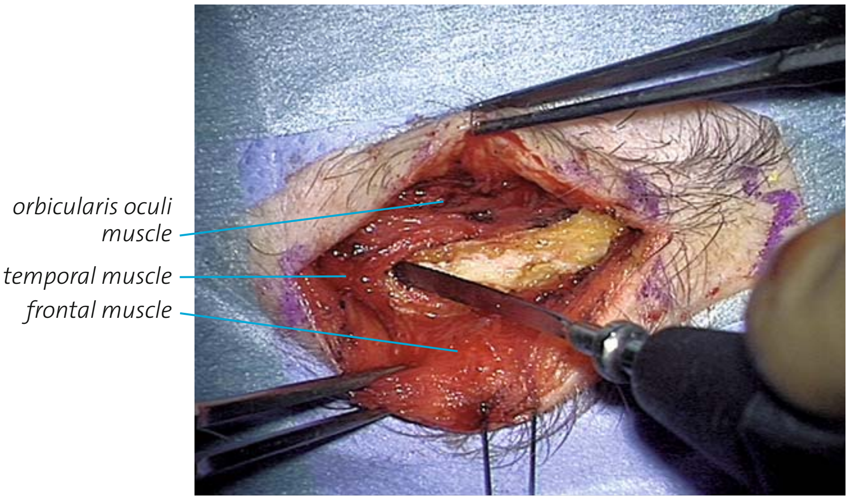


Fig. 1.0.42

Step 2

After skin incision, the skin flap is temporarily retracted with stitches exposing the frontal belly of the occipitofrontal muscle, the orbicular and the temporal muscles. The frontal muscles are cut with a monopolar electrode knife parallel to the glabella and the temporal muscle is stripped from its bony insertion. Note that the skin flaps are touched only with atraumatic forceps (Fig. 1.0.42).

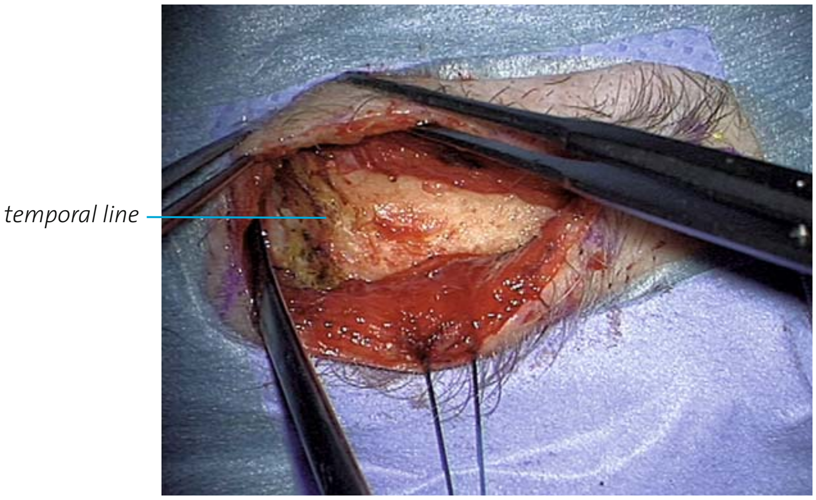


Fig. 1.0.43

Step 3

The temporal muscle is mobilized laterally using a blunt dissector. Note that exposure and mobilization of the temporal muscle should be restricted to the necessary minimum to prevent postoperative problems with chewing and later temporal atrophy. Note the temporal line; the dissector points to the level of the anterior skull base (Fig. 1.0.43).

Step 4

The temporal muscle is retracted with small wound hooks and the frontal muscle upwards and downwards with strong sutures allowing limited exposure of the supraorbital bony surface. Note that the frontal and orbicular muscles should be gently pushed downwards to the orbit. Careful dissection and minimal retraction of this muscular layer is essential to avoid postoperative periorbital hematoma. Using a high-speed drill, a single frontobasal burr hole is drilled posterior to the temporal line at the level of the frontal skull base (Fig. 1.0.44).

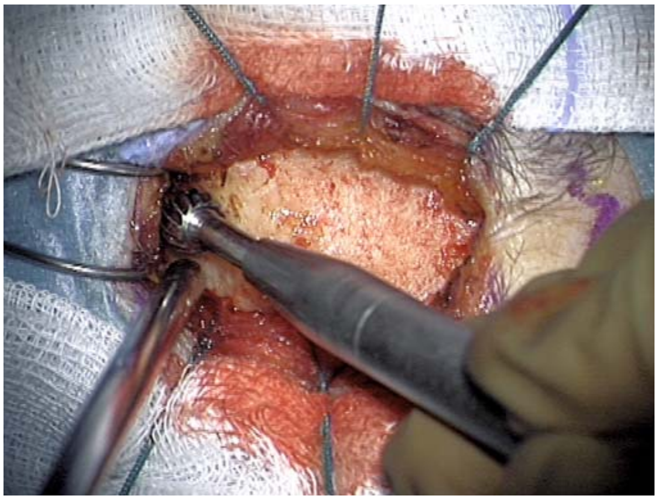


Fig. 1.0.44

Step 5

After minimal enlargement of the hole with fine punches and mobilization of the dura, a straight line is cut with a high-speed craniotome parallel to the glabella in a lateral to medial direction, taking into account the lateral border of the frontal paranasal sinus (Fig. 1.0.45).

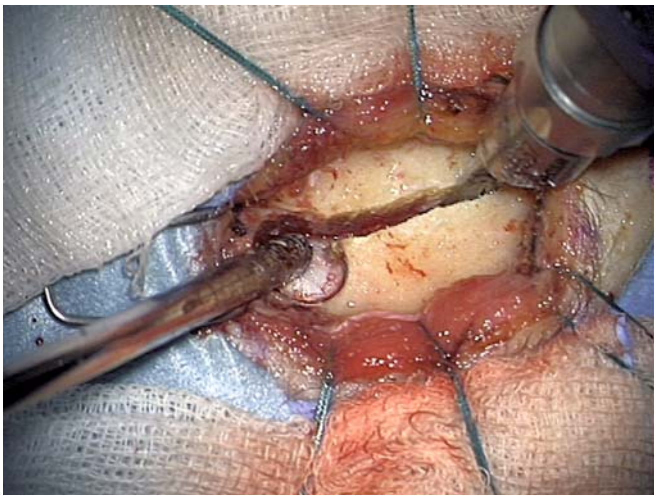


Fig. 1.0.45

Step 6

Thereafter a "C" shaped line is cut from the burr hole to the medial border of the previously cut frontobasal line, thus creating a bone flap with a width of ca. 15–20 mm and a frontal extension of ca. 10–15 mm (Fig. 1.0.46).

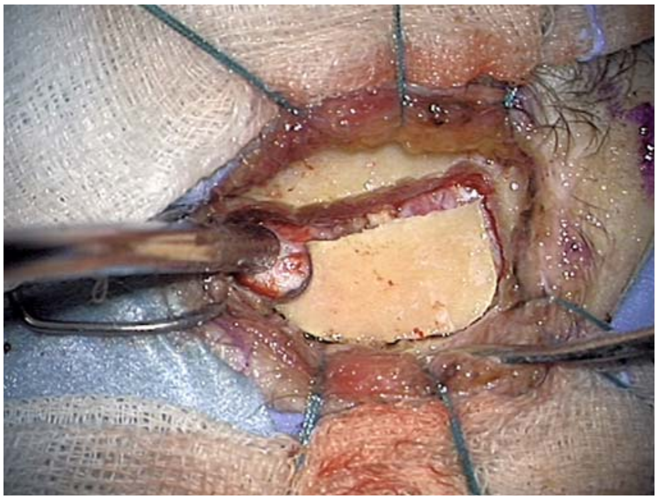


Fig. 1.0.46

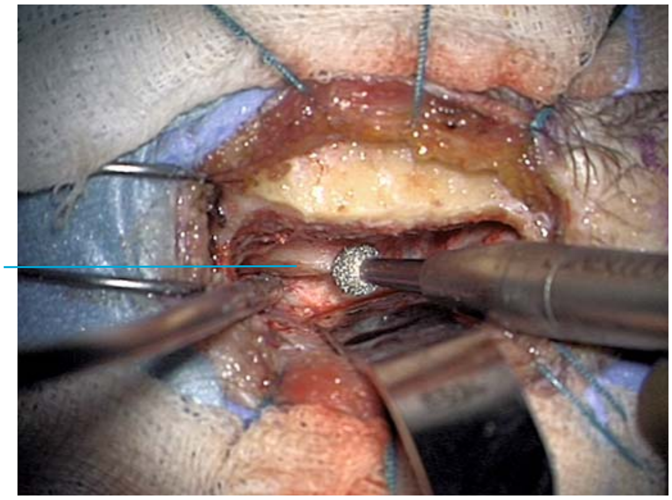


Fig. 1.0.47

Step 7
A very important stage of the craniotomy after removal of the bone flap is the high-speed drilling of the inner edge of the bone above the orbital rim under protection of the dura. Careful removal of this inner bone edge can significantly increase the angle for visualization and manipulation. Small osseous extensions of the superficial orbital roof, the so-called juga cerebralia, should also be drilled extradurally to obtain optimal intradural visualization. A small diamond drill is recommended. Note the application of a spatula for protection of the dural surface (Fig. 1.0.47).

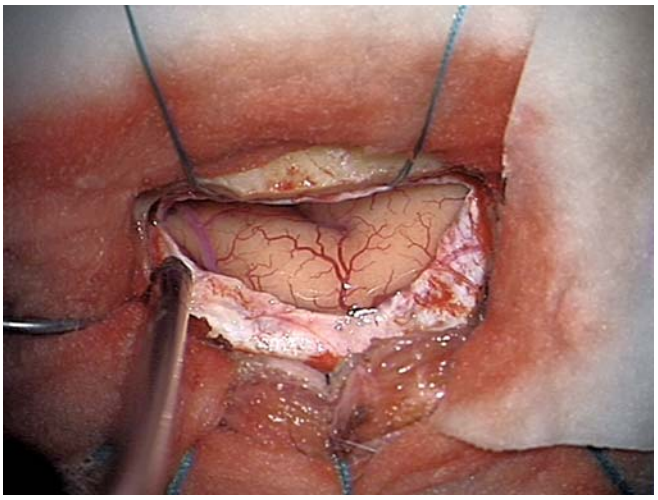


Fig. 1.0.48

Step 8
The dura should be opened in a curved fashion with its base toward to the supraorbital rim. The free dural flap is fixed downwards with sutures; other dural elevation sutures are not required (Fig. 1.0.48).

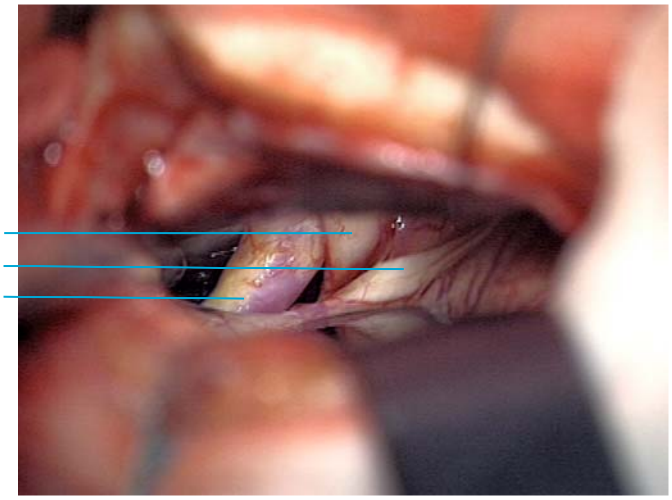


Fig. 1.0.49

Step 9
After opening the dura mater, the first step should be the sufficient drainage of CSF by opening the chiasmatic and carotid cisterns. After dissection of the arachnoid membranes, the anterolateral structures of the suprasellar region are exposed: the left CN I, CN II and the supraclinoid segment of the ICA. The frontal lobe is minimally retracted and the OPCA window is opened (Fig. 1.0.49).

Step 10

A 0° endoscope is introduced into the surgical field. Note the increased light intensity and the highly broadened observational field (A). In a close-up position (B), the anatomical details can be visualized and the deep-seated basilar bifurcation appears through the OPCA window (Fig. 1.0.50).

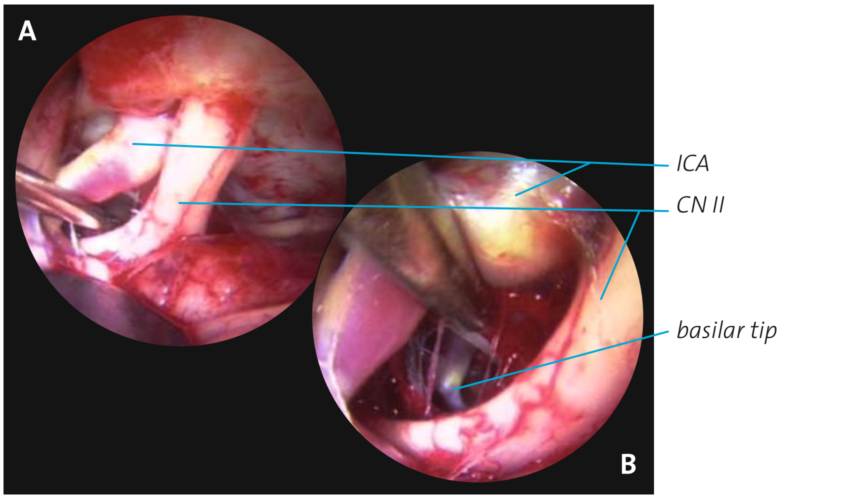


Fig. 1.0.50

Step 11

Dissecting to the midline, the aneurysm is approached. Note the lamina terminalis and a frontobasal branch of the ACA, adherent with the aneurysm sack (Fig. 1.0.51).

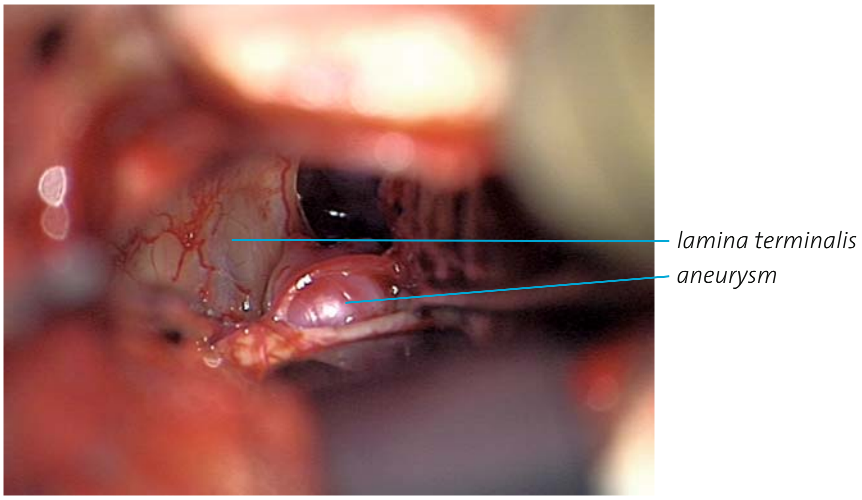


Fig. 1.0.51

Step 12

After further dissection, the entire aneurysm can be seen. Note the hypoplastic left A1 segment and the ACoA (Fig. 1.0.52).

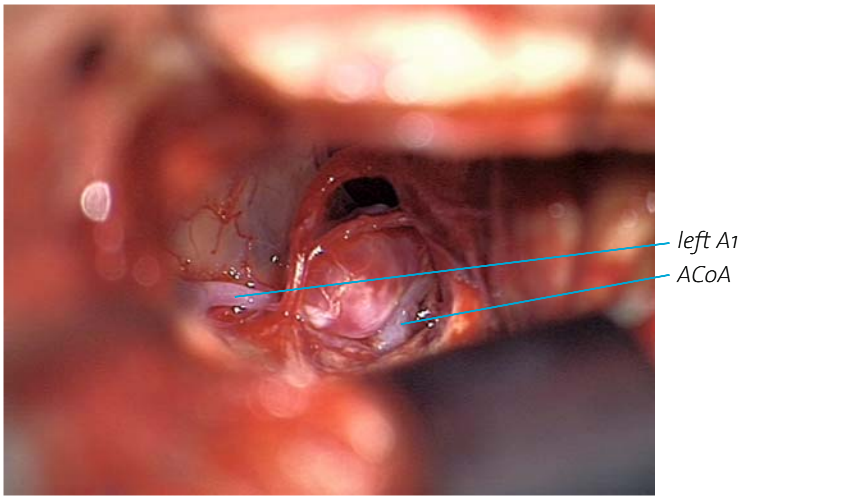


Fig. 1.0.52

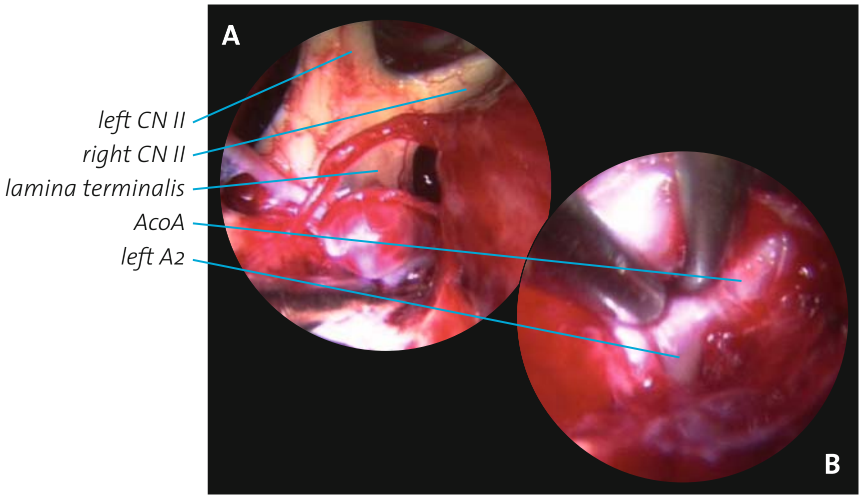


Fig. 1.0.53

Step 13
Upon introduction of the endoscope, the relationship between the aneurysm and the lamina terminalis becomes evident. Note the chiasm and both optic nerves (A). In a close-up position of the endoscope (B), the neck of the aneurysm is dissected with fine dissectors. Note the sack of the aneurysm, the left A2 and ACoA (Fig. 1.0.53).

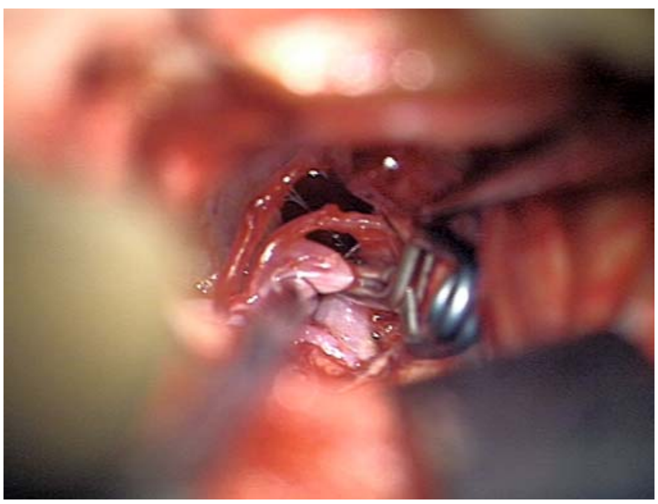


Fig. 1.0.54

Step 14
When the pathoanatomy of the aneurysm has been ascertained and the neck dissected, a straight aneurysm clip (Aesculap AG, Tuttlingen, Germany) is placed. The sack is collapsed after careful opening and aspiration of the aneurysm (Fig. 1.0.54).

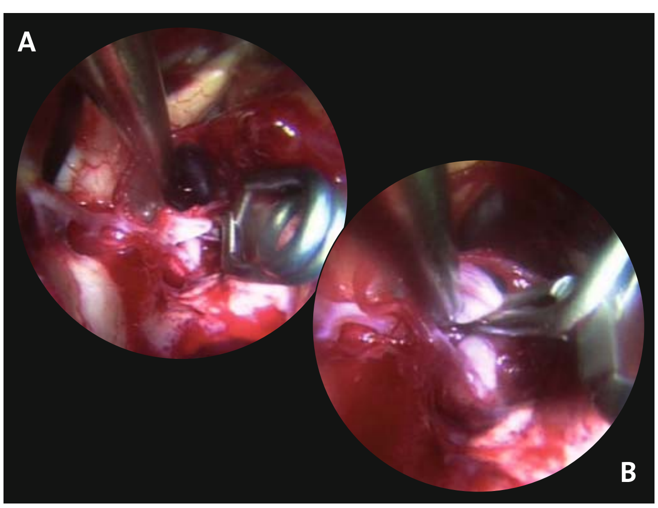


Fig. 1.0.55

Step 15
The endoscope offers adequate visual control of the clipping procedure (A). The complete closure can be effectively monitored in close-up (B) (Fig. 1.0.55).

Step 16
At the end of the intracranial procedure, the subarachnoid space is filled with artificial CSF solution at body temperature. The dural incision is closed with watertight continuous sutures. Note the extension of the limited craniotomy and minimal dural opening (Fig. 1.0.56).

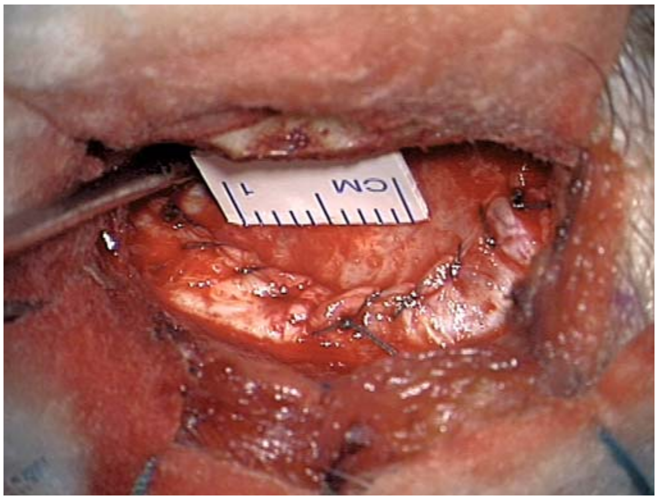


Fig. 1.0.56

Step 17
A plate of gelfoam is placed extradurally and the bone flap is fixed with a titanium Craniofix miniplate (Aesculap AG, Tuttlingen, Germany). Note that the burr hole should be closed with the plate and the bone flap tightly fixed both medially and frontally to achieve optimal cosmetic results (Fig. 1.0.57).

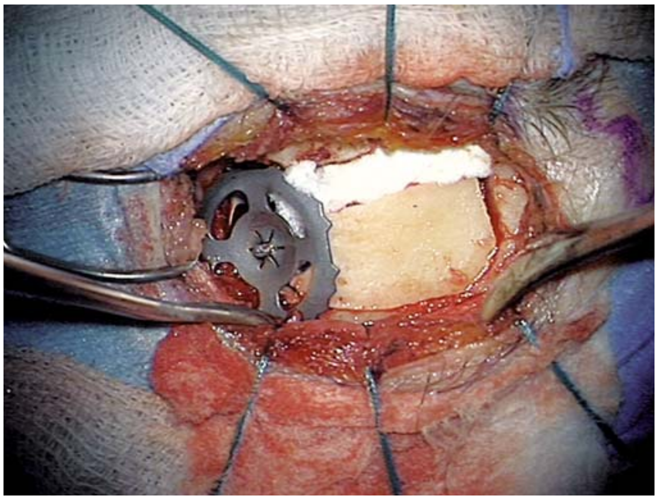


Fig. 1.0.57

Step 18
After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with intracutaneous sutures. On account of the limited skin incision and nontraumatic surgical technique, the use of a suction drain is not necessary and therefore not recommended (Fig. 1.0.58).

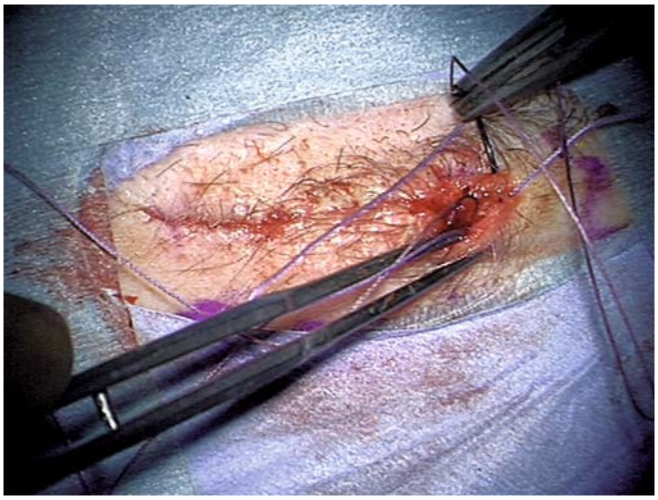


Fig. 1.0.58

Wound closure

After finishing the intracranial procedure, the subarachnoid space is filled with artificial CSF solution at body temperature. The dural incision is made watertight using either interrupted or continuous sutures (Step 16, Fig. 1.0.56). If tension has developed in the dural plane, a piece of muscle can be sewn into the dural closure. A plate of gelfoam is then placed extradurally. We do not recommend the use of fibrin or protein-containing fixative to assist with dural closure on account of the fibrinolytic effect of the CSF. The bone flap is fixed with a titanium miniplate. Usually one plate is enough to allow sufficient fixation; if possible, the titanium plate should close the burr hole trephination (Step 17, Fig. 1.0.57). Note that the bone flap should be fixed tightly to achieve optimal cosmetic results. After final verification of hemostasis, the muscle and subcutaneous layers are closed with interrupted sutures. For closure of the skin, different techniques can be used. An eyebrow skin incision can be closed with intracutaneous running sutures or with sterile adhesive tapes (Step 18, Fig. 1.0.58). A skin incision within the haired area can be closed with interrupted or running sutures or after adequate subcutaneous sutures with histoacryl glue. On account of the limited skin incision and nontraumatic surgical technique in keyhole neurosurgery, a suction drain is not required.

Fig. 1.0.59 *Patient's appearance the 2nd and 21st postoperative day. The limited skin incision, minimal muscular dissection and least possible bone damage obtained with this minimal invasive technique result in an optimal cosmetic outcome (published with patient's permission).*

Potential errors and their consequences

- Inadequate preoperative planning with subsequent inadequate exposure of the target region and significant deterioration in efficiency of surgically excising the lesion. Planning is the task of the surgeon!
- Inadequate positioning of the patient with insufficient intracranial exposure. To avoid a physiologically uncomfortable job during time-consuming procedures, the surgeon should perform the patient positioning himself.
- Inadequate placement of the craniotomy. The approach must be determined after accurate surgical orientation according to anatomical knowledge and preoperative planning. However, with the use of modern navigation tools, correct positioning of the craniotomy can effectively be monitored.
- Overlooked, but often unavoidable injury to the dura during craniotomy. Dural reconstruction may be necessary.
- Inadequate removal of CSF with injury to the cortical surface due to spatula pressure.

- Injuries to nerves and vessels in the surgical field during microsurgical manipulation resulting in postoperative neurological deterioration.
- Inadequate intracranial hemostasis causing severe postoperative rebleeding within the surgical field.
- Inadequate dural closure with postoperative CSF leak.
- Inadequate positioning and fixation of the bone flap with suboptimal cosmetic results.
- Inadequate extracranial hemostasis causing postoperative soft tissue hematoma.
- Inadequate closure of the skin causing postoperative wound healing disturbance or suboptimal cosmetic outcome.

Tips and tricks

- Take time for preoperative planning and positioning of patients. The reward is an excellent overview of the target area and an efficient working position.
- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and superficial neurovascular structures; 2. placement of craniotomy; 3. skin incision.
- The skin incision should be made in a cosmetically acceptable way.
- By retracting the soft tissue, the osseous surface should be optimally exposed. However, retraction and mobilization of the skin flap should be restricted to the necessary minimum to prevent postoperative necrosis.
- Be careful during the burr hole trephination: adequate placement but inadequate direction of the burring procedure may also penetrate structures of the skull base or may injure the dural and cortical surface!
- Stages of craniotomy: 1. burr hole trephination; 2. cutting with the craniotome according to the planned approach.
- Drilling of the inner edge of the craniotomy after removal of the bone flap is important for limited approaches to achieve unhindered intracranial visualization. Small osseous extensions of the skull base should also be carefully removed to provide an excellent overview and to allow microsurgical access to deep-seated sites.
- Open the dura in a “C” or “Y” shaped fashion and hold the dural flap with sutures.

- Many neurosurgeons believe that intracranial surgery should be done with the surgeon sitting. However, performing a keyhole approach, intraoperative changing of the surgeon's position is very frequent. In our experience, this "dancing around the table" is more comfortable for the surgeon whilst standing, even when performing long and time-consuming procedures.
- After completion of the intradural dissection, dural closure should be made watertight using either interrupted or continuous sutures. If tension has developed in the dural plane, a piece of muscle can be sewn into the dural closure.
- After dural closure, the bone flap should be tightly fixed to achieve optimal cosmetic results.
- A titanium plate can be successfully used for closure of the burr hole trephination.
- Because of the limited soft tissue dissection, the use of suction drain is not required.
- The skin should be closed within the haired area with sutures or after subcutaneous sutures with histoacryl glue.
- An eyebrow incision can be sufficiently closed with intracutaneous running sutures or with sterile adhesive tapes.

2.0
Supraorbital approach

History of the anterior subfrontal and frontolateral approaches

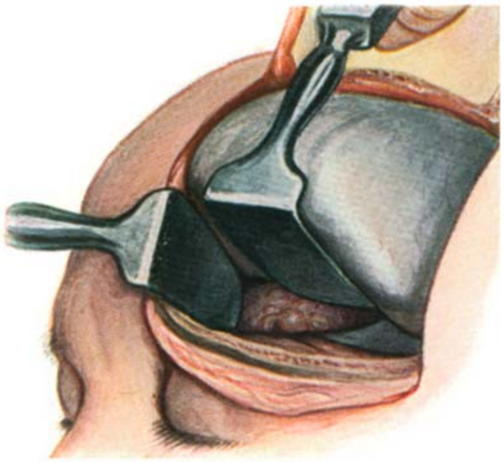


Fig. 2.0.1 *A picture taken from the first edition of* Fedor Krause*'s pioneering work "Surgery of the Brain and Spine". In this case,* Krause *approached an extended skull base meningeoma in two steps. After performing the subfrontal craniotomy, the tumor was partially removed in a second session using an extradural exposure, thus minimizing injury to the cortical surface. Due to the rough retraction of the frontal lobe which was necessary because of a severe brain swelling, the patient did not survive.*

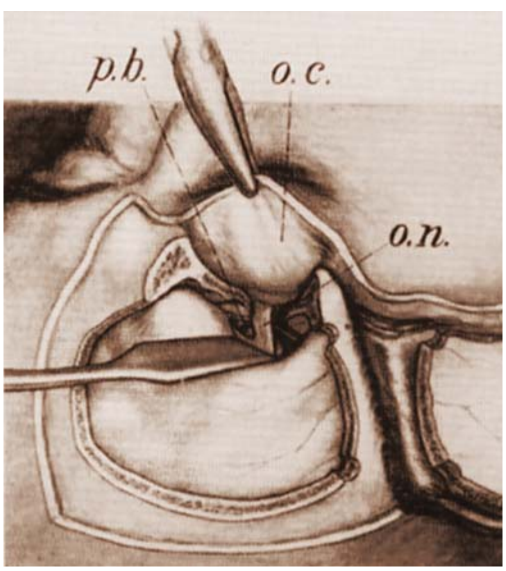


Fig. 2.0.2 *The extradural subfrontal approach of* Frazier*, published in 1913. Craniotomy included removal of the orbital rim and orbital roof, allowing minimal retraction of the frontal lobe.*

A sub- and transfrontal approach was first described by Francesco Durante for resection of an olfactory groove meningeoma [Durante 1885]. In this first historical description of a planned neurosurgical procedure, Durante reported in his own words that *"for the frontal exploration an osteocutaneous flap was formed, in its shape it resembled a horseshoe, the fronto-temporal bone formed the base of the flap"*. Using this osteoplastic technique, the postoperative course was uneventful and the patient showed no neurological deficits after subtotal resection of the tumor.

The first supraorbital, subfrontal exposure was reported by Fedor Krause in the first volume of his pioneering work "Surgery of the Brain and Spine" [Krause 1908]. According to the contemporary surgical technique, Krause also created a combined skin, periosteum, and bone flap to reduce intraoperative blood loss and avoid postoperative wound infection (Fig.2.0.1). Although the craniotomy was large, Krause used an extradural route; the frontal, parietal and temporal cortex was not exposed directly as the dura was opened at the sphenoid ridge.

A similar extradural exposure was also described by Charles H. Frazier to approach the pituitary gland and its neighboring region [Frazier 1913]. To minimize severe postoperative complications due to the excessive retraction of the frontal lobe, the author removed the supraorbital arch and the orbital roof using an osteoplastic procedure (Fig.2.0.2).

Other transcranial frontal approaches have required the partial exposure of the anterior half of the cerebral hemisphere as demonstrated in Cushing's, Heuer's and Dandy's historical descriptions of surgery of the suprasellar region. Harvey Cushing performed the first complete removal of a tuberculum sellae meningeoma via subfrontal exposure in 1916 and reported his experience of the resection of 28 tumors in his classical publication, co-authored by Louise Eisenhardt [Cushing & Eisenhardt 1938]. George J. Heuer described his subfrontal-frontotemporal approach to chiasmal lesions, a prototype of the later frontolateral-pterional craniotomy [Heuer 1920]. Walter E. Dandy published the results of his first eight cases of frontobasal meningeoma in 1922, using Heuer's frontotemporal approach [Dandy 1922]. The authors exposed a large cortical surface which was permanently contaminated with air during surgery causing cortical microinjuries with the subsequent possibility of postoperative epileptic seizures (Figs. 1.0.1, 2.0.3). As previously described, these extended openings were necessary for several reasons; however, the development of diagnostic imaging and surgical techniques allowed a stepwise reduction in the size of the skin incision and craniotomy. Dandy's personal learning process in reducing operative traumatization was well demonstrated in his publication of his so-called hypophyseal approach exposing an ICA aneurysm [Dandy 1938] (Fig. 1.0.2).

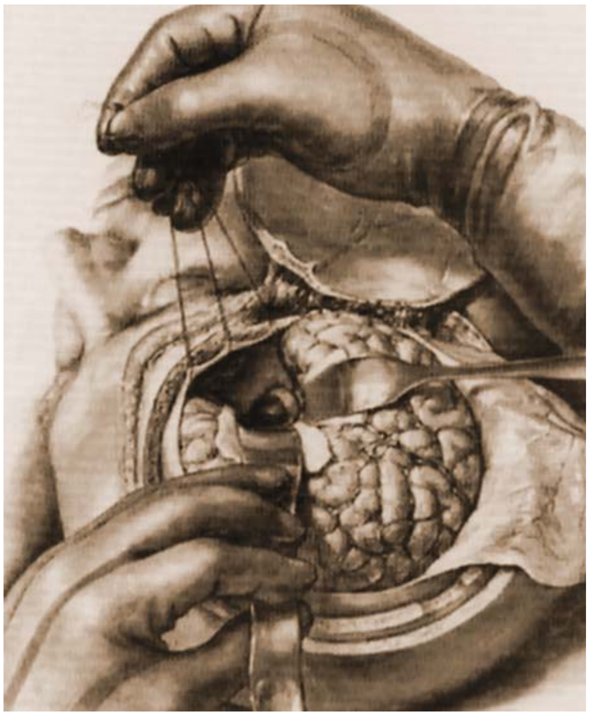


Fig. 2.0.3 *Heuer's frontotemporal craniotomy exposing the supra- and parasellar region. Note that only the anterior part of the exploration was used approaching the right optic nerve. Therefore, the extensive craniotomy and dural opening caused in this case an unnecessary trauma to the cortical surface.*

An unusual indication for the frontotemporal-hypophyseal approach was the occlusive hydrocephalus [Dandy 1922]. After subfrontal exposure of the suprasellar region, Dandy opened the lamina terminalis achieving an anterior ventriculocisternostomy of the third ventricle. Note that this initial technique to third ventriculostomy involved the sectioning of one optic nerve to expose the tuber cinereum. This method was refined by Byron Stookey and Ted Scarff by puncturing the lamina terminalis and then the floor of the third ventricle (Fig. 2.0.4). In 1963, Scarff published the results of 527 hydrocephalic patients in whom the postoperative mortality was 15% with an initial success rate of 70% [Stookey 1936, Scarff 1951, 1963].

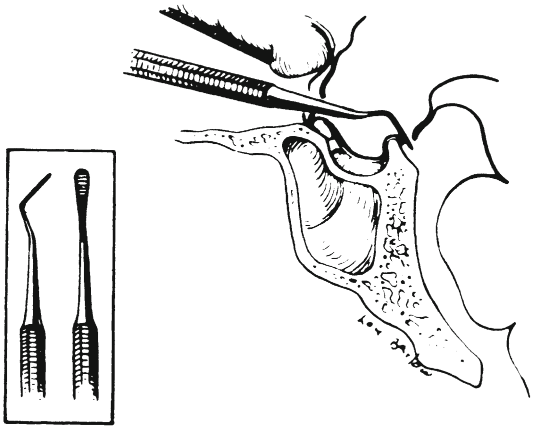


Fig. 2.0.4 *Third ventriculostomy by the subfrontal route, described by Scarff in 1951. Note the puncture of both the lamina terminalis and the floor of the third ventricle, allowing free CSF circulation.*

Concerning preoperative planning, many surgeons operated on the nondominant side; however, James L. Poppen suggested that right-handed surgeons should use the right frontal approach and left-handed surgeons the left frontal approach [Poppen 1960]. Note that 22 years after Dandy's description, Poppen's exposure did not respect the hairline (Fig. 2.0.5).

In the early 1970s, an enormous development in technical standards allowed neurosurgeons to use refined approaches. Heuer's and Dandy's fronto-temporal approach was refined by M. Gazi Yasargil [Yasargil 1975] (Fig. 2.0.6). A limited frontolateral approach to aneurysms of the anterior circulation was performed by Mario Brock and Dietz [Brock & Dietz 1978]. The authors summarized the advantages of the small craniotomy as 1) the temporal muscle remains intact because of minimal mobilization; 2) the craniotomy

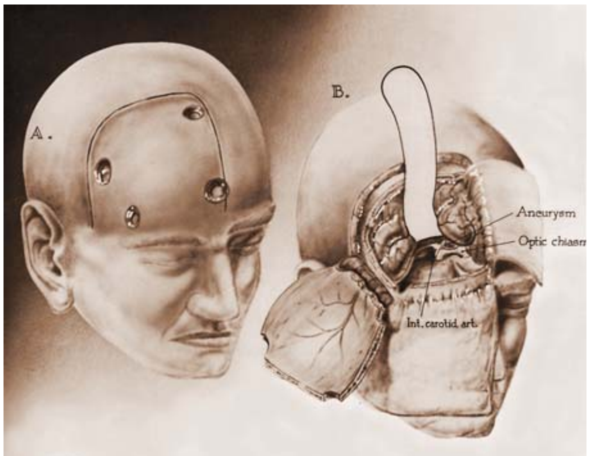


Fig. 2.0.5 *An unilateral subfrontal approach to aneurysms of the anterior communicating artery published by* Poppen *in 1960. Note that 22 years after* Dandy*'s description, Poppen's skin incision was not concealed behind the hairline giving an unacceptable cosmetic result.*

Fig. 2.0.6 *A refinement of* Dandy*'s hypophyseal approach using microsurgical techniques was published by* Yasargil *in 1975. This frontotemporal pterional approach is currently the most frequently used for surgical access to sellar and parasellar lesions.*

Fig. 2.0.7 *The limited frontolateral approach to aneurysms of the anterior circulation was published by* Brock *and* Dietz *in 1978.*

is exclusively osteoplastic; 3) opening the Sylvian fissure is unnecessary, avoiding injury of the Sylvian vessels. Special attention should be given to this pioneering description of a less invasive subfrontal approach which has provided *"the advantage of permitting an easy, direct and protective attack to such aneurysms through a small and merely osteoplastic craniotomy"* (Fig.2.0.7).

In 1982, James A. Jane reported a different subfrontal-supraorbital exposure to aneurysms and other lesions of the suprasellar area as well as to orbital lesions [Jane 1982]. This approach was modified by Johnny Delashaw by fracturing the orbital roof or including a temporal extension of the craniotomy [Delashaw 1992]. The inferior extension of the supraorbital craniotomy by removal of the orbital rim was also described by Roberto Delfini using an alternative technique with two bone flaps [Delfini 1992]. Ossama Al-Mefty published his experience concerning a supraorbital-pterional approach to skull base lesions by incorporating the superior and lateral orbital walls; Joseph M. Zabramsky described extended temporal and orbitozygomatic bone removal providing wide access to the anterior and middle cranial fossa [Al-Mefty 1990, Zabramsky 1998].

Most variations of these supraorbital and subfrontal approaches resulted in extensive soft tissue and bony exposure, extended dural opening and subsequently necessary brain retraction, causing a possible increase in surgical morbidity unrelated to the lesion itself. However, similar to the small frontolateral approach of Brock and Dietz, recent publications on subfrontal exposures have described limited traumatization of the extra- and intracranial structures. In 1998, Eric van Lindert reported the surgical experience using supraorbital subfrontal craniotomy for the treatment of 197 intracranial aneurysms; Sándor Czirják published his experience in 2001 and 2002 and Ramos-Zúniga presented the trans-supraorbital approach in 2002 [van Lindert 1998, Czirják 2001, 2002, Ramos-Zúniga 2002]. Hans Jakob Steiger described a small orbitocranial approach through a frontotemporal hairline incision to access aneurysms of the anterior communicating artery [Steiger 2001]. In 2002 and 2005, the Mainz technique of performing supraorbital craniotomy through an eyebrow skin incision was described [Reisch 2002, 2005].

During the last decades, many different subfrontal and frontolateral approaches to the suprasellar area have been described, even if some of these exposures were in fact quite similar. However, in his pioneering description, Fedor Krause had already grasped the essence of the subfrontal supraorbital exposure: the suprasellar anatomical structures are free for surgical dissection from an anterior direction, while the anterior part of the temporal lobe does not obscure access to the deep-seated areas.

In the following, this important anatomical fact will be discussed in detail.

General anatomical construction of the anterior cranial fossa and the suprasellar region

According to Krause's concept, to better understand the geometrical and topographical architecture of the anterior cranial fossa, the general anatomical construction and the essential anatomical characteristics of this area must first be discussed. The base of the suprasellar area with the quadrangle of the clinoid processes is on the same level as the anterior skull base. However, lateral to the sellar structures, the base of the middle cranial fossa is situated deeper than the plane of the anterior cranial fossa. According to Johannes Lang, this difference is on average 18 mm on the left and 20 mm on the right side [Lang 1981]. This means the temporal lobe overlaps the suprasellar region from a lateral direction thus necessitating extensive retraction of the temporal lobe when approaching from a lateral temporal direction (Fig. 2.0.8 A). In addition, the temporal pole has an extension anterior to the frontal part of the suprasellar area. Thus, when approaching this area from a frontotemporal pterional direction, the anterior part of the temporal lobe obscures the surgical access: splitting of the Sylvian fissure with manipulation of the temporal veins must also be performed (Fig. 2.0.8 B). However, using the anterior subfrontal approach, access to the suprasellar area is free for surgical dissection and retraction of the temporal lobe is unnecessary. In addition, the subfrontal approach allows early access to the suprasellar area without opening the Sylvian fissure (Fig. 2.0.8 C).

The main target region using a subfrontal approach is the suprasellar area with all its surrounding structures. To work within this region in a three-dimensional manner, it is best explained in a geometric way as a virtual pyramid (Fig. 2.0.9). The base of the pyramid is formed by the diaphragma sellae at the level of the frontal

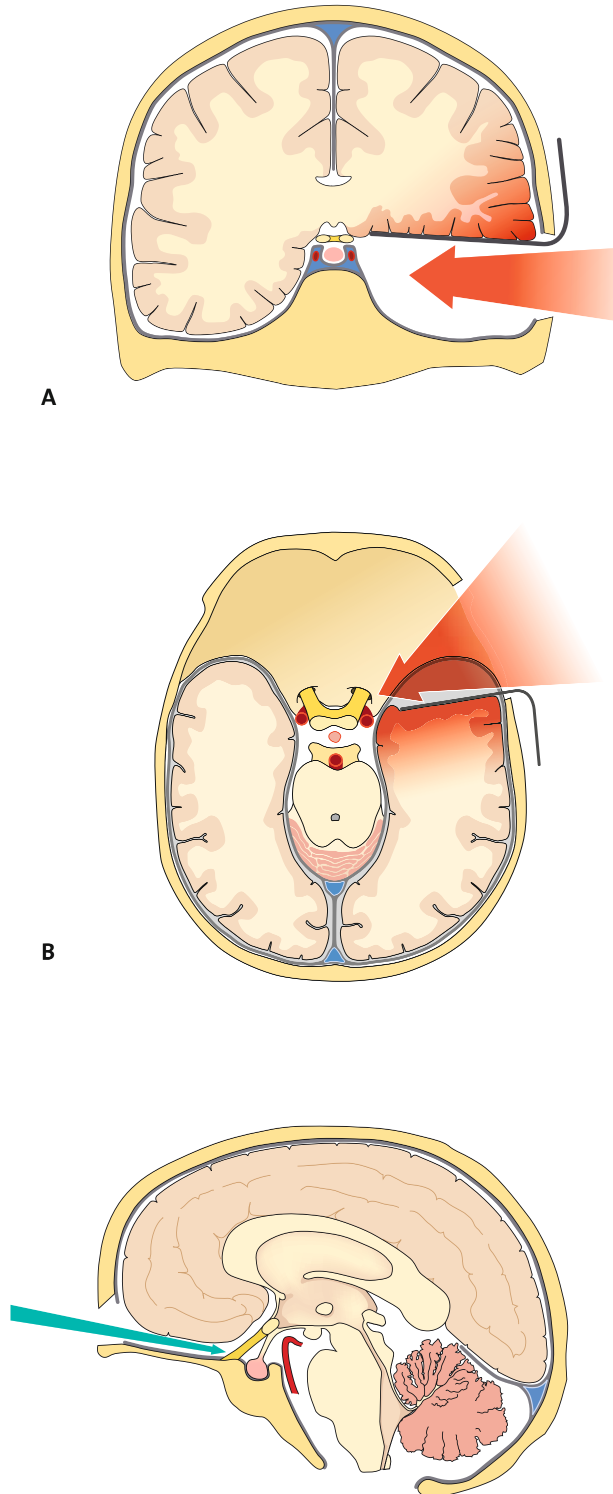
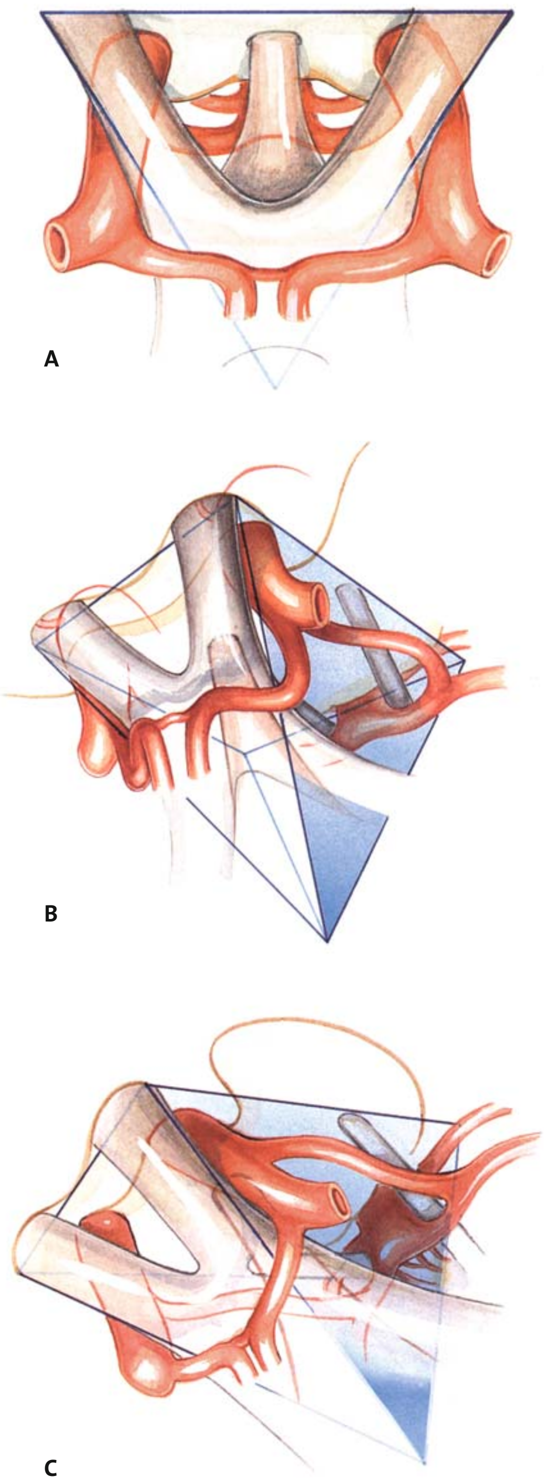


Fig. 2.0.8 *Schematic pictures demonstrating the sellar and parasellar region in the coronar, axial and sagittal planes. Note that when observing the suprasellar area from the lateral subtemporal or frontotemporal pterional direction, the temporal lobe obscures the surgical access (red arrows). Using the anterior subfrontal approach, access to the suprasellar area is free for surgical exploration (green arrow).*

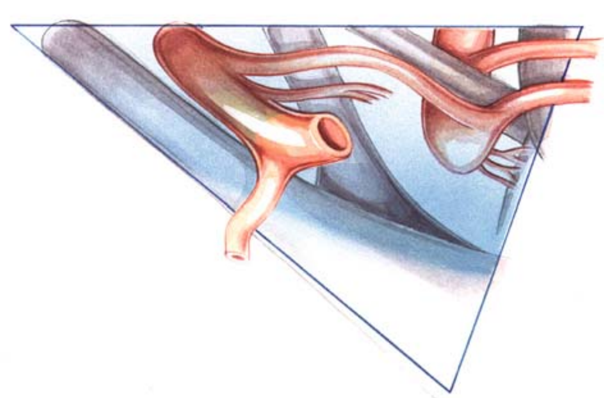
skull base. Each of the triangular planes of the pyramid is defined by certain structures. The anterior plane of the pyramid is formed almost completely by the optic nerves, chiasm and the lamina terminalis. The first segments of both ACA and the ACoA are also in direct relationship to this plane. The side of the pyramid includes the CN II and optic tract, the CN III, the ICA and its two supraclinoid branches, the posterior communicating and anterior choroidal arteries. The posterior pyramidal plane is defined by the ventral surface of the brain stem and BA with the posterior cerebral and superior cerebellar arteries. The axis of the pyramid is formed by the infundibulum and pituitary stalk. This virtual construction enables perception of the various viewing angles into this space; the pyramid and the different windows between its structures can be well approached using different optimal angles. In addition, it also helps to understand how anatomical structures are displaced in the case of a space-occupying lesion within the suprasellar area (Fig. 2.0.9).



A

B

C



D

Fig. 2.0.9 *Artist's drawing demonstrating the suprasellar area as a virtual pyramid from different viewing angles. Note that the same anatomical structures are visualized very differently according to diverse surgical exposures: A) median subfrontal exposure; B) frontolateral supraorbital exposure; C) frontotemporal pterional exposure; D) subtemporal exposure. This virtual construction also helps to understand how anatomical structures are displaced in the case of space-occupying lesions within the suprasellar region.*

Ipsilateral	Midline	Contralateral
Orbital roof Anterior clinoid process, APcL Posterior clinoid process Roof and lateral wall of the CS Basal frontal lobe Gyrus rectus Sylvian fissure Anteromedial temporal lobe Uncus hippocampi CN I, CN II, CN III, CN IV ICA, OphtA, PCoA, AChA, incl. perforators A1, A2, M1, M2, incl. perforators P1, P2, SCA, incl. perforators Superficial temporal vein	Crista Galli Olfactory groove Planum sphenoidale Tuberculum sellae Lamina terminalis Anterior third ventricle Pituitary stalk Interpeduncular fossa ACoA Distal BA with perforators	Orbital roof Anterior clinoid process Basal frontal lobe Gyrus rectus Sylvian fissure Temporal pole Crus cerebri CN I, CN II, CN III ICA, OphtA, PCoA, AChA, incl. perforators A1, A2, M1, M2, incl. perforators P1, P2, SCA, incl. perforators

Table 2.0.1 *Anatomical structures approached through the supraorbital cranitomy.*

Using the supraorbital craniotomy several anatomical structures of the supra- and parasellar area can be exposed (Table 2.0.1). In the following, the surgical technique of the supraorbital subfrontal approach is described as a step-by-step dissection.

Surgical technique

Fig. 2.0.10

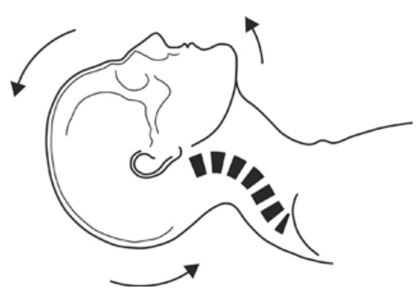


Fig. 2.0.11

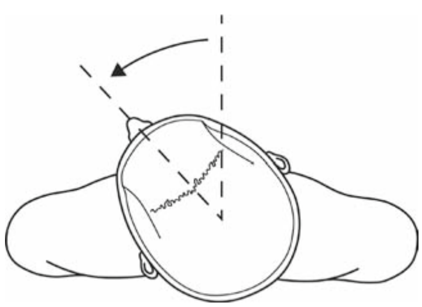


Fig. 2.0.12

Fig. 2.0.13

1. Patient positioning

The patient is placed supine on the operating table. If used, the single pin of the head fixator should be placed in the opposite frontal area to allow free manipulation of the ipsilateral side during the procedure. The pin should not be placed into the temporalis muscle as this diminishes the stability of the system and can cause postoperative temporal hematoma.

Step 1

Initially, the head is elevated ca. 15° and the head of the operating table is elevated above the thorax to facilitate venous drainage. Elevation provides decompression of the cervical vessels, larynx and ventilation tube (Fig. 2.0.10).

Step 2

Retroflexion not only supports gravity-related self-retraction of the frontal lobe but also depends upon the target region and the precise anatomical and pathological situation. Lesions with close proximity to the frontal skull base require a retroflexion of 10°–15°. Structures situated more cranially, such as lesions of the anterior third ventricle can be optimally approached with more head retroflexion of ca. 30° (Fig. 2.0.11).

Step 3

Thereafter, the head is rotated to the contralateral side, the degree of rotation depending on the target region: for the ipsilateral temporomesial area, Sylvian fissure and the MCA, a rotation of ca. 10° to 15° is sufficient. Approaching the lateral suprasellar and retrosellar area with the CN II, ICA, and BA, a rotation of ca. 30° is necessary. For the anterior suprasellar region with structures of the lamina terminalis and ACoA, a rotation of 30° to 45° and for the olfactory groove, 45° to 60° rotation is required. By choosing the correct angle between 30° and 60°, one can also make contralateral lesions visible. Note that right-handed surgeons using a left-sided craniotomy need more rotation to provide an efficient working position (Fig. 2.0.12).

Step 4

As the last positioning step, the head is lateroflected ca. 10° to the contralateral side, allowing an ergonomic working position during surgery (Fig. 2.0.13).

2. Anatomical landmarks and orientation

For the appropriate skin incision, the important anatomical landmarks of the osseous skull, such as the glabella, frontal paranasal sinus, orbital rim, supraorbital foramen, temporal line, frontobasis, impression of the Sylvian fissure and the zygomatic arch are palpated precisely and marked with a sterile pen. Special attention must be given to the course of the superficial neurovascular structures of the frontotemporal region such as the supraorbital nerves and artery, and the frontal branch of the facial nerve (Fig. 2.0.14).

Only thereafter should the borders of the craniotomy be marked, taking into consideration the position of the lesion and the landmarks drawn on the skin. After defining the craniotomy, the individual optimum line of the skin incision is marked with the pen. Usually this skin incision is placed laterally to the supraorbital nerve running within the eyebrow (Fig. 2.0.14). Shaving of the eyebrow is not necessary; for a pleasing cosmetic outcome, the incision line must be placed exactly in the haired area. If the eyebrow is not dominant, the skin incision should be made in a crease or scar of the supraorbital area. Alternatively, an incision behind the hairline is also possible. The eyelids are protected with sensitive tape and the skin and eyebrow disinfected with alcohol solution.

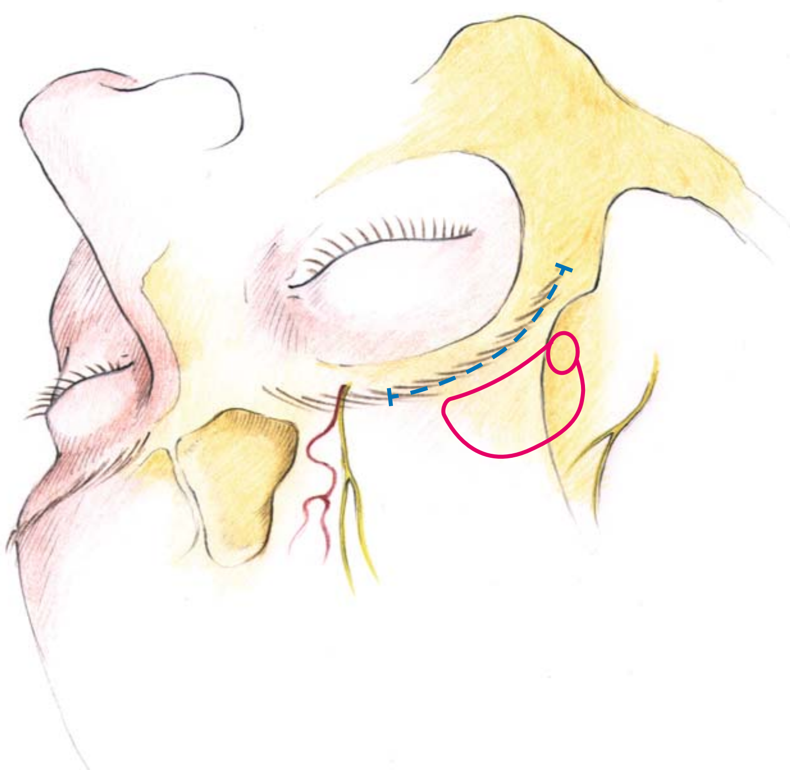


Fig. 2.0.14 *Definition of the craniotomy according to the anatomical landmarks of the frontotemporal region. The skin incision should be made within the eyebrow, giving a pleasing postoperative cosmetic result.*

3. Craniotomy

Step 1

Right side. The skin incision begins laterally from the supraorbital incisura, and is made within the eyebrow, in some cases extending a few millimeters over the lateral projection of the brow into the frontozygomatic area. To achieve a cosmetically optimal result, the incision must follow the orbital rim. Note that the skin incision should not extend medially to the supraorbital nerve so as to avoid frontal numbness. The frontal branch of the facial nerve and the superficial temporal artery never cross this type of skin incision; however, the frontal branch may be temporarily affected postoperatively because of compression due to skin retraction. After skin incision, the subcutaneous tissue should be dissected carefully in a frontal direction (Fig. 2.0.15).

Step 2

The skin flap is temporarily retracted with stitches exposing the frontal belly of the occipitofrontal muscle, the orbicularis oculi and the temporal muscles. Note that the skin flap should be gently pushed upward in an orbital direction to avoid periorbital hematoma; however, the flap should be retracted forcefully downwards in a frontal direction to achieve optimal exposure (Fig. 2.0.16).

Step 3

The frontal muscles are cut with a monopolar electrode knife parallel to the orbital rim and the temporal muscle is stripped from its bony insertion. The temporal muscle is retracted laterally, the frontal muscle upwards with strong sutures (Fig. 2.0.17). Exposure and mobilization of the temporal muscle should be restricted to the necessary minimum to prevent postoperative problems with chewing. Note that the frontal and orbicular muscles should be gently pushed upwards to the orbit. Careful dissec-

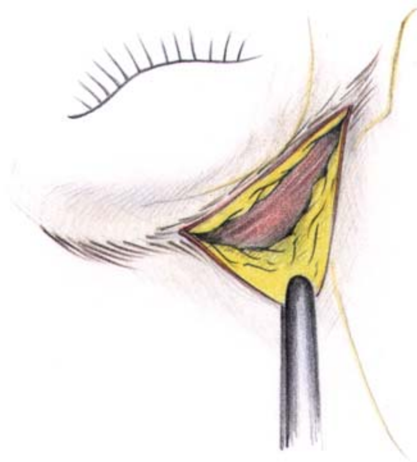


Fig. 2.0.15

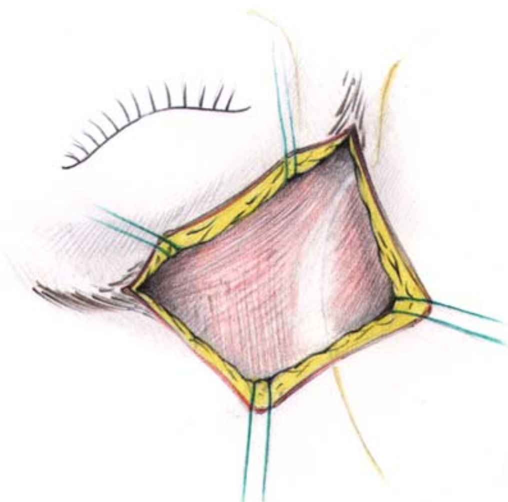


Fig. 2.0.16

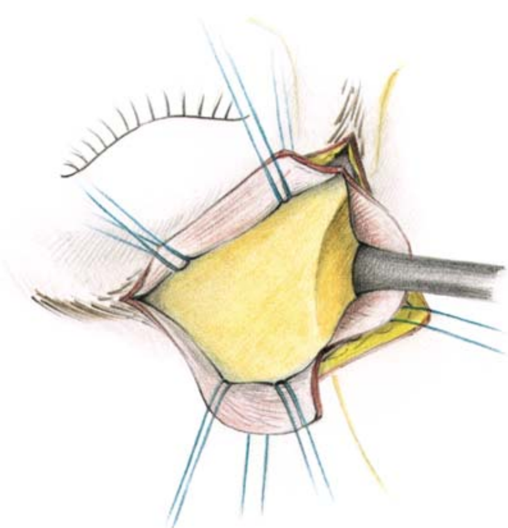


Fig. 2.0.17

Fig. 2.0.18

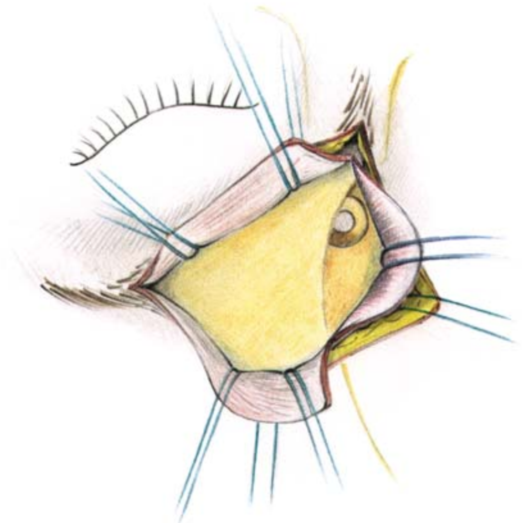


Fig. 2.0.19

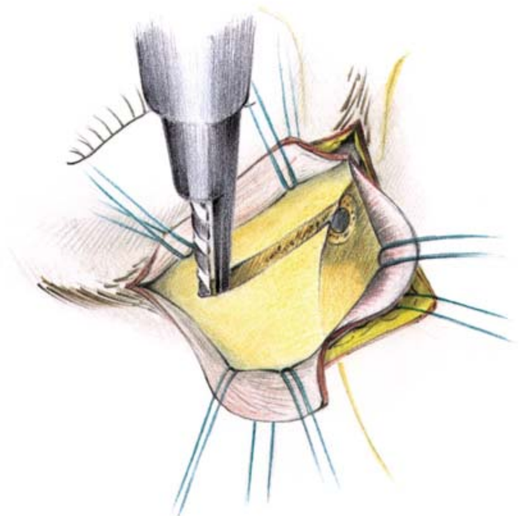
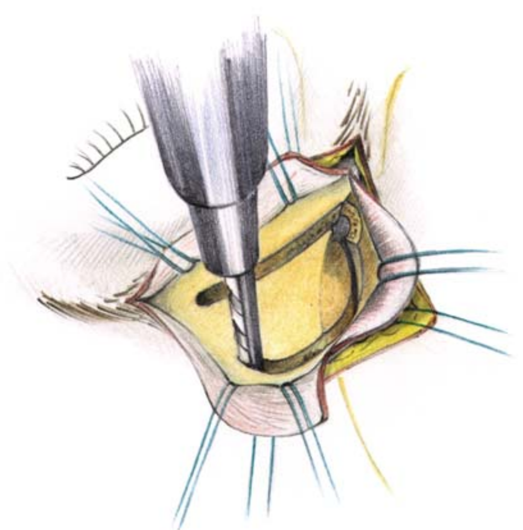


Fig. 2.0.20



tion and minimal retraction of this muscular layer is essential to avoid postoperative periorbital hematoma. Local hemostasis needs to be performed rapidly and with precision.

Step 4

In all cases, an osteoplastic craniotomy is performed. Using a high-speed drill, a single frontobasal burr hole is drilled posterior to the temporal line. Special attention must be given to this burr hole trephination, especially to its relationship to the frontal skull base and to the orbit. Note that after an optimum placement of the burr hole, the drill must be pushed downwards to expose the anterior fossa without penetrating the orbit (Fig. 2.0.18).

Step 5

After minimal enlargement of the hole with fine punches and mobilization of the dura, a straight line is cut with a high-speed craniotome parallel to the orbital rim in a lateral to medial direction, taking into account the lateral border of the frontal paranasal sinus (Fig. 2.0.19).

Step 6

Thereafter a "C" shaped line is cut from the burr hole to the medial border of the previously performed frontobasal line, thus creating a bone flap with a width of ca. 15–20 mm and a frontal extension of ca. 10–15 mm (Fig. 2.0.20). Hemorrhages occurring during the craniotomy can be stemmed by bipolar coagulation and wax.

Step 7

A very important stage of the craniotomy after removal of the bone flap is the high-speed drilling of the inner edge of the bone above the orbital rim under protection of the dura. Careful removal of this inner bone edge can significantly increase the angle for visualization and manipulation. These maneuvers greatly facilitate the use of the operating microscope and microsurgical instruments in the further course of the operation. Small osseous extensions of the superficial orbital roof should also be drilled extradurally to obtain optimal intradural visualization (Fig. 2.0.21).

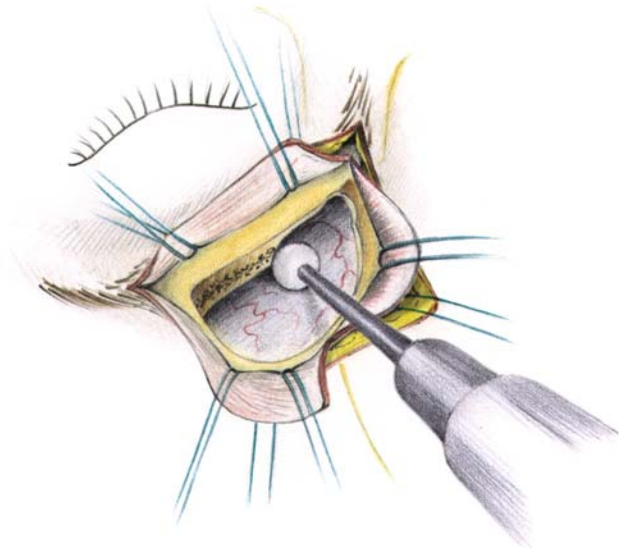


Fig. 2.0.21

Step 8

The dura should be opened in a curved fashion with its base toward to the supraorbital rim (Fig. 2.0.22).

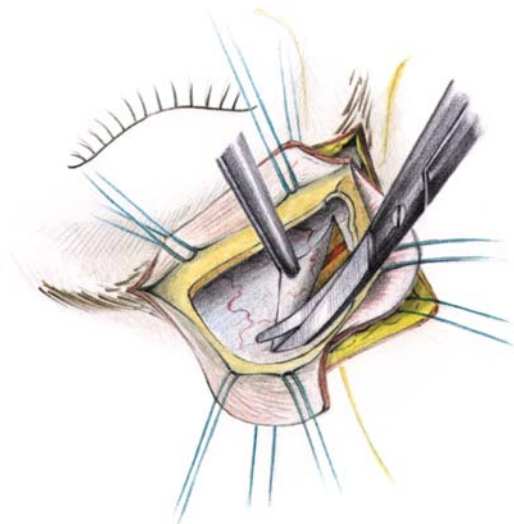


Fig. 2.0.22

Step 9

The free dural flap is fixed upwards with two sutures. Other dural elevation sutures are not required (Fig. 2.0.23).

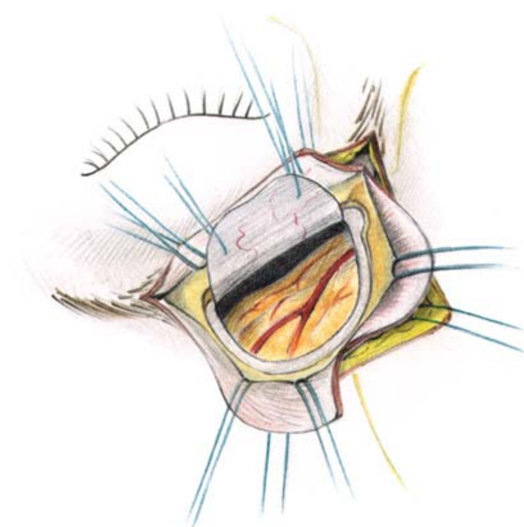


Fig. 2.0.23

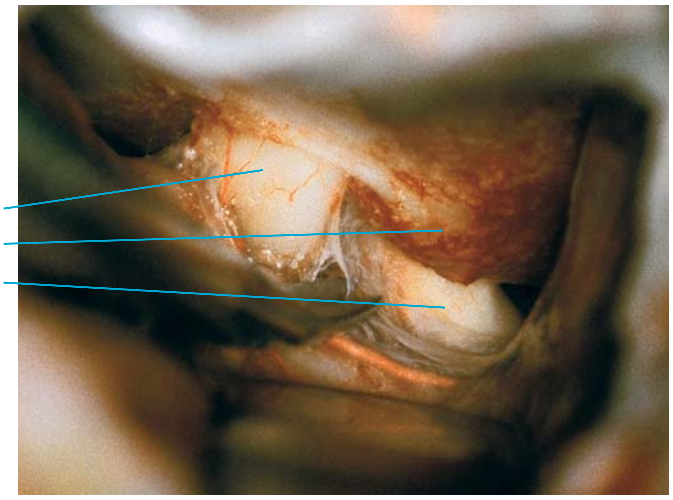


Fig. 2.0.24

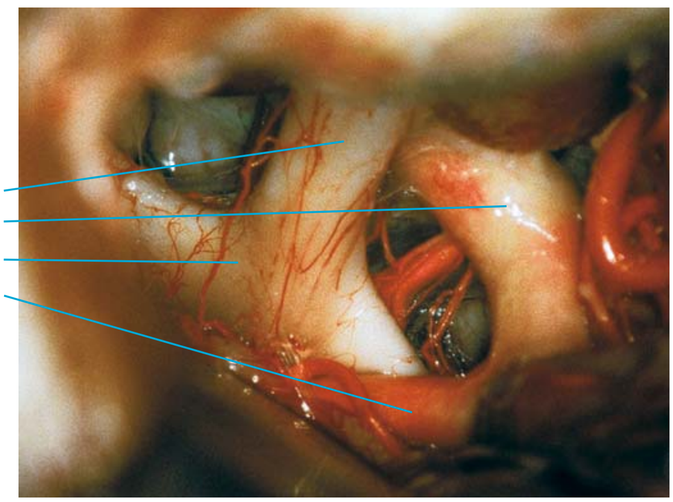


Fig. 2.0.25

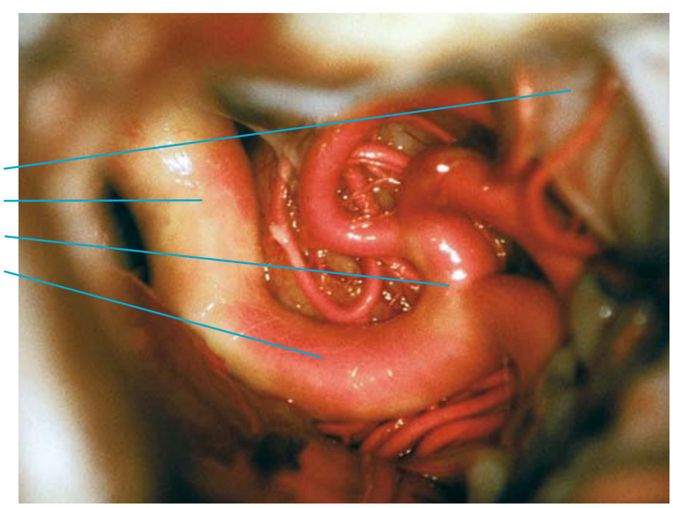


Fig. 2.0.26

4. Intradural dissection

Step 1

Right side. Dissection on fresh human cadaver. Arterial vessels are prepared with red colored latex solution. After opening the dura mater, the first step should be the sufficient drainage of CSF by opening the chiasmatic and carotid cisterns. In the case of high ICP, for example, after massive subarachnoid hemorrhage, the lateral ventricle should be punctured with a ventricular cannula. After removal of the subarachnoidal or ventricular CSF, the frontal lobe deflates spontaneously, rendering significant retraction of the frontal lobe unnecessary. Generally, the self-retaining spatula is left in place as a "brain protector" rather than the brain retractor. Through the subfrontal way the suprasellar region can be immediately approached, without time-consuming and traumatic opening of the Sylvian fissure (Fig. 2.0.24).

Step 2

After dissection of the arachnoid membranes, the anterolateral structures of the suprasellar pyramid are exposed: the ipsilateral CN II, chiasm, and the supraclinoid segment of the ICA and the A1 segment. The frontal lobe is minimally retracted and the INOP and OPCA windows are opened (Fig. 2.0.25).

Step 3

After opening the ipsilateral Sylvian fissure in a medial to lateral direction, the first part of the MCA can be seen. Note that from the subfrontal direction, the M1 segment can be optimally visualized without retraction of the temporal lobe. Splitting of the Sylvian fissure in a medial to lateral direction is time-consuming and less traumatic than the lateral to medial direction, using a frontotemporal pterional craniotomy (Fig. 2.0.26).

Step 4

Dissecting again to the midline, the entire A1 segment can be approached. Note the ACoA and the contralateral A1. The lamina terminalis is also visible. Aneurysms of the ACoA can be well approached via the supraorbital craniotomy, even without removal of the gyrus rectus. Note the Heubner artery on the right side (Fig. 2.0.27).

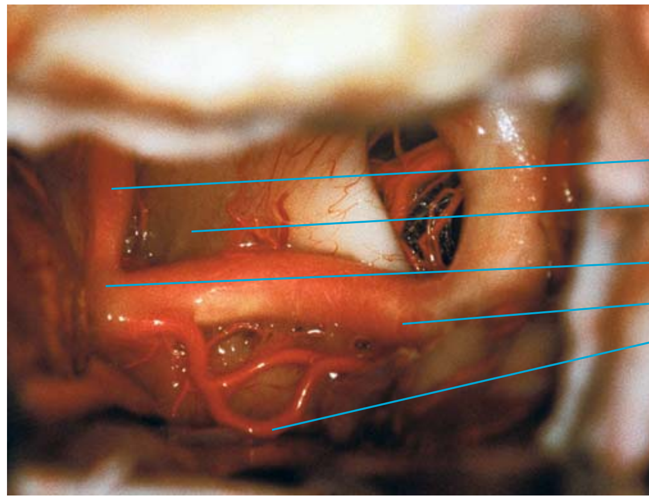


Fig. 2.0.27

Step 5

The dissection is continued in the contralateral direction observing the opposing CN II and ICA. Note the special relationship between the optic nerve and carotid artery and the origin of the OphtA. Medial located aneurysms of the OphtA can be optimally approached through a contralateral subfrontal craniotomy (Fig. 2.0.28).

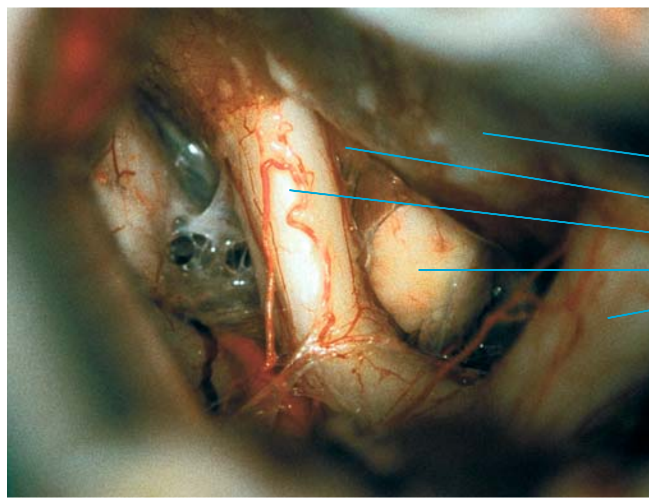


Fig. 2.0.28

Step 6

According to the keyhole concept, the contralateral ICA bifurcation can be also approached through the limited supraorbital craniotomy. The carotid cistern and the Sylvian fissure are opened; note the temporal lobe and the A1 and M1 segments of the opposite side (Fig. 2.0.29).

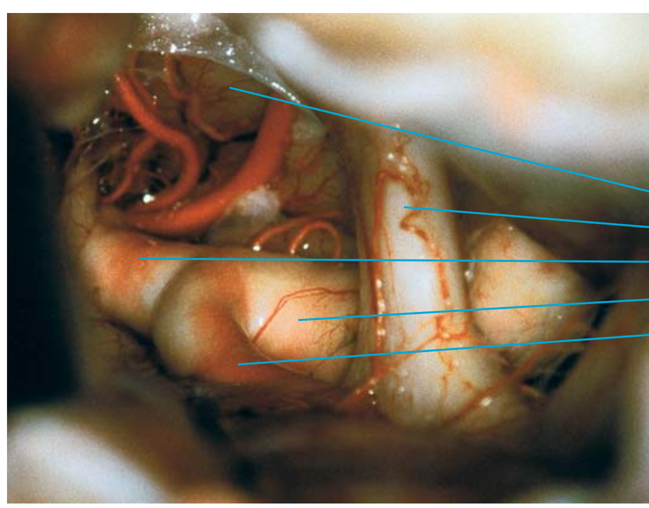


Fig. 2.0.29

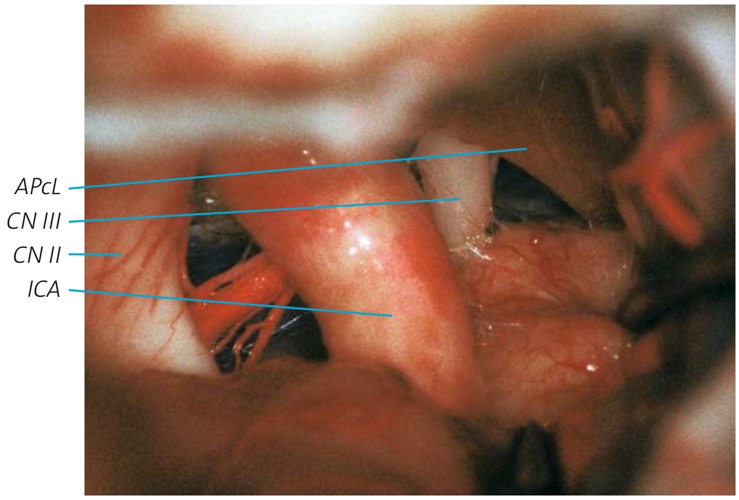


Fig. 2.0.30

Step 7

Using higher magnification, the ipsilateral suprasellar structures are again visualized. Note the anatomical windows between structures of the CN II, ICA, CN III and the anterior petroclinoid ligament. Through these windows the deep-seated prepontine and interpeduncular cisterns can be approached (Fig. 2.0.30).

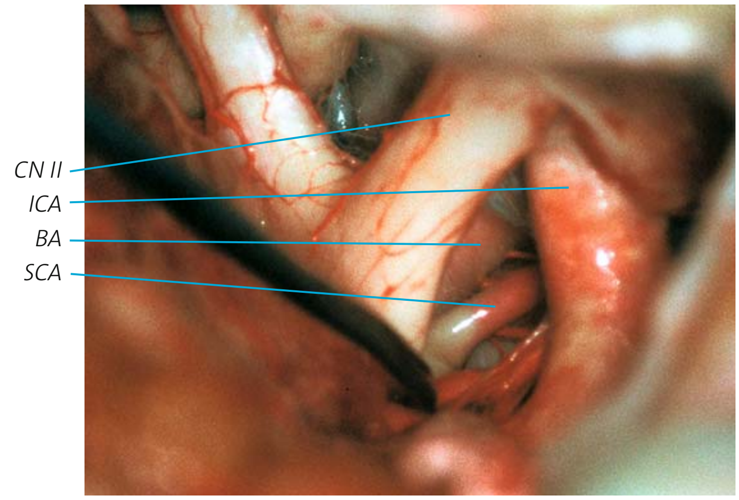


Fig. 2.0.31

Step 8

After further dissection, the deep-seated interpeduncular structures can be approached through the anatomical windows. In this case, the ipsilateral SCA and the basilar trunk are seen through the OPCA window (Fig. 2.0.31).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the subarachnoid space is filled with artificial CSF solution at body temperature. The dural incision is closed watertight using either interrupted or continuous sutures. If dehiscence has developed in the dural opening, a piece of muscle can be sewn into the dural closure. A plate of gelfoam is placed extradurally. The bone flap is fixed with a titanium miniplate, closing the previously performed burr hole trephination. Note that the bone flap should be tightly fixed both medially and frontally to achieve optimal cosmetic results. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with a running suture or sterile adhesive tapes. On account of the limited skin incision and nontraumatic surgical technique, a suction drain is not necessary.

Potential errors and their consequences

- Inadequate preoperative planning and positioning of the patient with subsequent inadequate exposure of the target region and significant deterioration in efficiency of surgically excising the lesion. Planning and positioning is the task of the surgeon!
- The skin incision is performed too medially with consequent injury to the supraorbital nerve and postoperative frontal numbness.
- Penetration of the orbit during burr hole trephination with postoperative orbital hematoma and swelling.
- Overlooked, but rarely unavoidable injury to the dura during craniotomy. Dural reconstrucion may be necessary.
- Penetration of the frontal paranasal sinus. The opening should be closed with wax, periosteal muscle flap or abdominal fat to avoid postoperative CSF leak.
- Penetration of the orbit during extradural removal of osseous extensions of the orbital roof with postoperative orbital hematoma and swelling.
- Inadequate removal of CSF with injury to the frontal lobe due to spatula pressure.
- Injuries to numerous nerves and vessels in the parasellar region during microsurgical manipulation resulting in postoperative neurological deterioration.
- Inadequate intracranial hemostasis with subsequent rebleeding.
- Inadequate dural closure with postoperative CSF leak.

- Inadequate positioning and fixation of the bone flap.
- Inadequate hemostasis in the periorbital region causing postoperative soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning of patients. The reward is an excellent overview of the target area and an efficient working position.
- For simple control of correct positioning of the patient's head, exposing the suprasellar region, note the following trick: the nasoorbital entrance touched by the flat hand should show a horizontal plane (Fig. 2.0.32).
- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and nerves; 2. placement of craniotomy; 3. skin incision.
- If the eyebrow is not dominant, the skin incision should be made in a crease or scar of the supraorbital area. Alternatively, an incision behind the hairline is also possible (Fig. 2.0.33).
- By retracting the soft tissue, the frontal muscle should be retracted downwards with two or three strong sutures to achieve sufficient overview of the frontal bone. Exposure and mobilization of the frontal and orbital muscle upward to the supraorbital rim should be restricted to the necessary minimum to prevent postoperative periorbital hematoma. Soft tissue should be carefully retracted to prevent postoperative necrosis (Fig. 2.0.34).
- Be careful during the burr hole trephination: adequate placement but inadequate direction of the burring procedure may also penetrate the orbit (Fig. 2.0.35).
- Stages of craniotomy (Fig. 2.0.36): 1. burr hole trephination; 2. frontobasal cutting with the craniotome parallel to the orbital rim in a lateral to medial direction; 3. sawing in a semilunar fashion from the burr hole to the medial edge of the former craniotomy line .

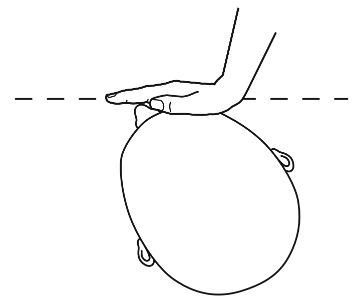
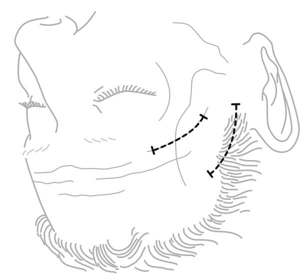


Fig. 2.0.32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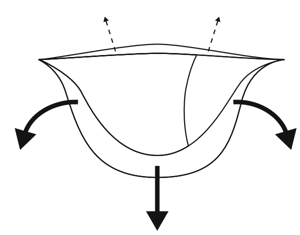


Fig. 2.0.34

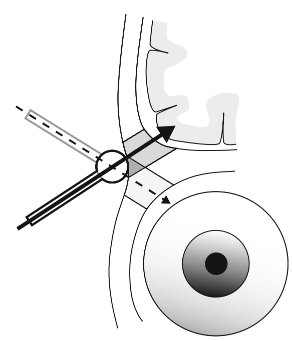


Fig. 2.0.35

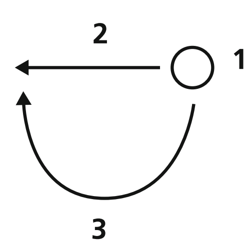


Fig. 2.0.36

- Drilling of the inner edge of the craniotomy after removal of the bone flap is important for limited approaches. Small osseous extensions of the orbital roof should also be carefully removed to provide an excellent overview and to allow microsurgical access to deep-seated sites (Fig. 2.0.37).

- Open the dura in a "C" shaped, semilunar fashion and hold the dural flap towards the supraorbital rim with two sutures (Fig. 2.0.38).

- After completion of the intradural dissection, dural closure should be made watertight using either interrupted or continuous suture. If dehiscence has developed in the dural opening, a piece of muscle can be sewn into the dural closure (Fig. 2.0.39).

- If the frontal paranasal sinus is penetrated, careful closure is required. Bone wax, a flap of galea or abdominal fat tissue can be used for this purpose (Fig. 2.0.40).

- After dural closure, the bone flap should be tightly fixed medially and frontally to achieve optimal cosmetic results. A titanium plate can be used for closure of the burr hole trephination (Fig. 2.0.41).

- The eyebrow skin incision should be closed with intracutaneous running sutures or with sterile adhesive tapes.

- On account of the limited skin incision and nontraumatic surgical technique, a suction drain is not required.

Fig. 2.0.37

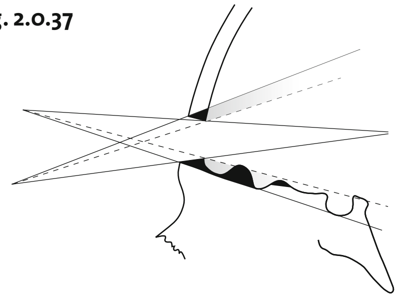


Fig. 2.0.38

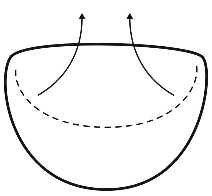


Fig. 2.0.39

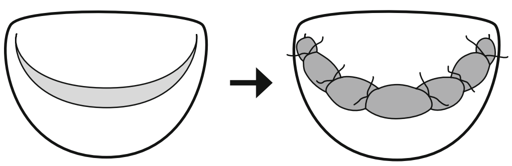


Fig. 2.0.40

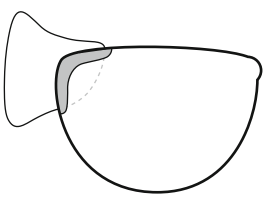
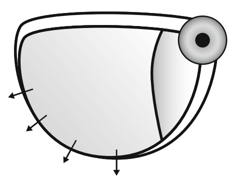


Fig. 2.0.41



2.1 Lateral variation of the supraorbital craniotomy

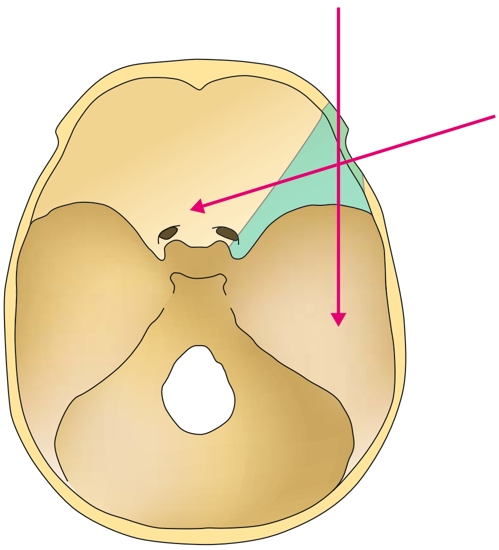


Fig. 2.1.1 *Schematic picture demonstrating the aim of the lateral variation of the supraorbital craniotomy. Removal of the lesser sphenoid wing provides a pterional surgical corridor for broad frontotemporal exploration.*

The essence of the lateral variation of the supraorbital craniotomy is not only the more lateral placement of the keyhole craniotomy but also a partial removal of the lesser sphenoid wing, also exposing the frontal and temporal dura mater (Fig. 2.1.1). The pterional surgical corridor exposes the anteromedial temporal lobe, frontal latero-basal cortex, the Sylvian fissure and the suprasellar pyramid more from the side. This allows safe dissection of the anterior part of the cavernous sinus and the paraclinoid region. Moreover, by removing the anterior clinoid process, the paraclinoid segment of the internal carotid artery can also be exposed without opening the venous chamber of the cavernous sinus.

In the following, the surgical technique of the lateral supraorbital approach is described.

Ipsilateral	Midline	Contralateral
Roof and lateral wall of the orbit Anterior clinoid process Posterior clinoid process Chamber of the CS Latero-basal frontal lobe Sylvian fissure Anteromedial temporal lobe Crus cerebri CN I, CN II, CN III, CN IV CN V, CN VI ICA, OphtA, PCoA, AChA, incl. perforators A1, A2, M1, M2, P1, P2, SCA	Crista Galli Olfactory groove Planum sphenoidale Tuberculum sellae Chiasm Lamina terminalis Pituitary stalk ACoA Distal BA, incl. perforators	Orbital roof Anterior clinoid process Basal frontal lobe Sylvian fissure Temporal pole CN I, CN II, CN III ICA, OphtA, PCoA, AChA A1, A2, M1, M2, P1, SCA, incl. perforators

Table 2.1.1 *Anatomical structures approached through the lateral supraorbital craniotomy.*

Surgical technique

1. Patient positioning

The patient is positioned supine. If used, the single pin of the Mayfield clamp should be placed on the opposite side, allowing free manipulation during surgery. The pins should not be placed in the temporalis muscle to avoid instability of the system and postoperative temporal hematoma.

Fig. 2.1.2

Step 1

With the patient in a supine position, the head is elevated approximately 15° above the level of the thorax. This maneuvre facilitates the cerebral venous drainage and provides effective decompression of the main cervical vessels, larynx and ventilation tube (Fig. 2.1.2).

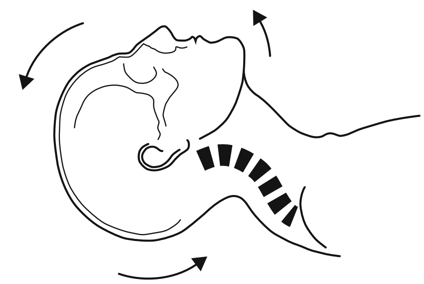


Fig. 2.1.3

Step 2

Ca. 20° retroflexion supports the gravity-related self-retraction of the frontal lobe. As the lateral variation is used for approaching the lateral suprasellar region and the CS, the degree of retroflection is usually less than that for supraorbital craniotomy (Fig. 2.1.3).

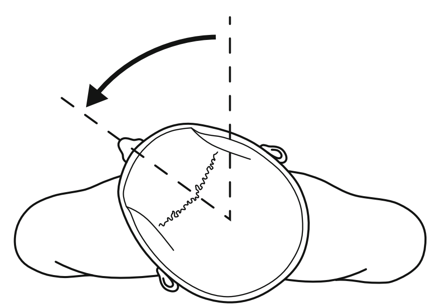


Fig. 2.1.4

Step 3

Thereafter, the head is rotated 30° to 75° to the contralateral side according to the precise location of the lesion. Compared to supraorbital craniotomy, the more pterionally situated lateral variation requires more rotation: for the lateral CS, a rotation of ca. 40° and for the olfactory groove that of 80° is sufficient. Note that right-handed surgeons using a left-sided craniotomy need more rotation to provide an efficient working position (Fig. 2.1.4).

Fig. 2.1.5

Step 4

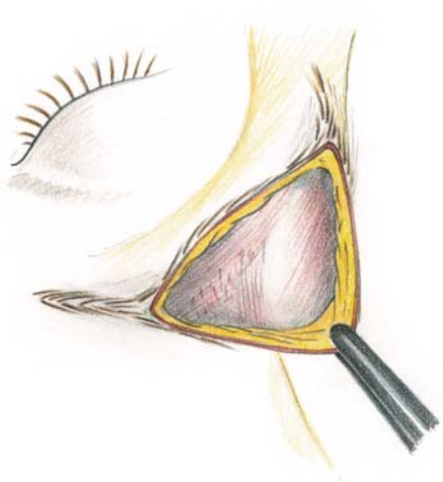
Similar to the supraorbital craniotomy, the head may be lateroflected ca. 10° to the contralateral side, allowing an efficient working position for the surgeon (Fig. 2.1.5).

2. Anatomical landmarks and orientation
For an optimal skin incision, the important anatomical landmarks of the osseous skull such as the glabella, frontal paranasal sinus, supraorbital foramen, temporal line, frontobasis, impression of the lesser sphenoid wing and the zygomatic arch are precisely defined and marked. Note the course of the supraorbital nerves and artery, and the frontal branch of the facial nerve (Fig. 2.1.6).

After positioning, the individual optimum line of the skin incision is marked with the pen, placed 5–10 mm laterally to the supraorbital foramen running within and extending some millimeters over the lateral edge of the eyebrow. The midpoint of this skin incision usually corresponds to the temporal line (Fig. 2.1.6). If the eyebrow appears thin, the laterally placed skin incision may give a suboptimal cosmetic result. In this case the skin incision should be performed behind the frontotemporal hairline or in a prominent wrinkle. The eyelids are protected carefully and the skin is disinfected with alcohol solution.

Fig. 2.1.6 *Definition of the craniotomy according to the anatomical landmarks of the frontotemporal region. The skin incision should be made within the eyebrow, extending some millimeters over its lateral edge. In the case of a thin and non-dominant eyebrow, the incision can be also concealed behind the hairline.*

Fig. 2.1.7

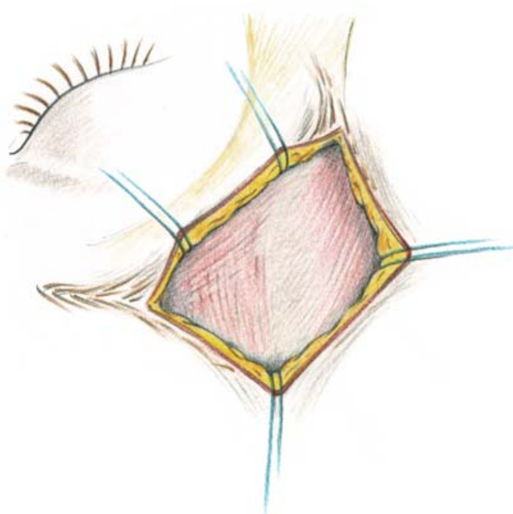


3. Craniotomy

Step 1

Right side. The skin incision begins about 5–10 mm laterally from the supraorbital incisura and is performed within the eyebrow, extending a few millimeters over the lateral projection of the brow into the frontozygomatic area. After skin incision the subcutaneous tissue is dissected in a frontal, frontolateral direction (Fig. 2.1.7).

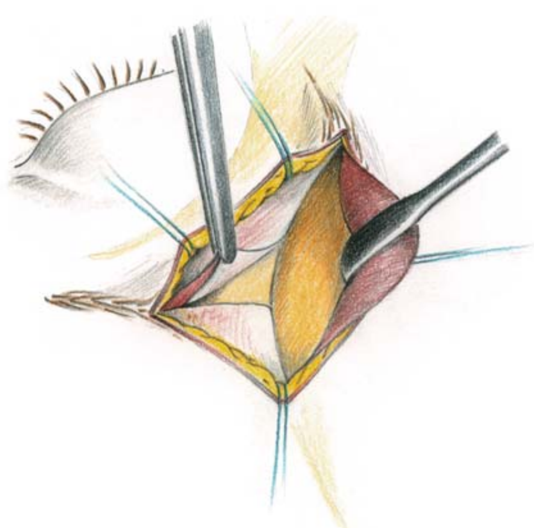
Fig. 2.1.8



Step 2

Thereafter, the flaps are retracted, pushed gently up towards the orbit and retracted strongly downwards in a frontal direction to achieve optimal exposure of the occipitofrontal, orbicular and temporal muscles. Compared with the supraorbital craniotomy, the lateral variant offers more exploration of the temporalis muscle (Fig. 2.1.8).

Fig. 2.1.9



Step 3

The frontal belly of the occipitofrontal muscle is cut parallel to the orbital rim in a medial to lateral direction and the temporal muscle is stripped from its bony insertion with a monopolar electrode knife. Compared with the supraorbital craniotomy, the temporal muscle should be more mobile, allowing exposure of the pterion. Hemostasis should be performed rapidly and with precision (Fig. 2.1.9).

Step 4

The temporal muscle is then forcibly retracted laterally, exposing the impression of the lesser sphenoid wing between the frontal and temporal skull base. The frontal muscular layer is retracted forcefully downwards with strong, careful stitches. After soft tissue dissection, a single frontobasal burr hole is drilled just posterior to the temporal line with a high-speed drill (Fig. 2.1.10).

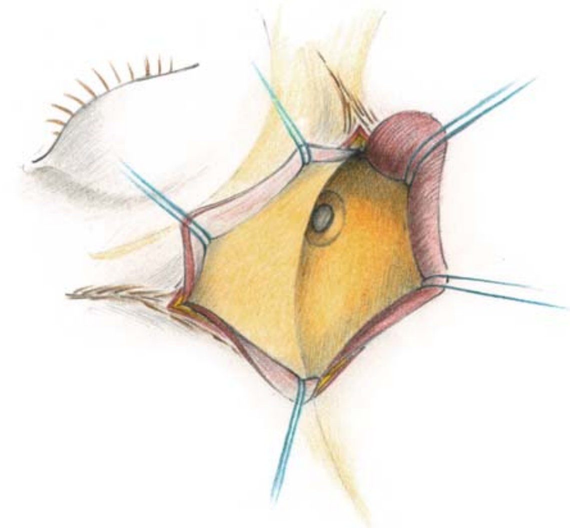


Fig. 2.1.10

Step 5

The hole is enlarged a little with fine punches. After mobilization of the dura mater, a ca. 10 mm long straight line is cut with a high-speed craniotome parallel to the orbital rim in a lateral to medial direction (Fig. 2.1.11).

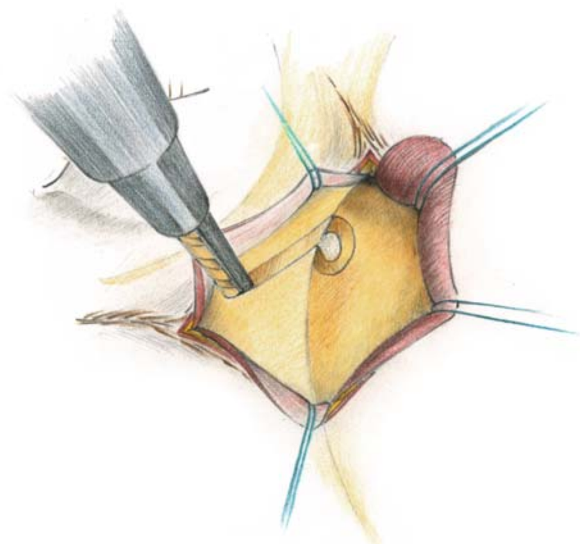


Fig. 2.1.11

Step 6

After the frontobasal cutting, a semicircular line is cut at first laterally from the burr hole, then to the medial border of the previously cut frontobasal line, creating a bone flap with a width of ca. 15–25 mm and a length of ca. 20–30 mm (Fig. 2.1.12).

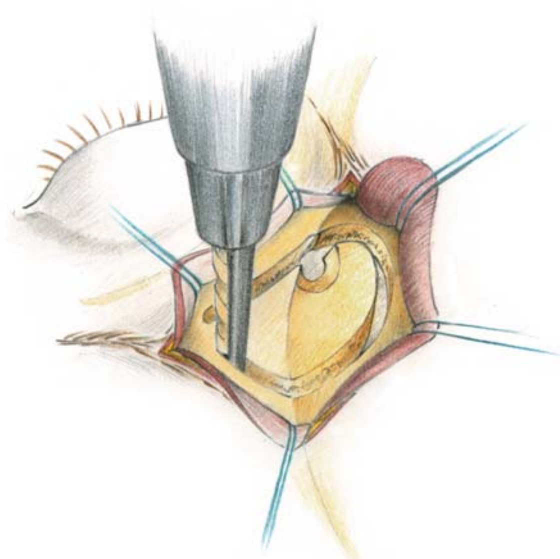
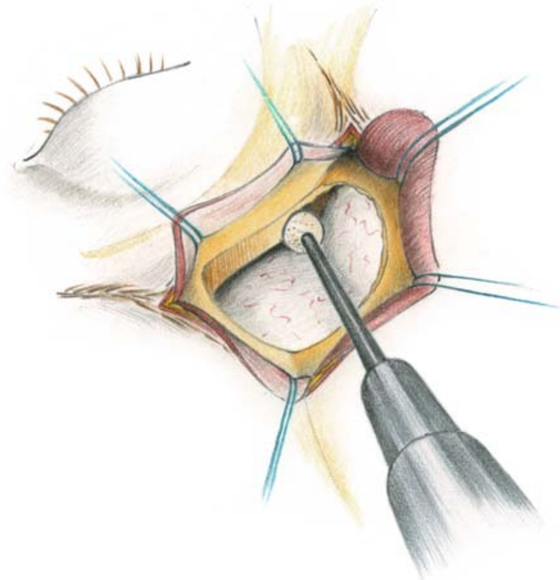


Fig. 2.1.12

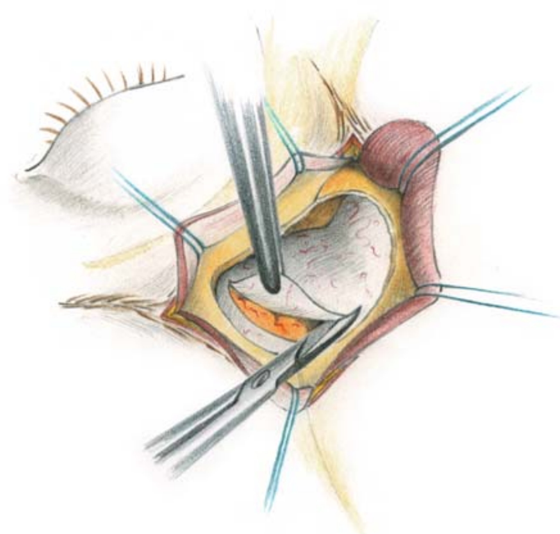
Fig. 2.1.13



Step 7

After removal of the bone flap, the inner edge of the bone above the orbital rim and the lateral part of the lesser sphenoid wing are removed with a high-speed drill exposing the transition between the frontal and temporal dura mater. Small bony protrusions of the orbital roof should also be drilled extradurally to obtain optimal intradural exposure (Fig. 2.1.13).

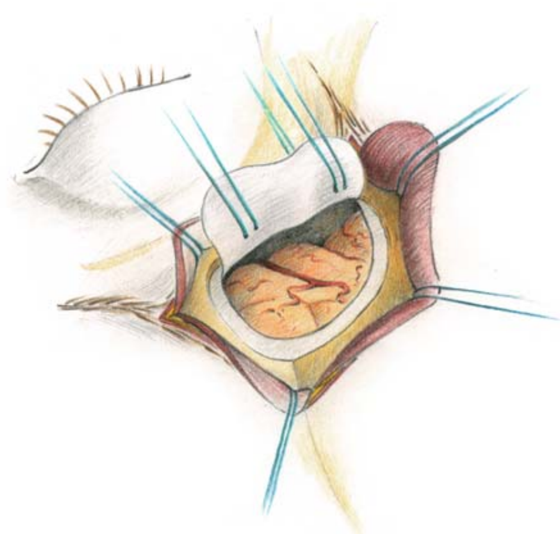
Fig. 2.1.14



Step 8

After exposure of the frontotemporal dura mater, the durotomy should be performed in a curved fashion with its base towards the supraorbital rim exposing the Sylvian fissure between the frontal and temporal lobes (Fig. 2.1.14).

Fig. 2.1.15



Step 9

The frontal and temporal lobes are exposed after opening the dura mater. The dural flap is fixed basally with holding sutures (Fig. 2.1.15).

4. Intradural dissection

Step 1

Right side. Dissection on fresh human cadaver; arterial vessels are filled with red colored latex solution. After withdrawing the bone flap, the lesser sphenoid wing is carefully removed with a fine high-speed diamond drill. After complete removal of the anterior clinoid process, the CN II and the paraclinoid segment of the ICA can be precisely observed. The covering dura mater of the anterior clinoid, which should be kept intact, forms the so-called proximal and distal rings of the carotid artery. The proximal dural ring separates the venous compartments of the CS from the paraclinoid area covering the CN III. The dural sheet of the distal ring encircles the ICA and the CN II and also forms the falciform ligament of the optic nerve (Fig. 2.1.16).

Step 2

After opening the dura mater, the carotid cistern and the medial part of the Sylvian fissure are dissected. After removal of CSF, the frontal and temporal lobes deflate, allowing intradural dissection with minimal brain retraction. Note the opening of the OPCA window with fine microscissors. The frontal lobe is gently retracted with a spatula (Fig. 2.1.17).

Step 3

Observation of the lateral suprasellar pyramid. Compared to the supraorbital craniotomy, the suprasellar structures are visualized more from the lateral side; note the CN II, optic tract, ICA and CN III. Using this lateral-pterional surgical corridor, retraction of the temporal lobe with a dissector is necessary for optimal exposure of the suprasellar region (Fig. 2.1.18).

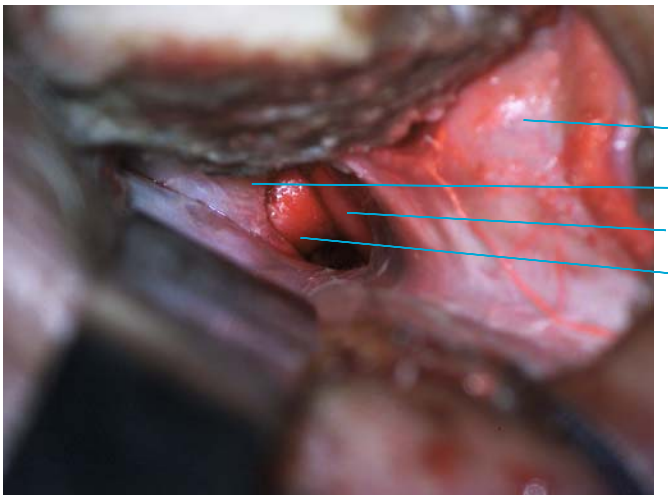


Fig. 2.1.16

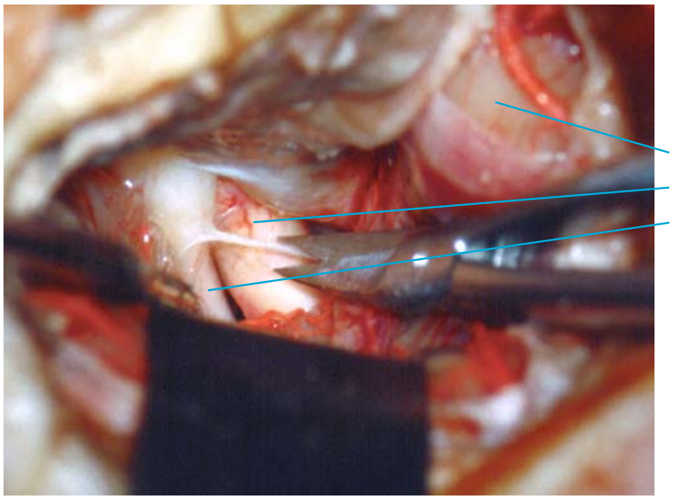


Fig. 2.1.17

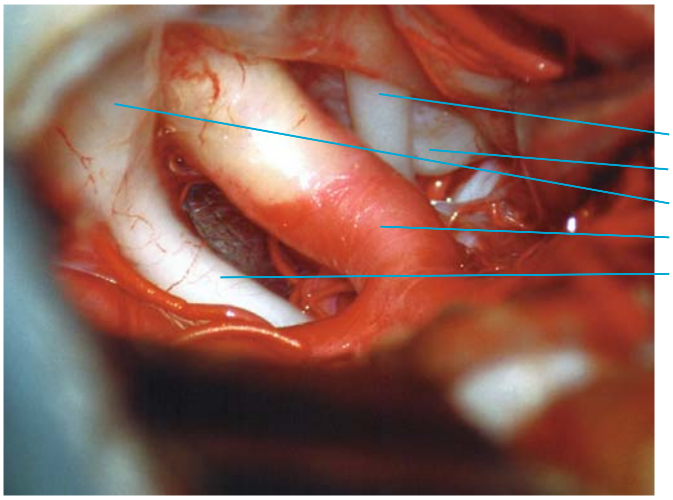


Fig. 2.1.18

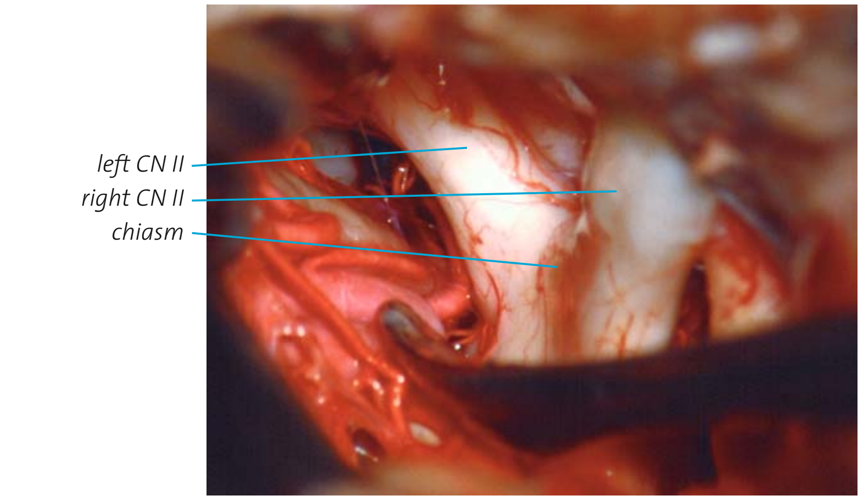


Fig. 2.1.19

Step 4
Dissecting in the medial direction, the chiasm and both optic nerves are observed. Note the contralateral CN II; the dissector is pointing to the ACoA complex and the opposite A1 segment of the ACA (Fig. 2.1.19).

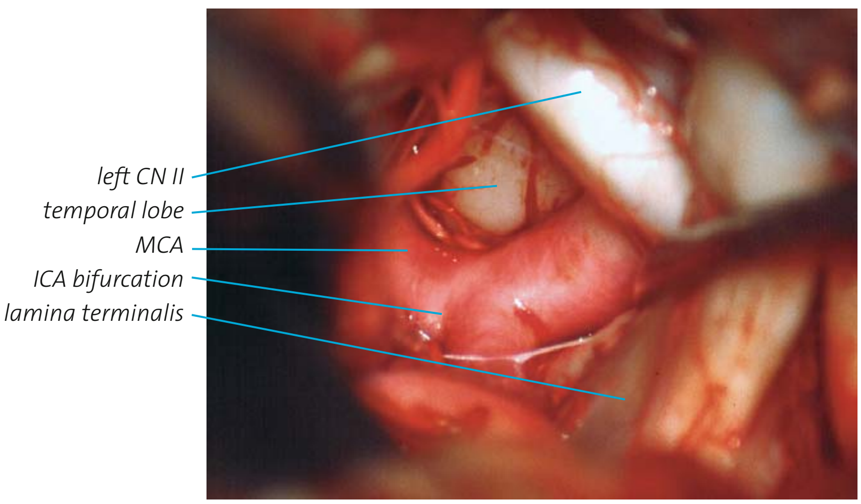


Fig. 2.1.20

Step 5
Observation of the contralateral ICA bifurcation. Through the lateral-pterional approach, the chiasm and the opposite CN II must be retracted to reveal the ICA; a clear disadvantage compared to the subfrontal supraorbital approach. Note the opposing temporal lobe behind the ICA; the MCA disappears within the opposite Sylvian fissure. Note the lamina terminalis (Fig. 2.1.20).

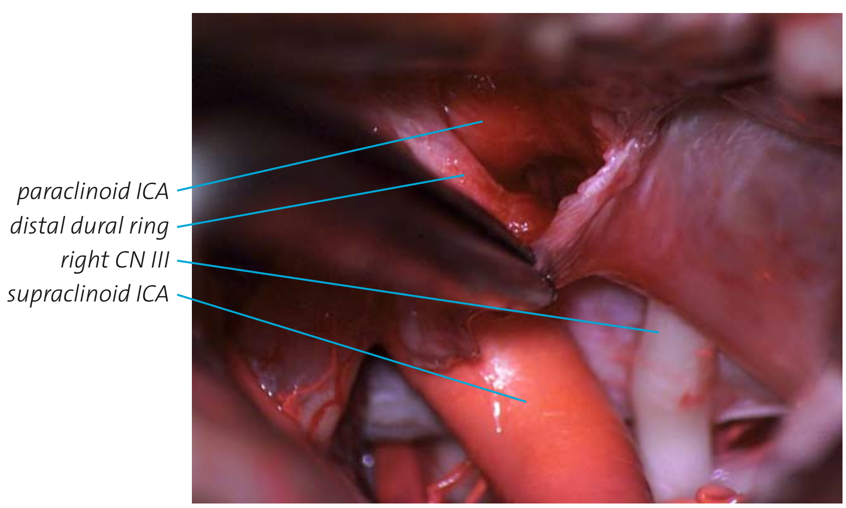


Fig. 2.1.21

Step 6
Approaching again from the ipsilateral side, the covering dura mater of the previously removed anterior clinoid process is incised and retracted with microforceps, allowing a clear depiction of the distal dural ring encircling the ICA. Note the supra- and paraclinoid segments of the ICA and the CN III (Fig. 2.1.21).

Step 7
The roof of the cavernous sinus is opened and retracted medially with microforceps. The proximal ring or so-called carotico-clinoid ligament appears medial to the CN III, closing the venous chamber of the cavernous sinus. Note the paraclinoid ICA and the ICA bifurcation within the subarachnoid space (Fig. 2.1.22).

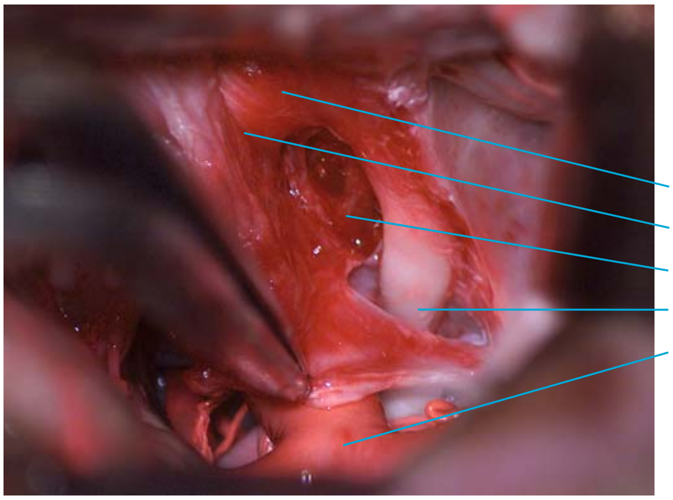


Fig. 2.1.22

Step 8
After resection of the proximal ring and the entire roof of the cavernous sinus, the chamber of the cavernous sinus is opened. Note the supraclinoid, paraclinoid and intracavernous segments of the ICA. The CN III and CN IV disappear into the superior orbital fissure. The BA can be observed within the posterior fossa medial from the subarachnoidal portion of the CN III (Fig. 2.1.23).

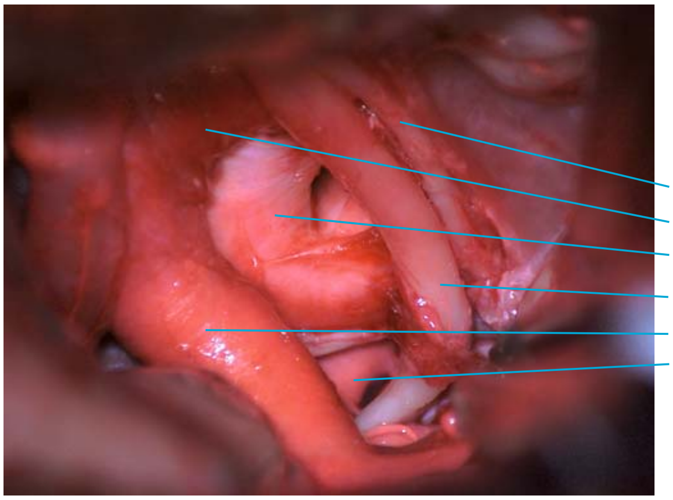


Fig. 2.1.23

Step 9
After partial removal of the lateral dural wall of the cavernous sinus, the posterior knee of the ICA is observed. After gentle retraction of the sensitive CN IV, the venous chamber of the posterior cavernous sinus can be seen. Note the CN III appearing behind the PCA and disappearing into the superior orbital fissure (Fig. 2.1.24).

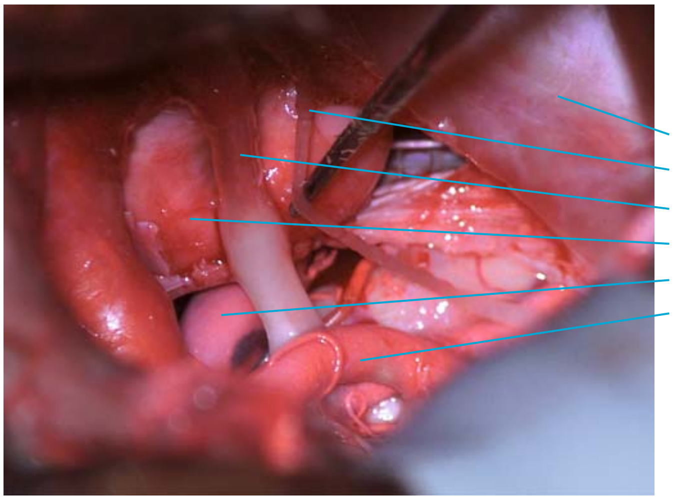


Fig. 2.1.24

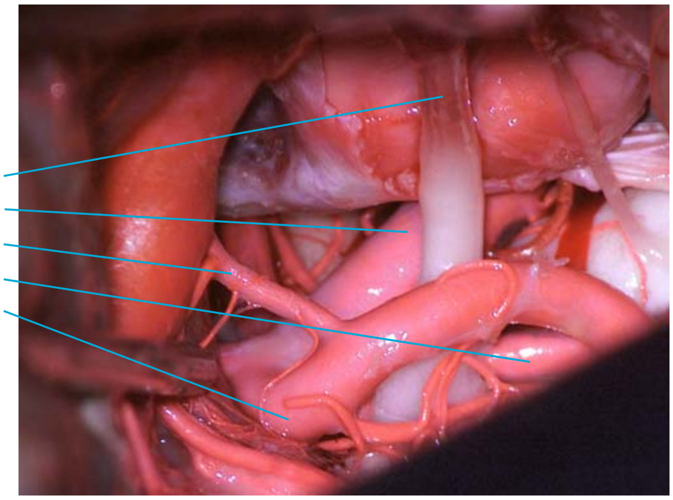


Fig. 2.1.25

Step 10

Observation of the subarachnoidal and intracavernous segments of the CN III after opening the cavernous sinus. Note the SCA, the P1 and P2 segments of the PCA. The PCoA connects the ICA to the PCA; in this case the P1 segment is more prominent than the PCoA. Note the laterally displaced BA within the posterior fossa. The supraclinoid ICA is gently retracted with a microsucker (Fig. 2.1.25).

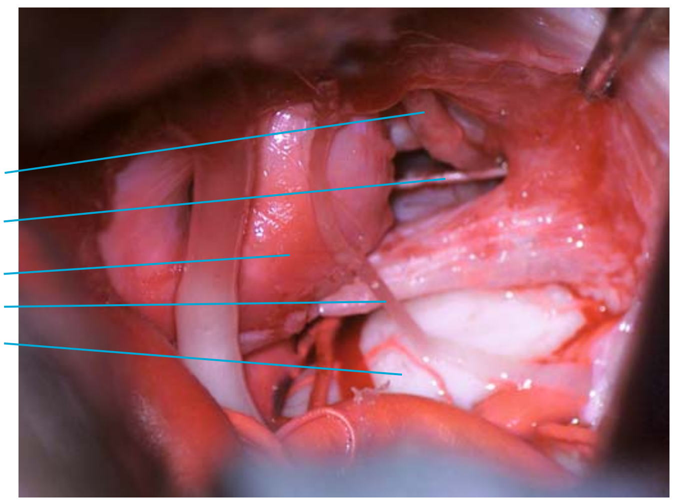


Fig. 2.1.26

Step 11

Observation of the posterior chamber of the cavernous sinus. Note the CN VI running within the Dorello canal, between the clivus and Gruber's petroclival ligament. Behind the clivus, the anterior surface of the pons can also be seen (Fig. 2.1.26).

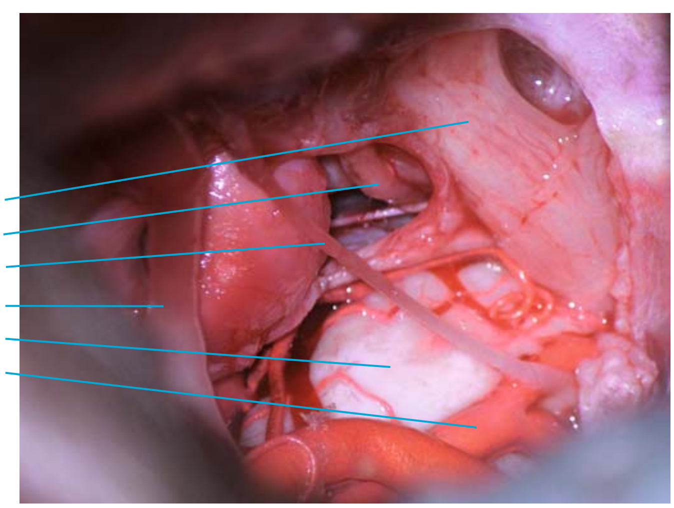


Fig. 2.1.27

Step 12

After additional removal of the lateral sinus wall, the entire cavernous sinus can be approached via the lateral supraorbital craniotomy. Note the intracavernous ICA, CN III, CN IV, CN V and the CN VI. The ventral surface of the pons with the superior cerebellar and posterior cerebral arteries appear in a special transcavernous aspect. Note the division of the SCA near to the CN IV (Fig. 2.1.27).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with artificial CSF and the dura closed with sutures. The closure should be made watertight to avoid postoperative CSF fistula. If tension or dehiscence has developed in the dural plane, a piece of muscle can be sewn into the dural closure. A plate of gelfoam is placed extradurally and the bone flap fixed with a titanium plate. Note that the bone flap should be tightly fixed both medially and frontally to achieve optimal cosmetic results. In the case of large bony defect areas after removal of the lesser sphenoid wing, we often use a large-sized titanium plate avoiding a cosmetically disturbing groove after wound healing within the temporal area. Alternatively, bone cement can be used covering the bony defect. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with a running intracutaneous suture or sterile adhesive tape. No suction drain is necessary.

Potential errors and their consequences

- Insufficient preoperative planning and positioning of the patient with subsequent insufficient exposure of the surgical field and significant deterioration in efficiency of excising the lesion. Planning and positioning is the task of the surgeon!
- The skin incision does not follow the orbital rim causing a suboptimal cosmetic result.
- Penetration of the orbit during burr hole trephination with postoperative orbital hematoma and swelling.
- Inadequate removal of the lesser sphenoid wing with limited temporal extension of the craniotomy and limited exposure of the Sylvian fissure.
- Overlooked, but often unavoidable, injury to the dura during craniotomy. In some cases, implantation of plastic material may be necessary.
- Penetration of the orbit during extradural removal of osseous extensions of the orbital roof and the lesser sphenoid wing with subsequent postoperative orbital hematoma and swelling.
- Inadequate removal of CSF after durotomy with contusion of the frontal or temporal lobe due to spatula pressure.
- Injuries to numerous nerves and vessels within the parasellar region during microsurgical manipulation with postoperative neurological deterioration.

- Inadequate intracranial hemostasis with postoperative rebleeding into the surgical field.
- Inadequate dural closure with a postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap resulting in poor cosmetic results.
- Inadequate hemostasis during wound closure with postoperative soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning of patients. The reward is an excellent overview of the target area and an efficient working position.

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and nerves; 2. placement of craniotomy; 3. skin incision.

- Compared to the supraorbital craniotomy, the lateral supraorbital approach requires more head rotation during positioning (Fig. 2.1.28).

- If the eyebrow is not dominant, the skin incision may be performed behind the frontotemporal hairline or in a skin crease to achieve optimal cosmetic results (Fig. 2.1.29).

- During soft tissue dissection, the frontal muscle should be forcibly retracted downwards in a frontal direction with two or three sutures providing sufficient overview of the frontal bone. Exposure and mobilisation of the frontal and orbital muscles upwards should be restricted to the necessary minimum to prevent postoperative periorbital hematoma. Compared with the supraorbital craniotomy, the temporal muscle must be retracted more forcibly to the lateral side, allowing exposure of the lesser sphenoid wing. However, note careful retraction to prevent postoperative necrosis (Fig. 2.1.30).

- To avoid penetration of the orbit, take care of the placement of the burr hole and direction of the burring procedure (Fig. 2.1.31).

- Stages of craniotomy (Fig. 2.1.32): 1. burr hole trephination; 2. frontobasal cutting parallel to the orbital rim; 3. sawing in a semi-

Fig. 2.1.28

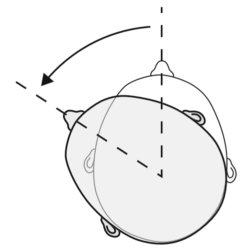


Fig. 2.1.29

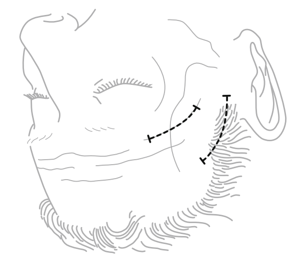


Fig. 2.1.30

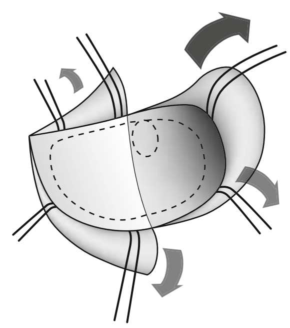


Fig. 2.1.31

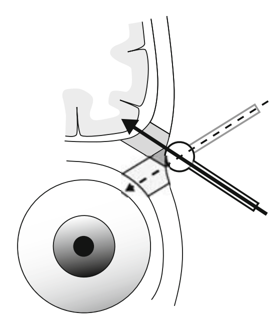
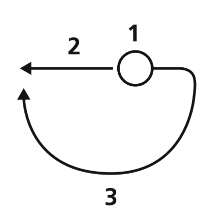


Fig. 2.1.32



circular fashion from the burr hole, at first in a lateral direction then to the medial edge of the first craniotomy line.

- Drilling the lesser sphenoid wing allows a temporal extension of the supraorbital craniotomy (Fig. 2.1.33).
- Extradural drilling of the inner edge of the craniotomy rim and removal of the osseous extensions of the orbital roof offer an increased intracranial view during the later surgical procedure (Fig. 2.1.34).
- Opening the frontotemporal dura in a semilunar fashion is time-consuming but avoids unnecessary exploration of the frontal and temporal lobe (Fig. 2.1.35).
- After completion of the intradural dissection, dural closure should be made watertight to avoid postoperative CSF fistula. If tension or dehiscence has developed in the dural plane, a piece of muscle can be sewn into the dural closure (Fig. 2.1.36).
- According to the laterally placed approach, penetration of the frontal paranasal sinus is uncommon. If it happens, careful closure is recommended with bone wax, a flap of galea or with abdominal fat tissue (Fig. 2.1.37).
- During wound closure, the bone flap should be tightly fixed medially and frontally to achieve optimal cosmetic results (Fig. 2.1.38). In the case of large bony defect areas after removal of the lesser sphenoid wing, one should use a large titanium plate to cover the defect (A). Alternatively, bone cement can be used (B).
- The eyebrow skin incision should be closed with intracutaneous running sutures or with sterile adhesive tapes.
- On account of the limited skin incision and nontraumatic surgical technique, a suction drain is not required.

Fig. 2.1.33

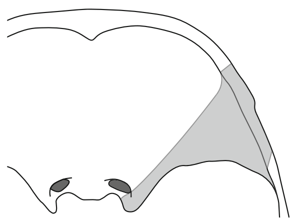


Fig. 2.1.34

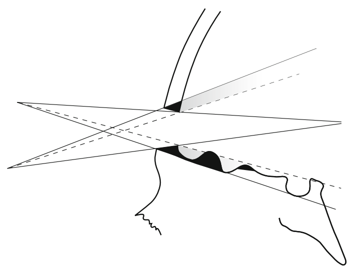


Fig. 2.1.35

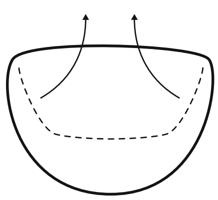


Fig. 2.1.36

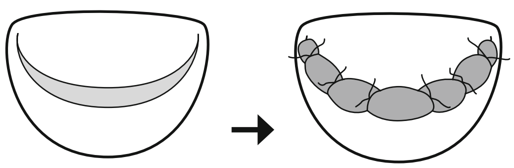


Fig. 2.1.37

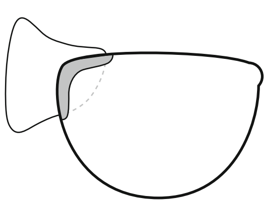
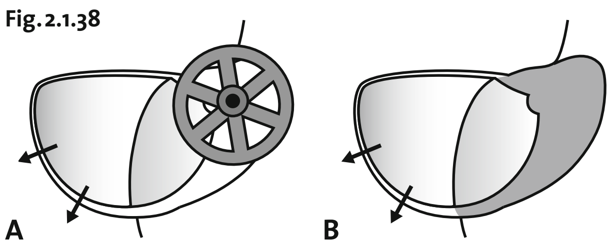


Fig. 2.1.38



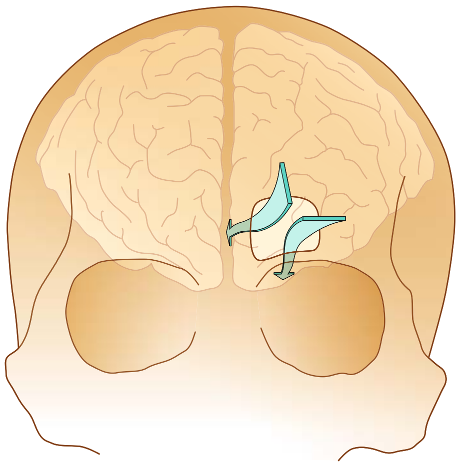


Fig. 2.2.1 *Schematic picture illustrating the goal of the medial modification of the supraorbital craniotomy, namely the possibility of the simultaneous interhemispheric and subfrontal dissection.*

2.2
Medial modification of the supraorbital craniotomy

The goal of the medial modification of the supraorbital approach is the almost paramedian placement of the craniotomy allowing not only a subfrontal surgical view but also an interhemispheric dissection providing simultaneous exposure of the suprasellar and interhemispheric structures (Fig.2.2.1). A disadvantage of this technique is that depending on the patient's individual anatomy, in some cases injury to the supraorbital neurovascular structures and opening of the frontal paranasal sinus are unavoidable. Typical indications for this modification are cases with multiple aneurysms of the anterior circulation combined with distal aneurysms of the anterior cerebral artery.

In the following, the basic surgical technique of the medial supraorbital approach is described.

Ipsilateral	Midline	Contralateral
Orbital roof Anterior clinoid process Basal frontal lobe Sylvian fissure Anteromedial temporal lobe Anterior pontomesencephal junction, crus cerebri CN I, CN II, CN III ICA, OphtA, PCoA, AChA A1, A2, A3, A4, M1, M2, incl. perforators P1, P2, SCA	Crista galli Anterior falx cerebri Olfactory groove Planum sphenoidale Tuberculum sellae Pituitary stalk Lamina terminalis Anterior third ventricle Rostrum corporis callosi Genu corporis callosi Interhemispheric fissure Interpeduncular fossa ACoA Tip of the BA	Orbital roof Anterior clinoid process Basal frontal lobe Sylvian fissure Temporal pole Crus cerebri CN I, CN II, CN III ICA, OphtA, PCoA, AChA A1, A2, A3, A4, M1, M2, incl. perforators P1, SCA

Table 2.2.1 *Anatomical structures approached through the medial supraorbital craniotomy.*

Surgical technique

1. Patient positioning

The patient is positioned supine on the operating table. If used, the single pin of the Mayfield clamp should be placed on the opposite side, allowing free manipulation during surgery. The pins should not be placed in the temporalis muscle to avoid instability of the system and postoperative temporal hematoma.

Fig. 2.2.2

Step 1

As the first step, the head is raised to ca. 15° above the level of the thorax, facilitating venous drainage during surgery. In addition, this maneuver provides decompression of the main cervical vessels, larynx and the intratracheal tube (Fig. 2.2.2).

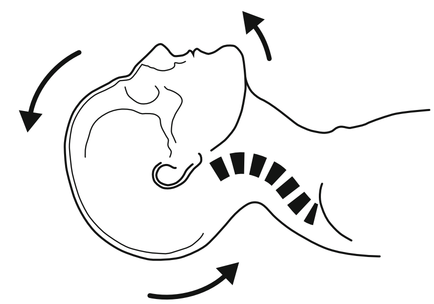


Fig. 2.2.3

Step 2

Thereafter, the head is retroflected by 15° to 45°. Compared to the supraorbital craniotomy, the medial modification requires more retroflection according to the precise location of the interhemispheric target point. Lesions close to the frontal skull base, such as proximal aneurysms of the A2, require a retroflexion of ca. 15°. Structures situated more cranially, such as distally situated aneurysms of ACA, need a retroflexion up to 45° (Fig. 2.2.3).

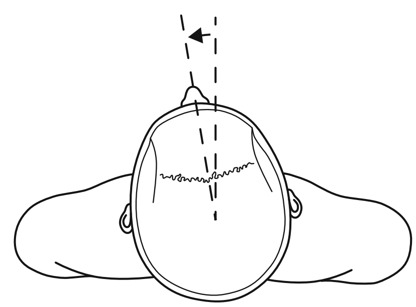


Fig. 2.2.4

Step 3

A slight rotation to the contralateral side is necessary offering an efficient working position during surgery; however, more than ca. 10° rotation should be avoided to allow a nontraumatic retraction of the interhemispheric fissure. Note that right-handed surgeons using a left-sided craniotomy need more rotation to provide an efficient working position (Fig. 2.2.4).

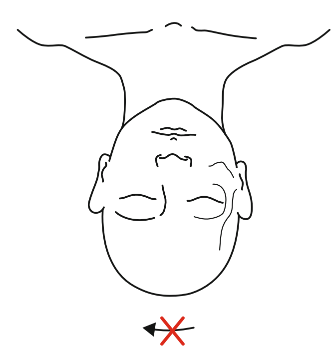


Fig. 2.2.5

Step 4

According to the interhemispheric dissection, lateroflexion of the head is not required (Fig. 2.2.5).

2. Anatomical landmarks and orientation

After positioning, the important anatomical landmarks of the osseous skull, such as the midline, glabella, frontal paranasal sinus, supraorbital foramen, orbital rim, temporal line and the frontobasis are precisely defined and marked with a sterile pen. Note the superficial neurovascular structures, especially the course of the supraorbital nerves and artery (Fig. 2.2.6). Craniotomy is then determined based upon these anatomical structures and the surgical target. The correct line of the skin incision depends not only on the exact site und size of the craniotomy but also on the physiognomy of the patient: the individual form of the eyebrow, wrinkles of the forehead or the frontal hairline. In this way, the skin incision can be made within the eyebrow, a wrinkle or scar on the face, or even bifrontally behind the hairline providing a pleasing cosmetic postoperative outcome. The eyelids are protected with sensitive tapes and the skin is carefully disinfected.

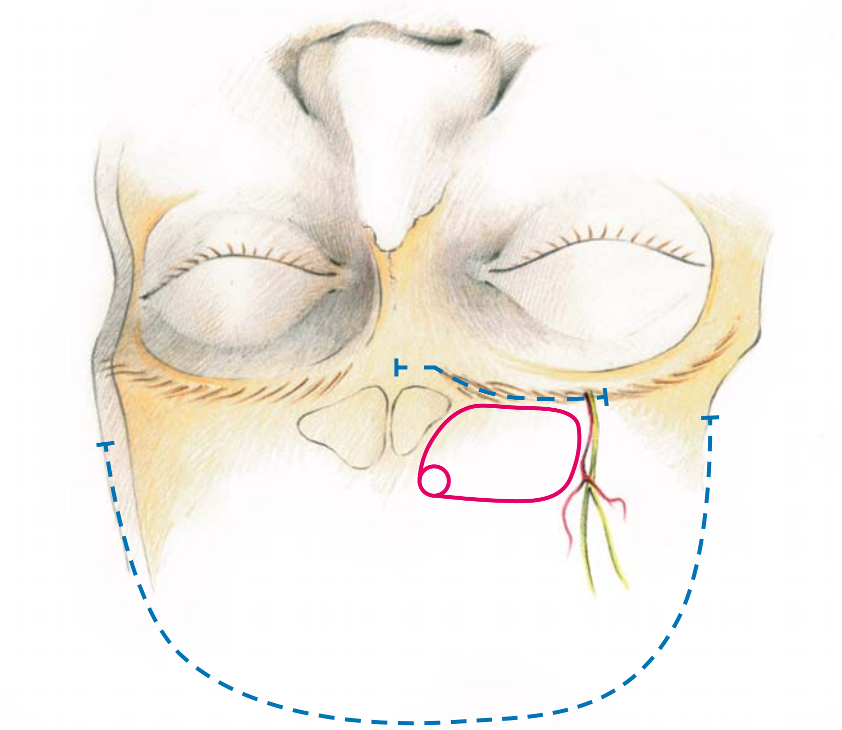


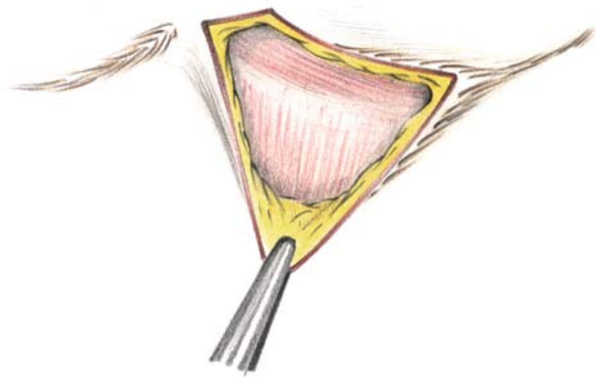
Fig. 2.2.6 *Despite a paramedially placed craniotomy, opening of the frontal paranasal sinus can be principally avoided. In cases with an extended frontal sinus, the craniotomy should be placed more apically or even a transfrontal-sinus approach can be performed. According to patient's individual appearance, the skin incision can be performed within the eyebrow or bifrontally behind the hair line.*

3. Craniotomy

Step 1

As mentioned above, the skin incision should be made according to the individual physiognomy of the fronto-orbital face. In most cases, an eyebrow incision is made with an extension in a wrinkle of the glabellar region. The subcutaneous tissue is dissected downwards in a frontal direction, exposing the orbicular oculi and frontal muscles. In the case of a thin and nondominant eyebrow, the incision can be performed within a wrinkle or concealed behind the hairline performing a bicoronar skin incision. Right side (Fig. 2.2.7).

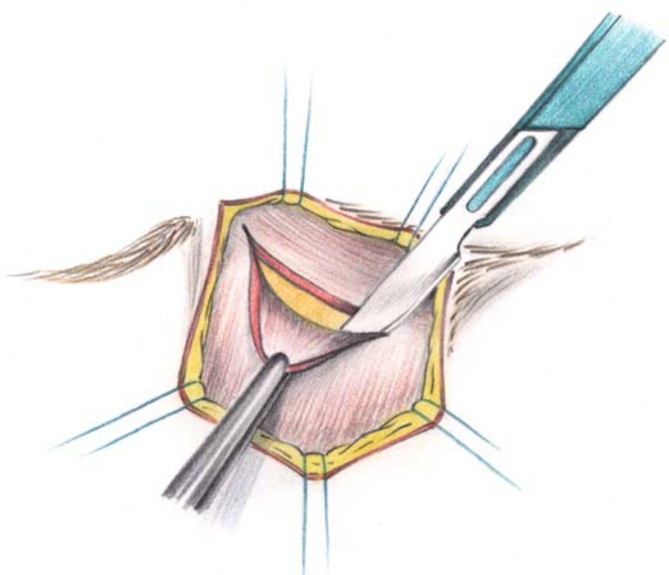
Fig. 2.2.7



Step 2

After performing a cosmetically suitable incision, the skin flaps are temporarily retracted with holding sutures. The frontal belly of the occipitofrontal muscle is incised parallel to the orbital rim, then retracted frontally exposing the frontal bone (Fig. 2.2.8).

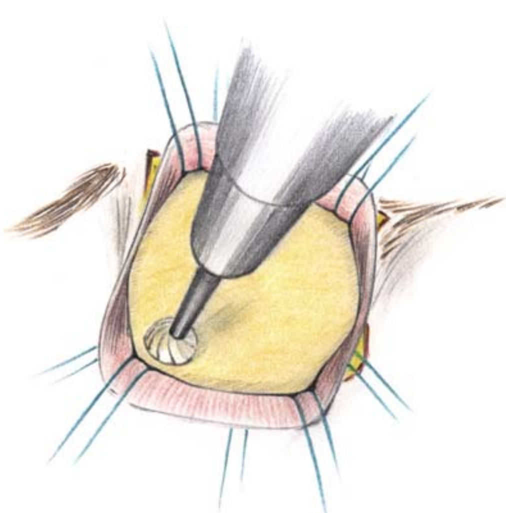
Fig. 2.2.8



Step 3

When exposing the bony surface, note that retraction of the frontal muscular layer in both the medial and frontal direction should be done firmly, allowing optimal exposure of the bony surface, but gently in the orbital direction to avoid severe postoperative periorbital hematoma. After soft tissue retraction, a single frontobasal burr hole is drilled frontally in the median-paramedian plane (Fig. 2.2.9).

Fig. 2.2.9



Step 4

After minimal enlargement of the hole with fine punches and movement of the dura, a high-speed craniotome is used to saw in an orbital direction. According to the extension of the frontal paranasal sinus and to the form of the orbital rim, the saw line is continued in a medial to lateral direction, taking into account the upper border of the frontal sinus (Fig. 2.2.10).

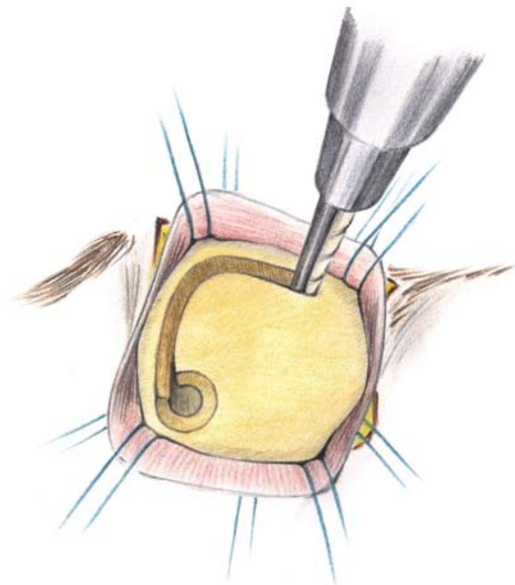


Fig. 2.2.10

Step 5

Thereafter a curved line is sawed from the burr hole to the lateral border of the previously performed frontobasal cutting, thus creating a bone flap with a width of about 20–25 mm and a height of about 15–20 mm. If the frontal paranasal sinus was opened, plastic closure is necessary after completion of the intracranial procedure (Fig. 2.2.11).

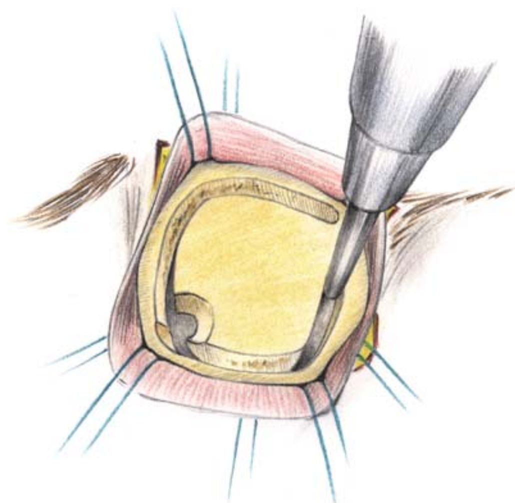


Fig. 2.2.11

Step 6

An important step of the craniotomy after removal of the bone flap is the high-speed drilling of the inner basal margin of the bone above the orbital rim without opening the frontal paranasal sinus. In some cases, prominent extensions of the orbital roof should be also removed with a high-speed diamond drill. With careful removal of this inner bone edge, the angle for visualization and manipulation can be significantly increased (Fig. 2.2.12).

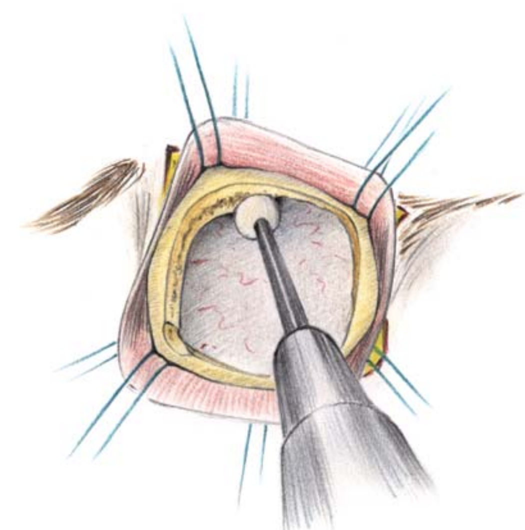
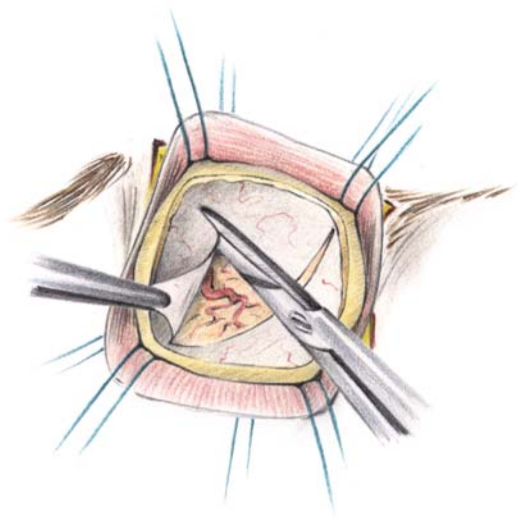


Fig. 2.2.12

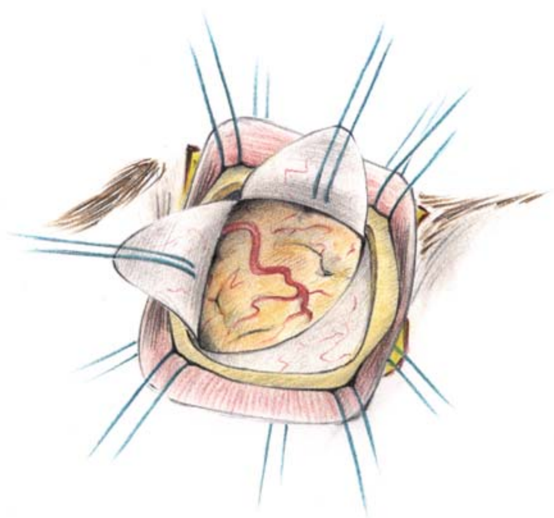
Fig. 2.2.13



Step 7

The dura should be opened in a "T" shaped fashion allowing both supraorbital and inter-hemispheric dissection (Fig. 2.2.13).

Fig. 2.2.14



Step 8

The free dural flaps are fixed upwards and in a medial direction with sutures. With the limited craniotomy, other dural lifting sutures are not required (Fig. 2.2.14).

4. Intradural dissection

Step 1

Right side. Dissection on fresh human cadaver; arteries are filled with colored solution. After opening the dura mater, the anterior suprasellar region is exposed. The first step is the efficient drainage of CSF by opening the arachnoid membranes with microsurgical instruments. Note the CN II and the arachnoid membranes of the carotid cistern (Fig. 2.2.15).

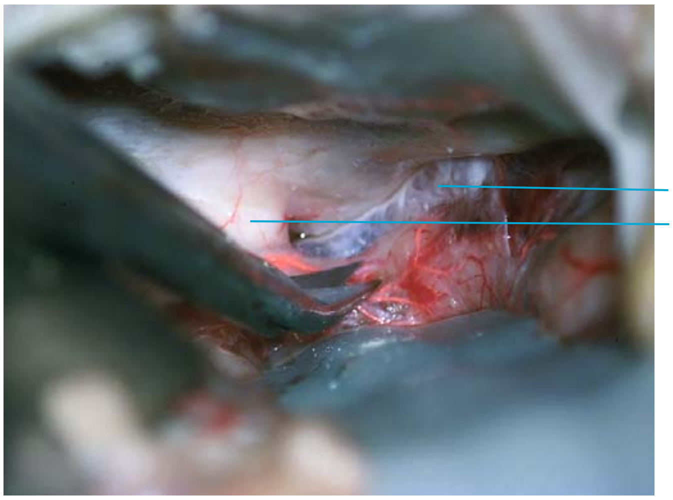


Fig. 2.2.15

Step 2

After removal of CSF, the frontal lobe is gently retracted. Due to the significant retroflexion and removal of CSF, the frontal lobe subsides, hereby keeping retraction of the frontal lobe to the necessary minimum. After opening the chiasmatic and carotid cisterns, the right CN II, ICA and A1 segment of the ACA are exposed. The Sylvian fissure is not yet opened; note that the frontal and temporal lobes cover the MCA. Note the lateral aspect of the optic tract (Fig. 2.2.16).

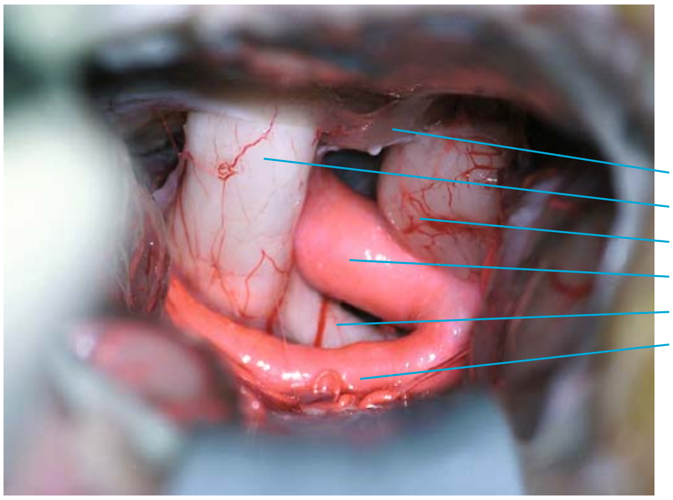


Fig. 2.2.16

Step 3

After opening the medial part of the Sylvian fissure and mobilization of the temporal lobe, the lateral part of the suprasellar region is observed. Lateral from the CN III, the posterior fossa can be seen with the anterior surface of the pons. Note the PCA and SCA, the posterior clinoid process and the roof of the cavernous sinus medially from the CN III. The ICA is retracted medially with a fine microdissector (Fig. 2.2.17).

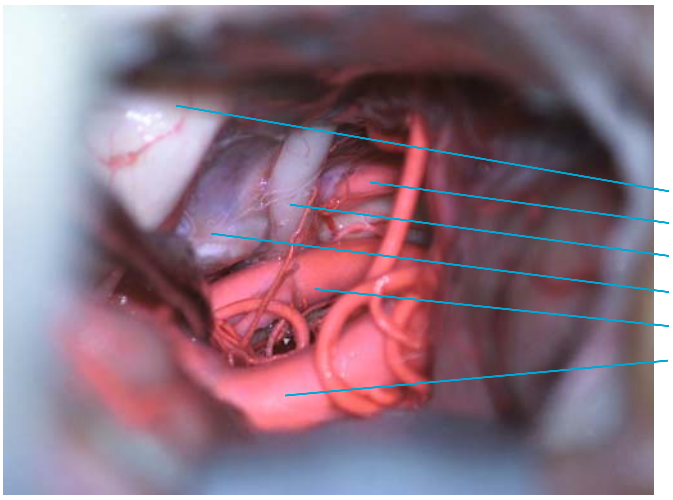


Fig. 2.2.17

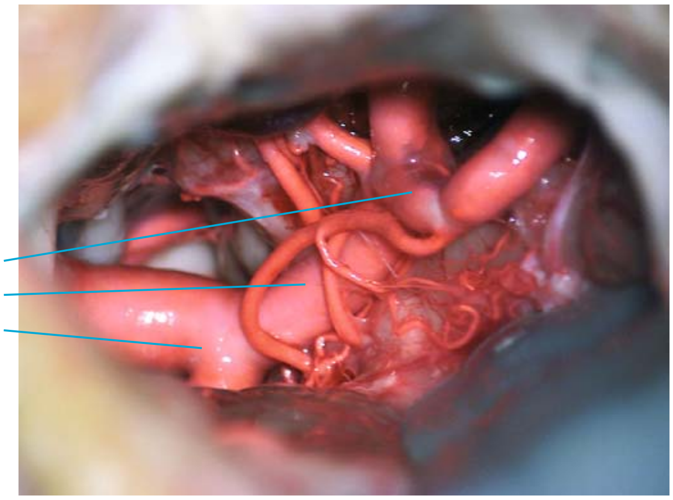


Fig. 2.2.18

Step 4

Dissecting from a medial to lateral direction, the ipsilateral Sylvian fissure is opened. Note the M1 segment and bifurcation of the right MCA. In this subfrontal technique, retraction of the temporal lobe is not necessary for approaching the MCA (Fig. 2.2.18).

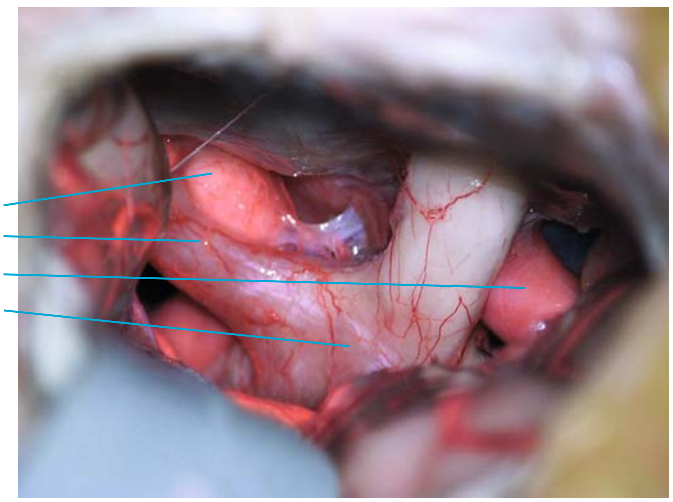


Fig. 2.2.19

Step 5

Dissecting again in a medial direction, the anterior suprasellar region is seen via the subfrontal route. Behind the optic nerves, both ICA are well seen and the medial surface of the contralateral ICA can be approached through the INOP window. Note the frontal skull base and the optic chiasm (Fig. 2.2.19).

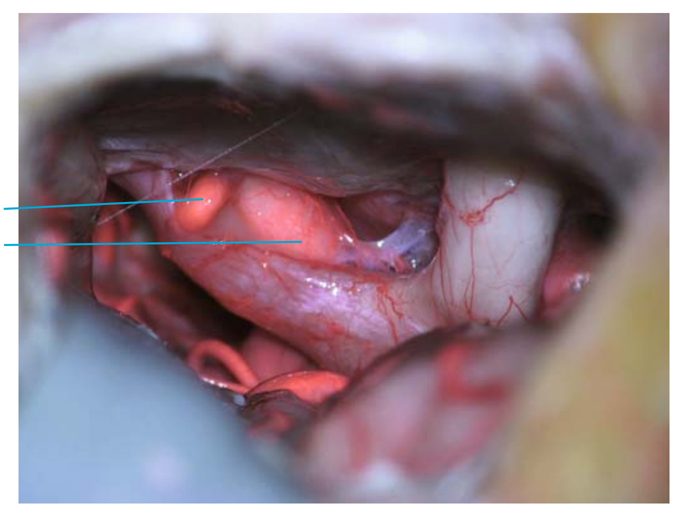


Fig. 2.2.20

Step 6

After further retraction of the frontal lobe, the opposite CN II is seen. Note the left ICA and ophthalmic artery, approached through a right-sided craniotomy. In this case a loop of the OphtA causes severe vascular compression of the left CN II (Fig. 2.2.20).

Step 7

After finishing the subfrontal dissection, the frontal lobe is gently moved from the medial to lateral and the interhemispheric fissure is carefully opened via the paramedian created craniotomy (Fig. 2.2.21).

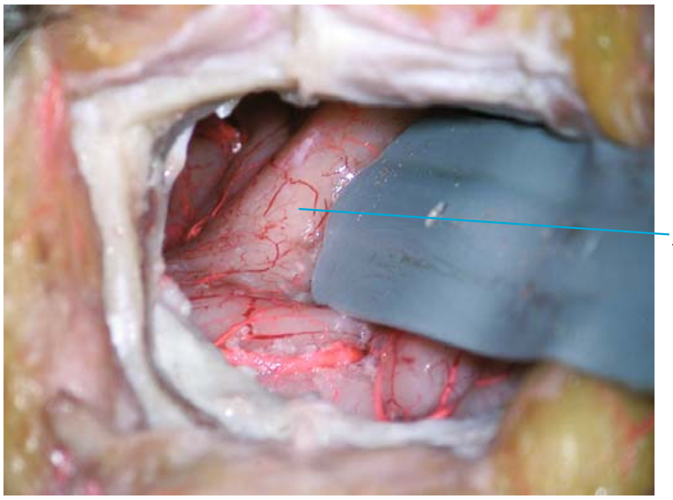


Fig. 2.2.21

Step 8

With further opening of the interhemispheric fissure, the distal course of the ACA can be attained. Note the A2-A3 segments running around the genu of the corpus callosum (Fig. 2.2.22).

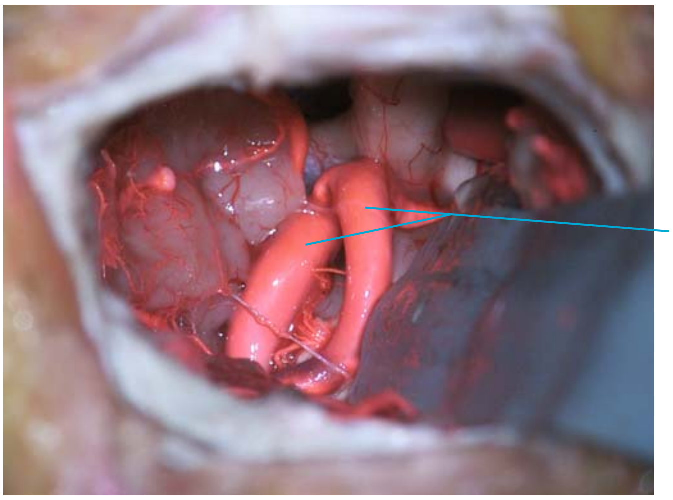


Fig. 2.2.22

Step 9

The anterior suprasellar region is seen through the interhemispheric fissure. Note that the ACoA and the A2 segments of the bilateral ACA can be approached in a nontraumatic manner without resection of the gyrus rectus. In the background, the contralateral ICA can be observed through the intraoptic window (Fig. 2.2.23).

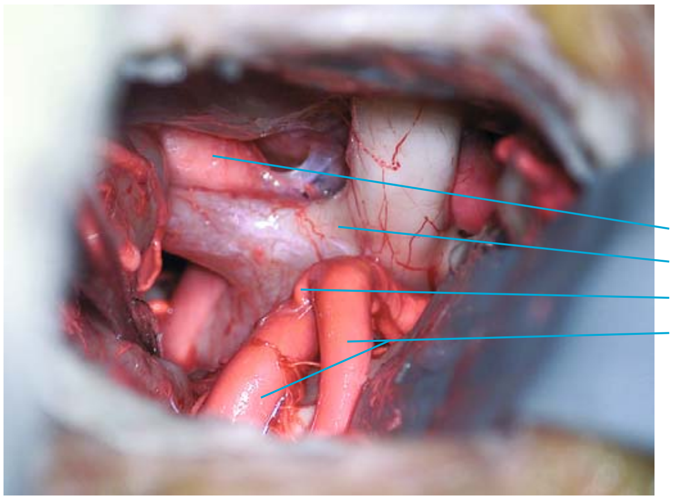


Fig. 2.2.23

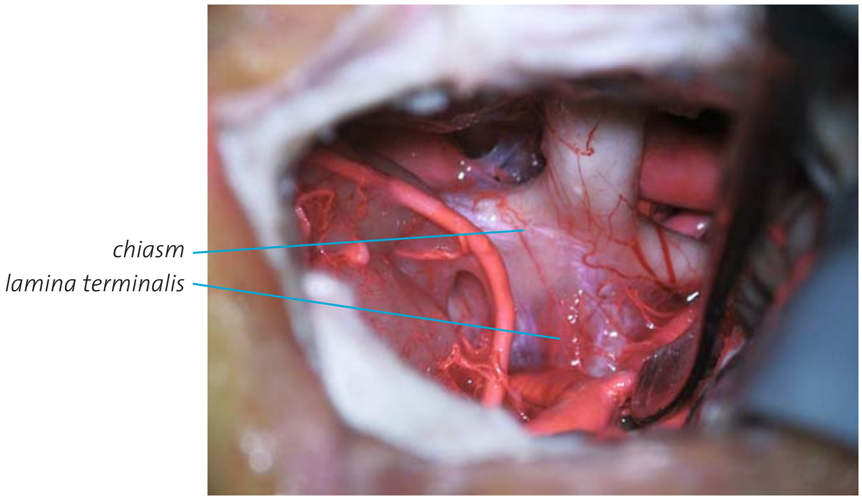


Fig. 2.2.24

Step 10

The frontal lobe and the ACoA complex are gently retracted, allowing visualization of the optic chiasm and the lamina terminalis (Fig. 2.2.24).

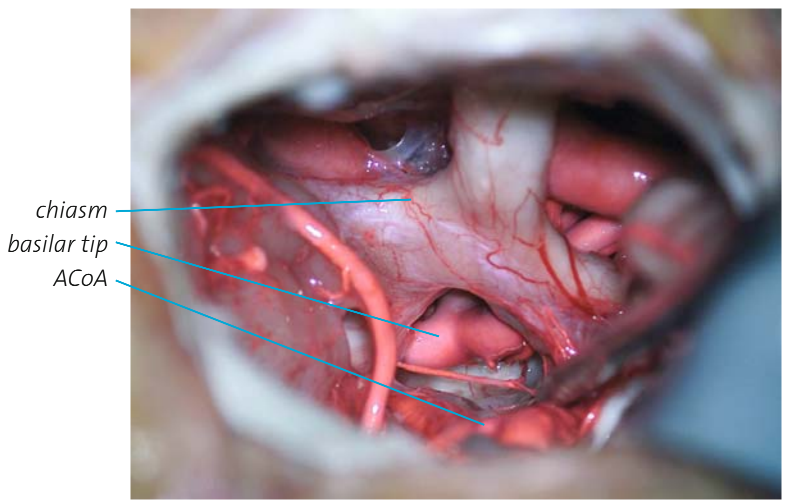


Fig. 2.2.25

Step 11

The lamina terminalis and the floor of the third ventricle are opened. Note the tip of the BA within the interpeduncular cistern, observed through the anterior chamber of the third ventricle (Fig. 2.2.25).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the subarachnoid space is filled with arteficial CSF. Dural closure should be made watertight avoiding postoperative CSF fistula; if dehiscence has developed in the dural opening, a piece of muscle can be sewn into the dural closure. A plate of gelfoam is placed extradurally, and, if necessary, the frontal paranasal sinus is closed. Bone wax, a flap of the galea or orbicular muscle tissue can be used for this purpose. In cases with an extended frontal sinus, abdominal fat can also be very useful. The bone flap is fixed with a titanium plate. Note that this plate should close the frontal burr hole. The bone flap should be tightly fixed both medially and frontally to achieve a pleasant cosmetic result. After final monitoring of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with an intracutaneous suture or sterile adhesive tape. No suction drain is necessary.

Potential errors and their consequences

- Inadequate planning with subsequent inadequate exposure of the target region and significant deterioration in efficiency of surgically excising the lesion.
- The patient is inadequately positioned with insufficient intracranial exposure. Planning and positioning should be performed by the surgeon himself.
- The skin incision is made within the median eyebrow with injury to the supraorbital nerve. In some cases, a prominent frontal wrinkle or scar can be used for skin incision. If wrinkles or scars are not present and the eyebrow skin incision would result in a suboptimal cosmetic result with postoperative frontal numbness, an extended frontal-bicoronar skin incision can be proposed.
- Inadequate placement of the craniotomy with penetration of the frontal paranasal sinus. The approach must be determined after accurate planning and surgical orientation. The opening should be closed carefully after completion of the intracranial procedure to avoid postoperative CSF fistula and meningitis.
- Injury to the dura mater during craniotomy.
- Penetration of the orbit during extradural removal of osseous extensions of the orbital roof with postoperative orbital hematoma and swelling.

- Inadequate removal of CSF with injuries and contusion of the frontal lobe due to spatula pressure.
- Injuries to numerous nerves and vessels in the parasellar region during microsurgical manipulation with postoperative neurological deterioration.
- Inadequate intracranial hemostasis causing severe rebleeding.
- Inadequate dural closure resulting in a postoperative CSF fistula. If the frontal sinus was opened, nasoliquorrhea can occur postoperatively.
- Inadequate positioning and fixation of the bone flap with the titanium plate resulting in poor cosmetic results.
- Inadequate hemostasis during wound closure with subsequent soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning of patients. Compared to the supraorbital craniotomy, the medial supraorbital approach requires less head rotation and more retroflexion during positioning (Fig. 2.2.26).

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and superficial neurovascular structures; 2. placement of craniotomy; 3. skin incision.

- The skin incision should be made in a cosmetically acceptable way. If the eyebrow is not dominant, the skin incision can be made within a wrinkle or scar on the face, or even bifrontally behind the hairline (Fig. 2.2.27).

- During soft tissue dissection, the frontal muscle should be forcibly retracted upwards and medially in a frontomedial direction with holding sutures providing sufficient overview of the medial supraorbital region. However, retraction and mobilization of the skin flap should be restricted to the necessary minimum to prevent postoperative necrosis. Manipulation of the frontal and orbital muscles upwards over the supraorbital rim should be minimized, avoiding postoperative periorbital hematoma (Fig. 2.2.28).

- Preoperative computed tomography and cranial X-ray in the anteroposterior and lateral view can determine the extension of

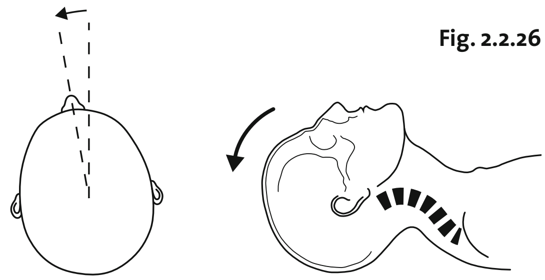


Fig. 2.2.26

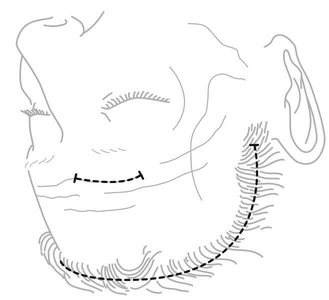


Fig. 2.2.27

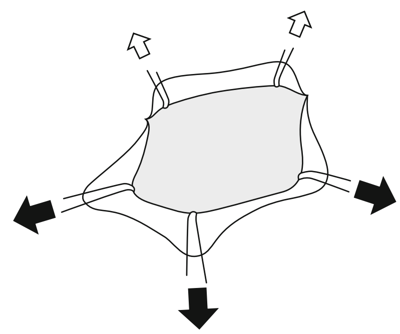


Fig. 2.2.28

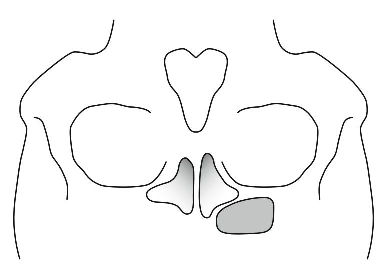


Fig. 2.2.29

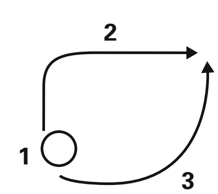


Fig. 2.2.30

Fig. 2.2.31

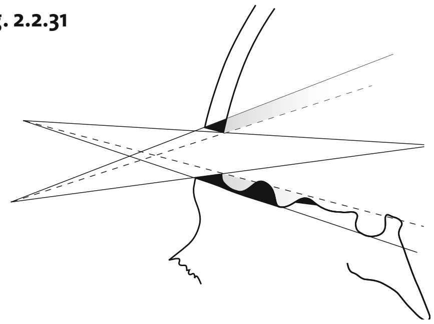


Fig. 2.2.32

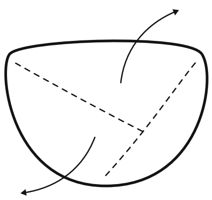
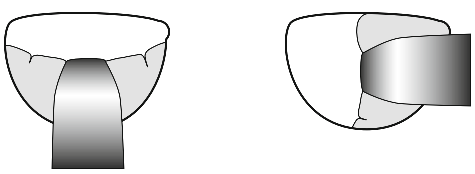


Fig. 2.2.33



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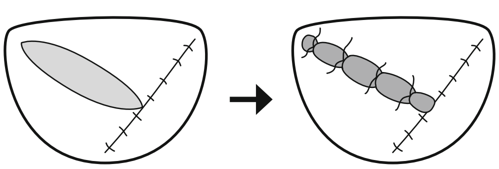

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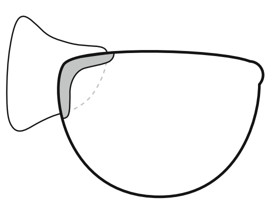
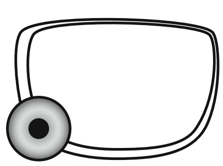


Fig. 2.2.36



the frontal paranasal sinus. In most cases, the frontal paranasal sinus is located more basally than the planned craniotomy, thus penetration of the sinus can be avoided (Fig. 2.2.29).

- Stages of craniotomy (Fig. 2.2.30): 1. paramedian frontal burr hole trephination; 2. frontobasal cutting with the craniotome; 3. sawing in a curved fashion from the burr hole to the lateral edge of the first craniotomy line.
- Removal of the inner edge of the craniotomy with a high-speed drill facilitates the intracranial visualization. If necessary, osseous extensions of the orbital roof should also be carefully removed (Fig. 2.2.31).
- Opening the frontal dura in a simple "T"-shaped fashion avoids unnecessary exploration of the frontal lobe and optimal combination of the subfrontal and interhemispheric dissection (Fig. 2.2.32).
- The paramedian placement of the craniotomy allows subfrontal as well as interhemispheric dissection (Fig. 2.2.33).
- After completion of the intradural dissection, dural closure should be made watertight to avoid postoperative nasal CSF fistula. If tension or dehiscence has developed in the dural plane, a piece of muscle can be sewn into the dural closure (Fig. 2.2.34).
- If penetration of the frontal paranasal sinus could not be avoided, meticulous closure is required. The penetration should be closed with bone wax, with a frontal galeal or muscular layer, or with abdominal fat tissue (Fig. 2.2.35).
- The bone flap should be closed tightly to achieve optimal cosmetic results. A titanium plate can be successfully used for closure of the burr hole trephination (Fig. 2.2.36).
- The eyebrow skin incision should be closed with intracutaneous running sutures or with sterile adhesive tapes.
- On account of the limited skin incision and nontraumatic surgical technique, a suction drain is not required.

2.3
Basal variation of the supraorbital approach: the supraorbito-orbital craniotomy

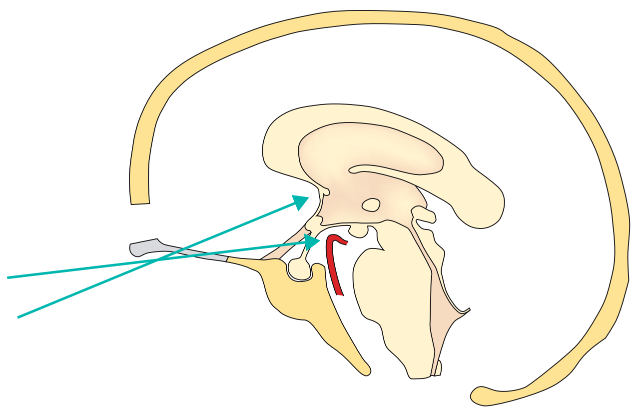


Fig. 2.3.1 *Schematic picture depicting the aim of the basal variation of the supraorbital craniotomy. By partial removing the supraorbital rim and orbital roof, a more oblique view of the suprasellar region can be achieved exposing lesions of the interpeduncular region and the upper part of the cisterna laminae terminalis.*

Supraorbital craniotomy allows a broad exposure of the suprasellar neurovascular structures; however, in special situations narrow anatomical windows may hinder the dissection through the important suprasellar surgical pathways. In particular, approaching high situated basilar tip aneurysms and supra-retrosellar space-occupying lesions may require a very oblique view to guarantee safe interpeduncular manipulation without retraction of the sensitive optic structures, which can be highly complicated by the combination of a short internal carotid artery and prefixed low optic chiasm.

The essence of the supraorbito-orbital approach is to gain a more oblique view of the deep-seated prepontine and interpeduncular region via the subfrontal exposure, after removing the orbital rim and partially removing the orbital roof (Fig. 2.3.1). In this angled view, the roof of the interpeduncular cistern with the mamillary bodies, infundibulum, and the tip of the BA can be well visualized without removal of the anterior clinoid process and mobilization of the paraclinoid ICA and CN II.

In the following, the surgical technique of the basal supraorbito-orbital approach is described.

Ipsilateral	Midline	Contralateral
Orbital roof	Olfactory groove	Orbital roof
Anterior clinoid process	Planum sphenoidale	Anterior clinoid process
Basal frontal lobe	Tuberculum sellae	Basal frontal lobe
Gyrus rectus	Lamina terminalis	Sylvian fissure
Sylvian fissure	Anterior third ventricle	Temporal pole
Anteromedial temporal lobe	Rostrum corporis callosi	Crus cerebri
Anterior pons	Genu corporis callosi	CN I, CN II, CN III
Crus cerebri	Pituitary stalk	ICA, OphtA, PCoA, AChA
CN I, CN II, CN III	Infundibulum	A1, A2, M1, M2, incl. perforators
ICA, OphtA, PCoA, AChA	Mamillary bodies	P1, SCA
A1, A2, M1, M2, incl. perforators	Interpeduncular fossa	
P1, P2, SCA	ACoA, Tip of the BA, incl. perforators	

Table 2.3.1 *Anatomical structures approached through the basal supraorbital craniotomy.*

Surgical technique

1. Patient positioning

The patient is positioned supine with the head secured in a head holder. If used, the single pin of the Mayfield clamp should be placed on the opposite side, allowing free manipulation during surgery. The pins should not be placed in the temporalis muscle to avoid instability of the system and postoperative temporal hematoma.

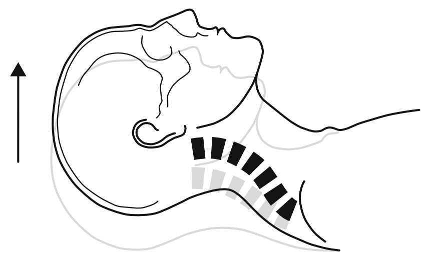


Fig. 2.3.2

Step 1

The head is elevated to ca. 15° above the level of the thorax to allow free venous drainage and effective decompression of the cervical vessels, larynx and the intratracheal tube (Fig. 2.3.2).

Step 2

Because of the angled approach to the interpeduncular region, the basal supraorbito-orbital variation requires more retroflexion than the supraorbital craniotomy. This maneuvre of ca. 30° retroflexion also supports the gravity-related self-retraction of the frontal lobe (Fig. 2.3.3).

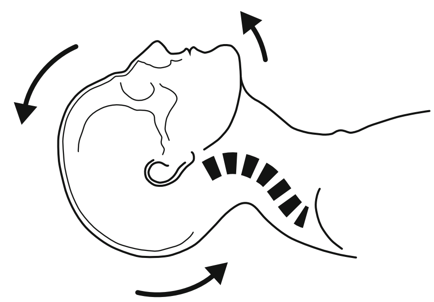


Fig. 2.3.3

Step 3

Thereafter, the head is rotated to the contralateral side. As the main direction of the intracranial dissection is through the suprasellar OPCA window, a ca. 30° rotation of the head is required. Note that right-handed surgeons using a left-sided craniotomy need more rotation to provide an efficient working position (Fig. 2.3.4).

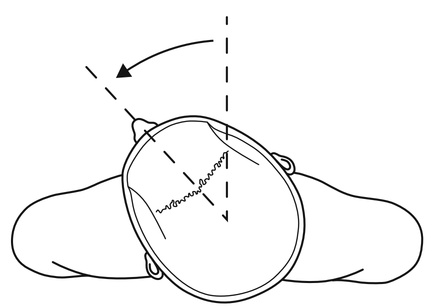


Fig. 2.3.4

Step 4

The head may also be lateroflected to about 10° on the contralateral side, to provide a suitable working position for the surgeon (Fig. 2.3.5).

Fig. 2.3.5

2. Anatomical landmarks and orientation

Firstly, the anatomical landmarks of the frontal skull, such as the glabella, frontal paranasal sinus, supraorbital foramen, orbital rim, frontobasis, temporal line, impression of the lesser sphenoid wing and the zygomatic arch are palpated. Note the supraorbital neurovascular structures and the course of the facial nerve (Fig. 2.3.6).

After this essential orientation, the size and site of the craniotomy should be defined. According to the craniotomy which incorporates removal of the orbital rim and partial removal of the orbital roof, the individual line of the skin incision is marked, placed laterally to the supraorbital foramen running within the eyebrow (Fig. 2.3.6). The eyelids are carefully taped and the skin is disinfected meticulously.

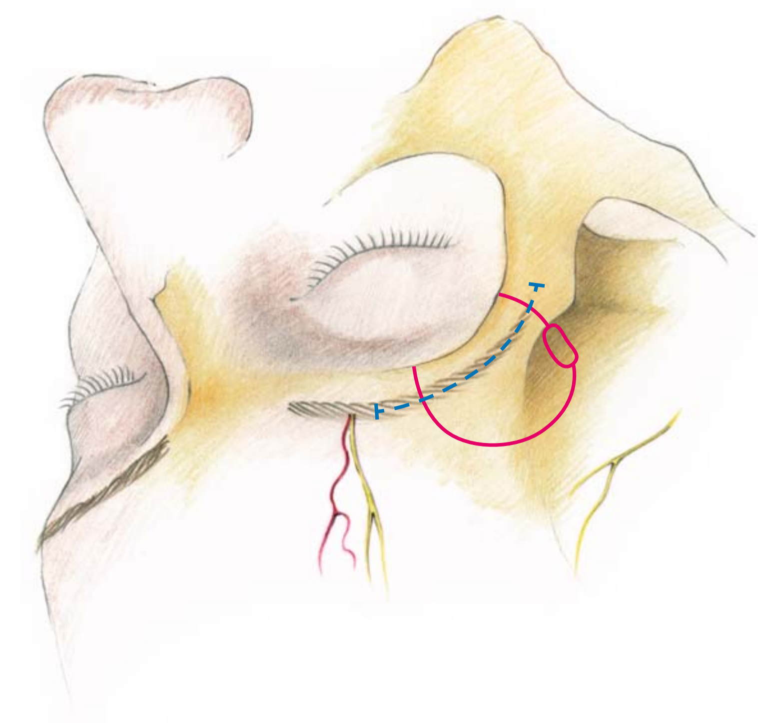


Fig. 2.3.6 *Definition of the craniotomy according to the anatomical landmarks of the frontotemporal region. Note the placement of the skin incision which should be made within the eyebrow.*

Fig. 2.3.7

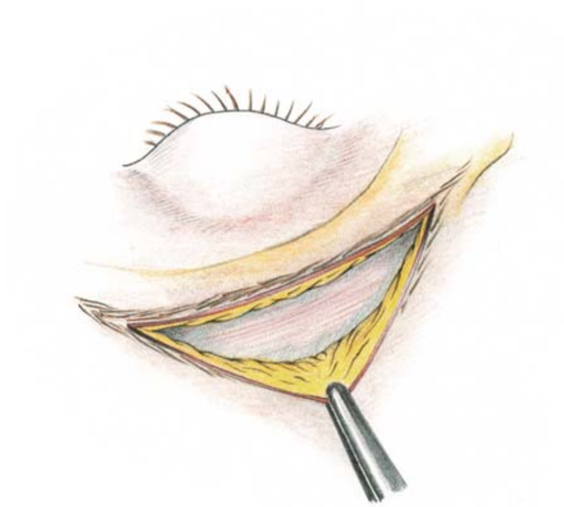


Fig. 2.3.8

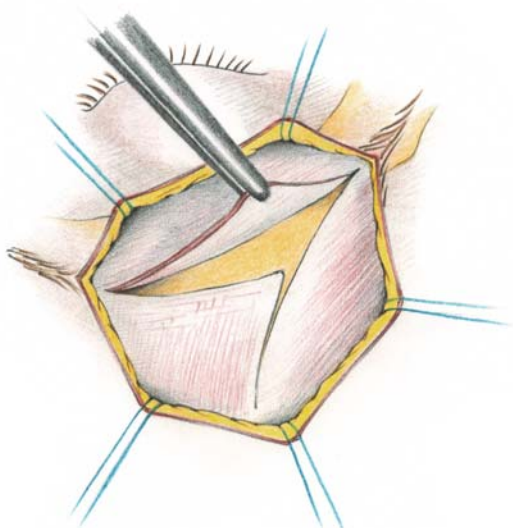
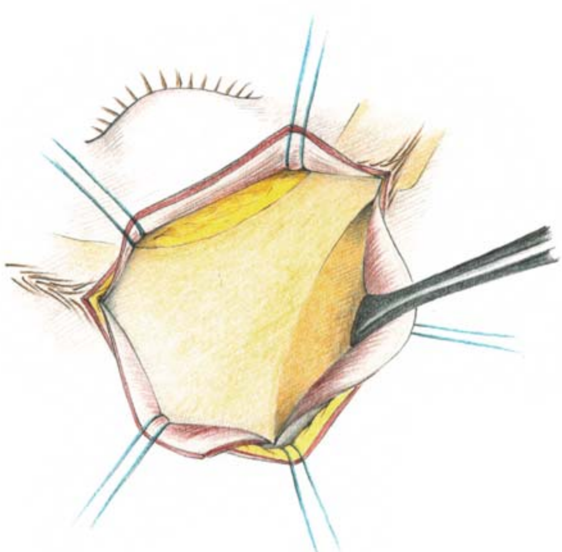


Fig. 2.3.9



3. Craniotomy

Step 1

The eyebrow skin incision is placed lateral from the supraorbital foramen, in some cases extending a few millimeters over the lateral projection of the brow into the frontozygomatic area. For a cosmetically pleasing postoperative result, the skin incision may follow the orbital rim. Right side (Fig. 2.3.7).

Step 2

After skin incision, the skin flaps are temporarily retracted with holding sutures, exposing the supraorbital area with the frontal belly of the occipitofrontal muscle, the orbicularis oculi and temporal muscles. The frontal muscles are cut parallel to the orbital rim, the temporal muscle is stripped from its bony insertion at the temporal line (Fig. 2.3.8).

Step 3

The temporal muscle is retracted laterally with strong sutures noting the impression of the lesser sphenoid wing, thus showing the level of the frontal skull base. Compared to the supraorbital craniotomy, the basal variation requires more movement of the temporalis muscle. The frontal and orbicularis oculi muscles are dissected upwards together with the frontal periost exposing the orbital rim. The orbital rim is carefully dissected from the periorbita using a blunt curved dissector. The orbicularis oculi muscle and the periorbital sheet are then forcibly retracted upwards using strong holding sutures. The frontal muscle and the frontal periost are retracted downwards in a forward direction, exposing the supraorbital region (Fig. 2.3.9).

Step 4

With a high-speed drill, a single burr hole is performed posterior to the temporal line according to the level of the frontal skull base. Thereafter, the burring direction should be changed, thus opening the lateral aspect of the orbit. The goal of this enlarged single burr hole trephination is to penetrate both the anterior fossa and the orbit by different bidirectional drilling (Fig. 2.3.10).

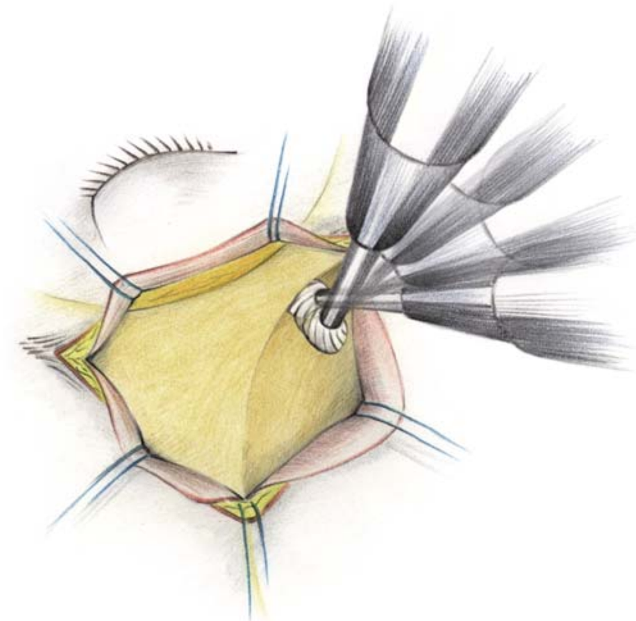


Fig. 2.3.10

Step 5

After inspecting the periorbita and the frontal dura mater, a curved semicircular line is sawed from the frontal part of the burr hole in a lateral to medial direction to the level of the frontal skull base. Thereafter, the lateral orbital wall and the zygomatic process of the frontal bone is divided from the orbital part of the burr hole (Fig. 2.3.11).

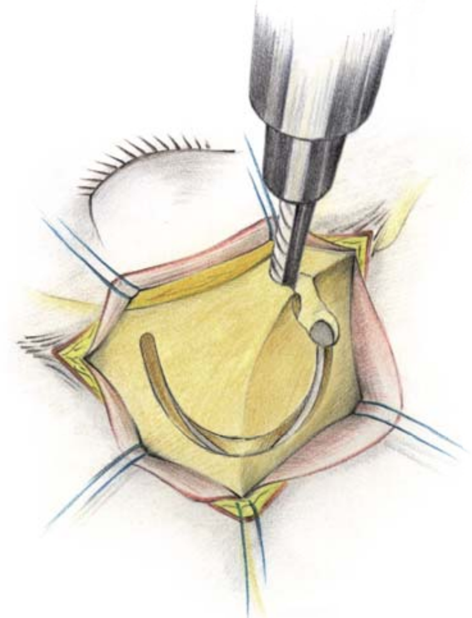


Fig. 2.3.11

Step 6

The orbital rim is then sawed both medially and laterally using the craniotome. Special attention should be given to avoid injury to the delicate periorbita (Fig. 2.3.12).

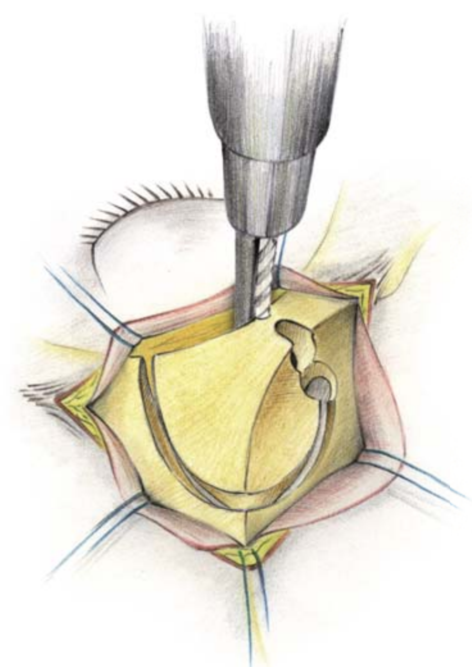
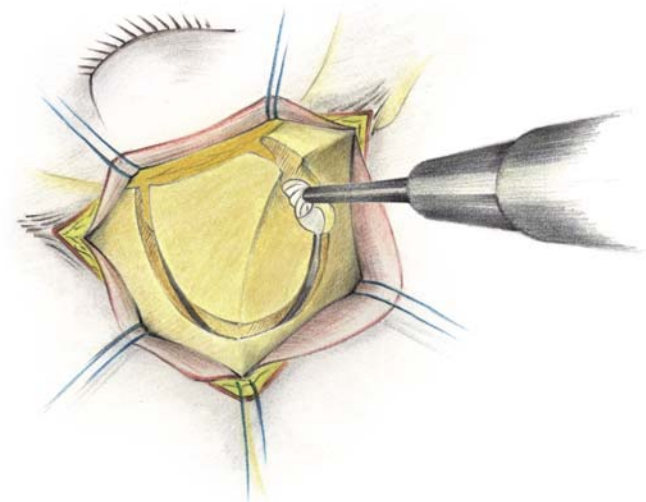


Fig. 2.3.12

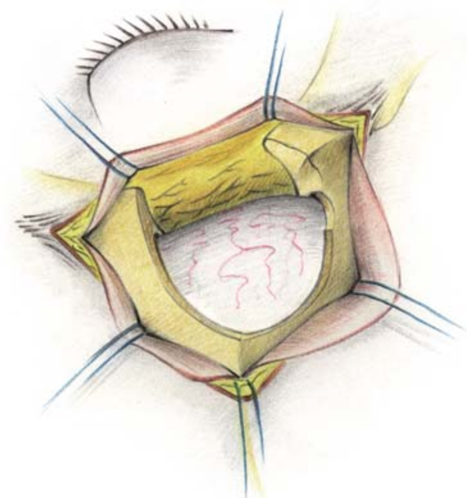
Fig. 2.3.13



Step 7

The lateral aspect of the orbital roof is then divided with a diamond drill allowing secure lifting of the bone flap and fracturing of the orbital roof. Care should be taken to place the fracture line as far back as possible without damaging the optic canal and nerve (Fig. 2.3.13).

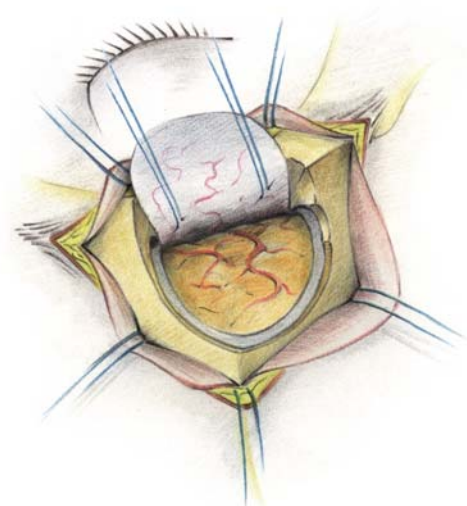
Fig. 2.3.14



Step 8

After the bone flap is removed, the frontal dura mater and the thin periorbita can be seen. An extended removal of the residual orbital roof in an osteoclastic manner is not advised, thus avoiding postoperative enophthalmos or pulsating exophthalmos (Fig. 2.3.14).

Fig. 2.3.15



Step 9

The dura should be opened in a curved fashion with its base towards the orbit. The free dural flap is fixed forcibly upwards with strong elevating sutures, allowing a slanted view during intracranial dissection (Fig. 2.3.15).

4. Intradural dissection

Step 1

Right side. Dissection shown on a fresh human cadaver; the arterial vessels are prepared with colored latex solution. After a "C" shaped incision, the dura mater is forcibly retracted upwards, allowing a slanted view during intracranial observation. Note that according to this oblique view, the frontobasal cortical surface can be optimally exposed without retraction of the frontal lobe. (Fig. 2.3.16).

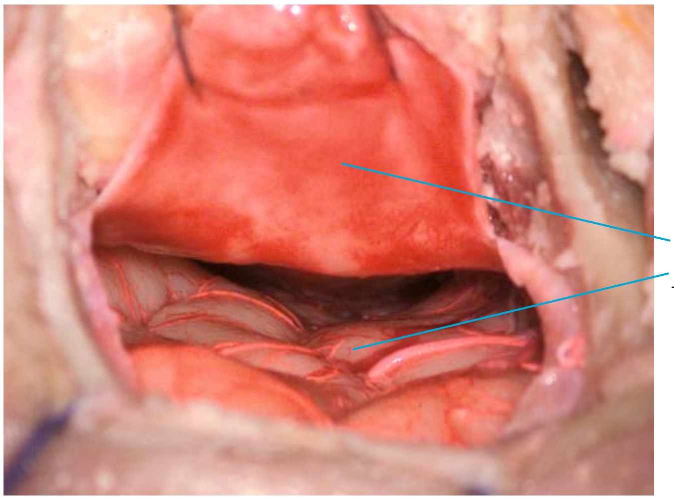


Fig. 2.3.16

Step 2

After opening the dura, the first step should be an adequate drainage of CSF by opening the suprasellar cisterns. In the case of elevated ICP after aneurysmal subarachnoid hemorrhage, the lateral ventricle should be punctured. After removal of subarachnoidal or ventricular CSF, the frontal lobe subsides spontaneously allowing careful dissection with minimal brain retraction. Note the CN II and the ICA after opening the OPCA window with a fine microknife. The sucker partially covers the CN I (Fig. 2.3.17).

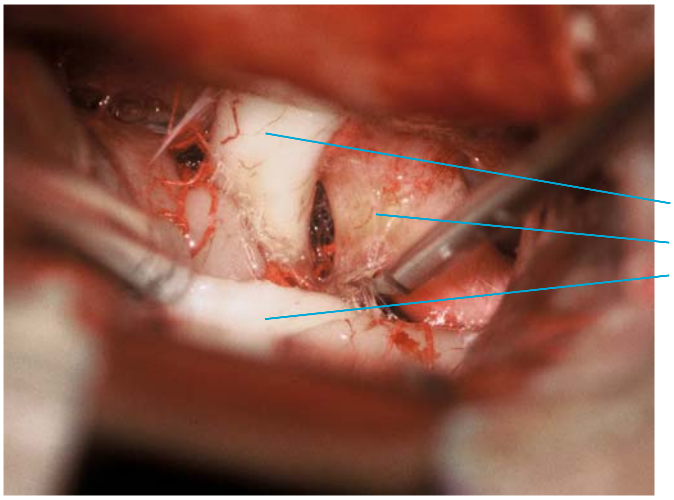


Fig. 2.3.17

Step 3

Dissecting to the midline, the arachnoid membranes of the chiasmatic cistern are opened using fine microscissors. Note the chiasm and both optic nerves (Fig. 2.3.18).

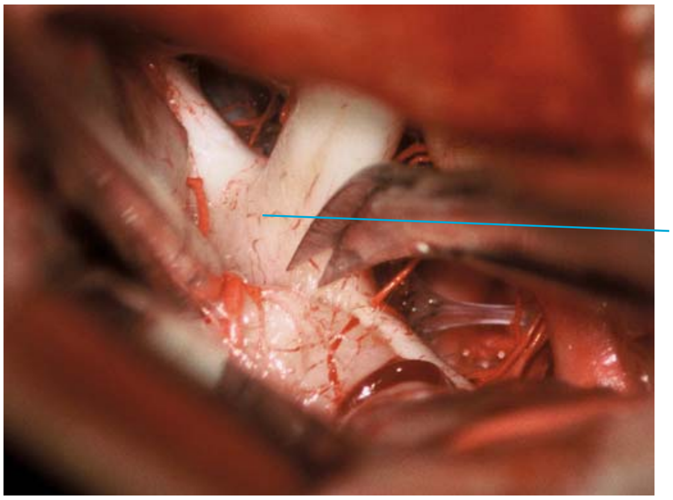


Fig. 2.3.18

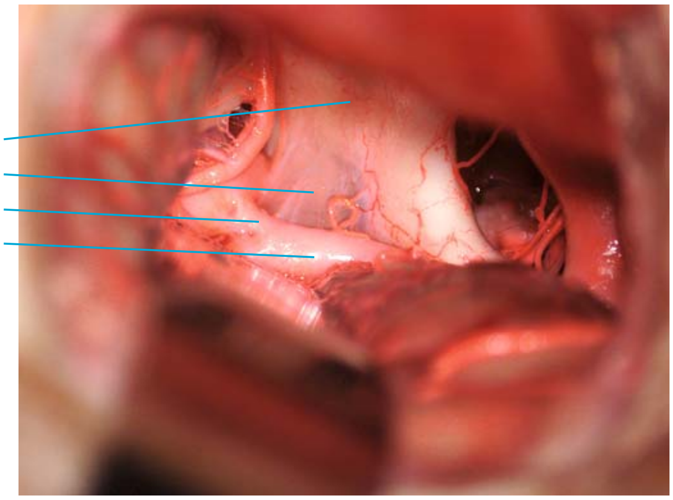


Fig. 2.3.19

Step 4

After further dissection and retraction of the frontal lobe, the lamina terminalis and the ACoA can be approached. Due to the oblique view and surgical dissection, removal of the gyrus rectus is not necessary when nearing the ACoA complex (Fig. 2.3.19).

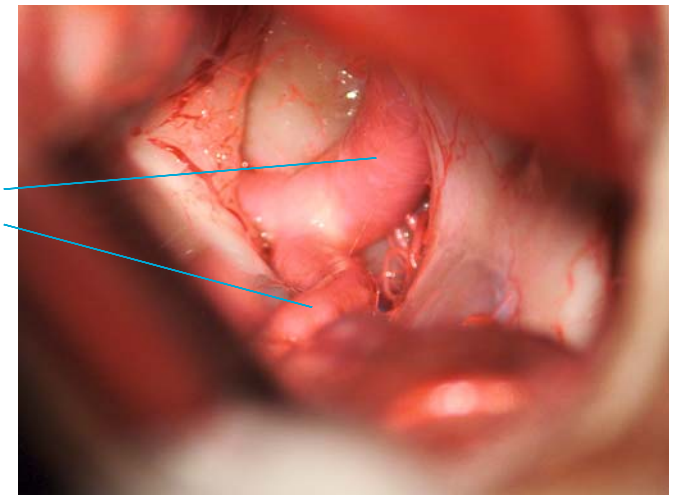


Fig. 2.3.20

Step 5

Dissecting towards to the contralateral direction, the opposite carotid artery is approached. Note the carotid bifurcation, the MCA disappears into the Sylvian fissure (Fig. 2.3.20).

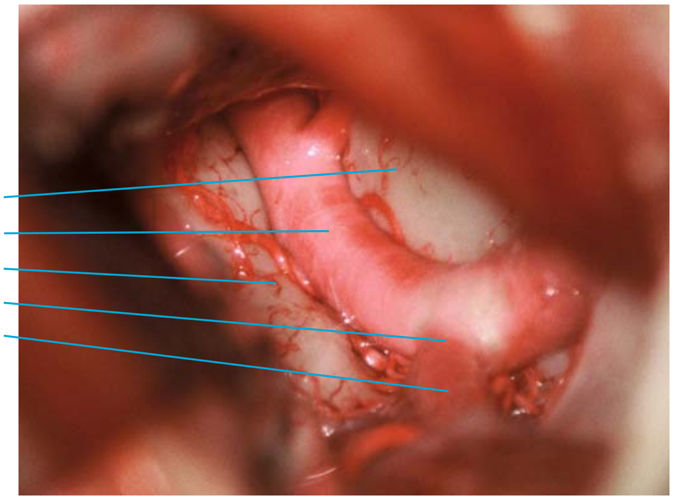


Fig. 2.3.21

Step 6

After opening the medial aspect of the opposite Sylvian fissure, the left MCA can be observed. Note the contralateral frontal and temporal lobes and the origin of the ACA (Fig. 2.3.21).

Step 7

Dissecting again on the ipsilateral side and opening the anterolateral suprasellar subarachnoid spaces, the entire supraclinoid segment of the ICA can be seen. The Sylvian fissure is not yet opened; here the temporal lobe covers the MCA, the frontal lobe prevents observation of the ACA. Note the dorsum sellae and the CN III, which is dissected away from arachnoidal adhesions with fine microscissors (Fig. 2.3.22).

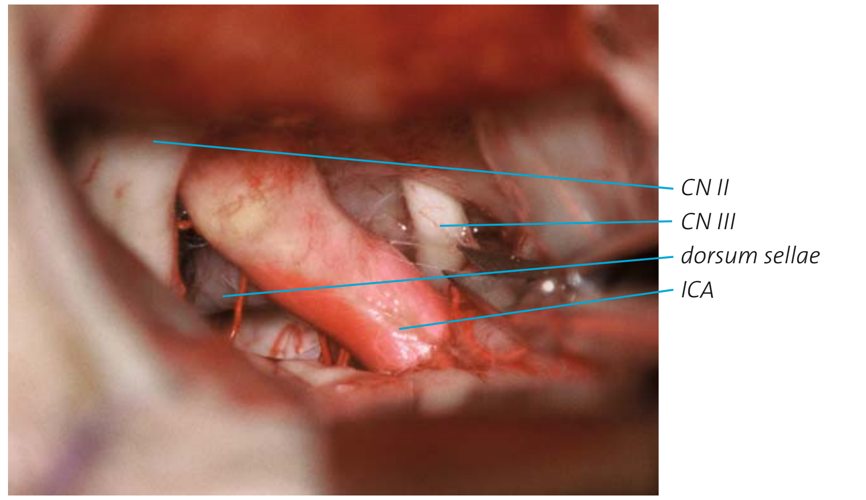


Fig. 2.3.22

Step 8

The ipsilateral Sylvian fissure is opened allowing investigation of the right MCA. According to the subfrontal view, the M1 segment can be approached without retraction of the temporal lobe. Note the carotid bifurcation with the origin of the right ACA (Fig. 2.3.23).

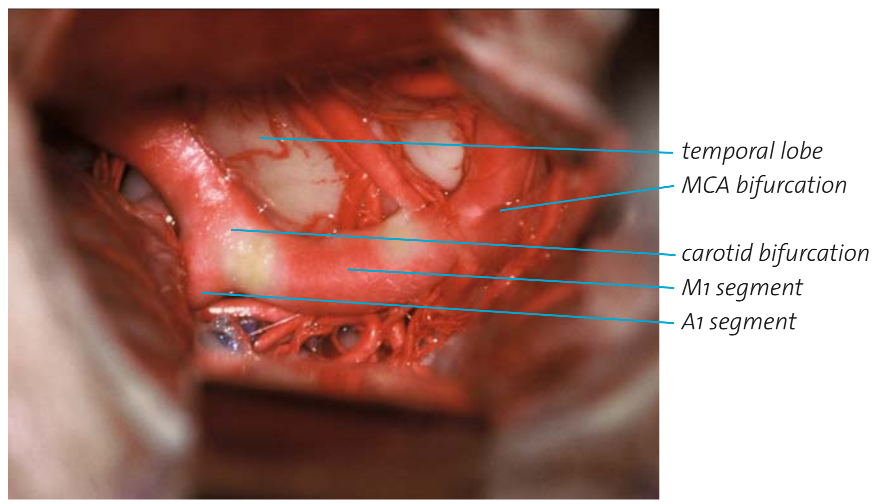


Fig. 2.3.23

Step 9

After further dissection, the lateral aspect of the suprasellar area is visualized; the anatomical windows medial and lateral to the CN III are opened. Through the OPCA and lateral suprasellar windows, the deep retrosellar region appears without retraction of the neurovascular structures. Note the angled surgical view according to the slanted aspect after removal of the orbital rim. Within the posterior fossa, the anterior surface of the pons appears; note the lateral prepontine, medial ambient and crural cisterns with the SCA and P2 segment of the PCA; the CN III appears between the posterior cerebral and superior cerebellar arteries (Fig. 2.3.24).

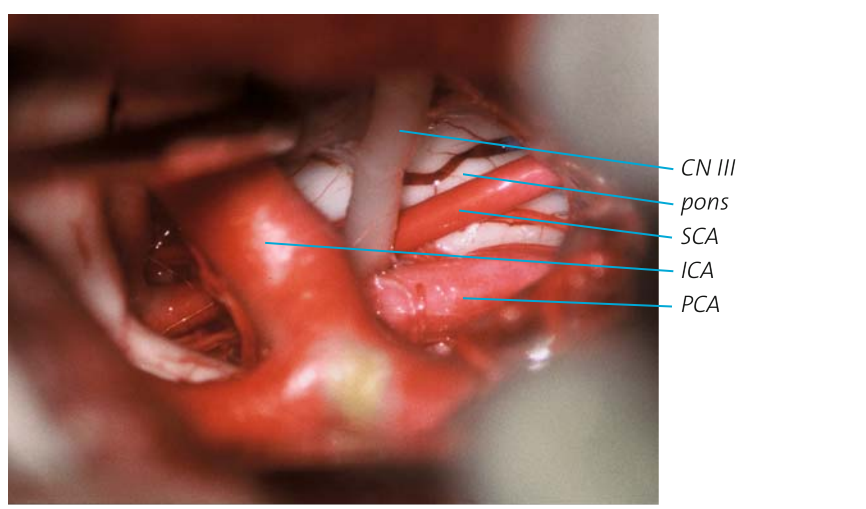


Fig. 2.3.24

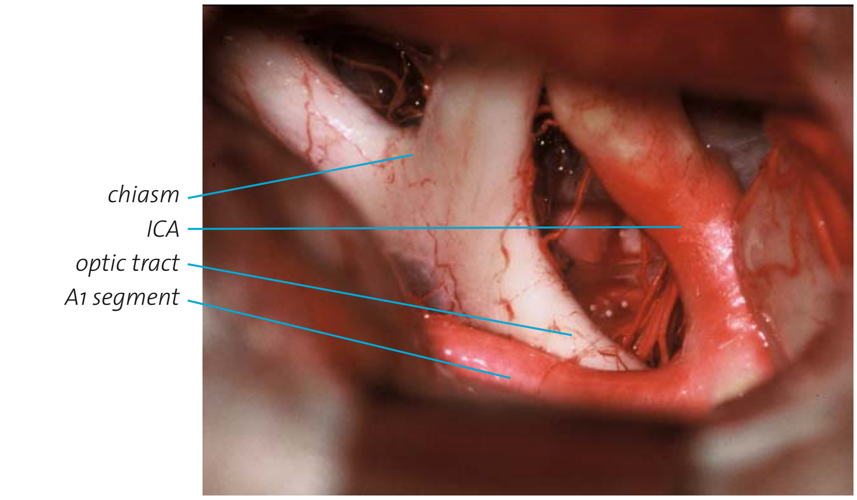


Fig. 2.3.25

Step 10

Focusing through the OPCA window, the interpeduncular cistern can be seen. The distal BA appears behind the dorsum sellae, the Lilljequist membrane is not yet opened. Note the A1, the optic chiasm and the right optic tract (Fig. 2.3.25).

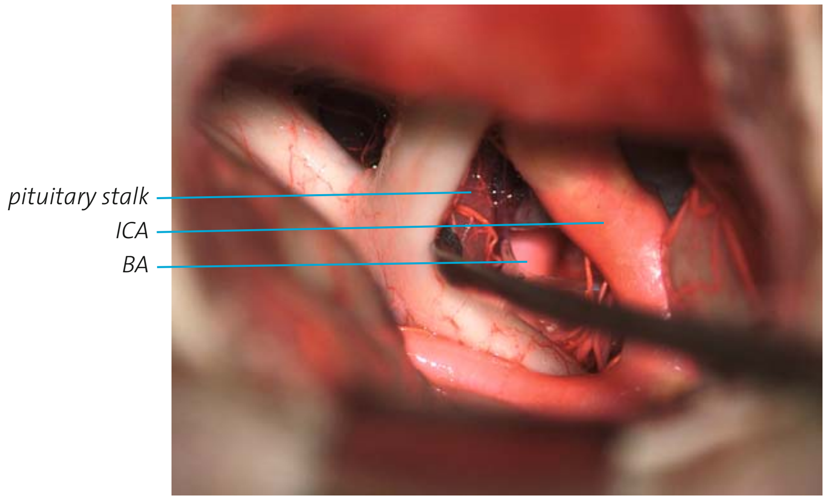


Fig. 2.3.26

Step 11

After gentle retraction of the chiasm with a microdissector, the pituitary stalk can be observed. After opening the Lilljequist membrane, the BA appears behind the dorsum sellae (Fig. 2.3.26).

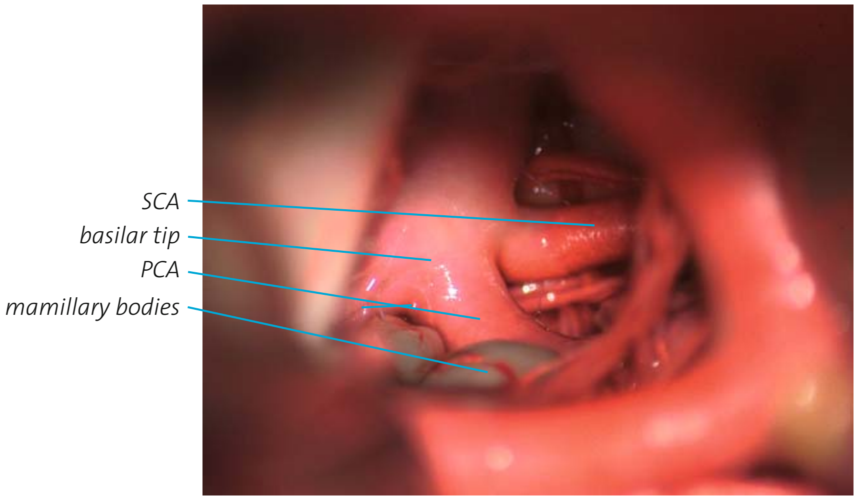


Fig. 2.3.27

Step 12

The basal supraorbito-orbital variation of the supraorbital craniotomy provides a safe surgical exposure of the upper interpeduncular cisterns with the tip of the BA and the mamillary bodies. Traumatic retraction and extended movement of the suprasellar neurovascular structures are not necessary when exposing the basilar tip (Fig. 2.3.27).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the subarachnoid space is filled with arteficial CSF. Dural closure should be made watertight avoiding postoperative CSF fistula. If dehiscence has developed in the dural opening, a piece of muscle can be sewn into the dural closure. If the periorbita is injured, periorbital tears should be repaired avoiding protrusion of the orbital fat. A plate of gelfoam is placed extradurally, the bone flap is repositioned and attached using one or two titanium plates. Note that the bone flap should be fixed in an anatomically correct manner, not only achieving optimal cosmetic results but avoiding postoperative en- or exophthalmos with a subsequent disturbance of eyeball motion. After carefully obtaining complete hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures, the skin with intracutaneous running sutures or sterile adhesive tapes. Because of the limited skin incision and non-traumatic surgical technique, a suction drain is not necessary.

Potential errors and their consequences

- Incorrect planning and patient positioning with insufficient intracranial exposure of the lesion. Planning and positioning are tasks of the operating neurosurgeon himself.
- The skin incision is performed too medially with injury to the supraorbital nerve and subsequent postoperative frontal numbness.
- Penetration of the frontal paranasal sinus during craniotomy. The opening should be closed to avoid a postoperative CSF fistula and meningitis. For this reason, bone wax, a galeal flap or abdominal fat tissue can be used.
- Overlooked but sometimes unavoidable injury to the dura mater during craniotomy. For watertight closure, small pieces of the temporal muscle can be used. In some cases, dural reconstruction may be necessary using plastic material.
- Penetration of the periorbita with occasional damage to intraorbital structures. Postoperative ophthalmologic disturbances may occur.
- Inadequate removal of CSF as the first step of the intradural procedure with subsequent contusion of the frontal lobe due to spatula pressure.
- Injuries to numerous nerves and vessels in the parasellar region during microsurgical manipulation causing postoperative neurological deterioration in some patients.

- Inadequate hemostasis and subsequent intracranial rebleeding.
- Inadequate dural closure causing a postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap with postoperative en- or exophthalmos, subsequent eye movement disorders and poor cosmetic results.
- Inadequate hemostasis during wound closure causing postoperative soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning.

- Compared to the supraorbital craniotomy, the supraorbito-supraorbital approach requires more retroflexion during head positioning (Fig. 2.3.28).

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and superficial neurovascular structures; 2. placement of craniotomy; 3. skin incision.

- If the eyebrow is not dominant, the skin incision may be performed in a wrinkle or scar in the supraorbital frontotemporal area. If they are also not present, a curved frontotemporal skin incision can be made behind the hairline. However, soft tissue retraction should be restricted to the necessary minimum to avoid postoperative necrosis (Fig. 2.3.29).

- The frontal and orbicular muscles should be forcibly retracted both downwards in a frontal and upwards in an orbital direction with strong holding sutures, exposing the orbital rim and the frontolateral region (Fig. 2.3.30).

- With a suitably placed burr hole, both the anterior fossa and the orbit can be opened without damaging the dura mater and the periorbita (Fig. 2.3.31).

- Stages of craniotomy (Fig. 2.3.32): 1. burr hole trephination with opening of both the anterior fossa and the orbit; 2. frontal cutting in a curved fashion from the burr hole in a lateral to medial direction; 3. cutting of the zygomatic process of the frontal

Fig. 2.3.28

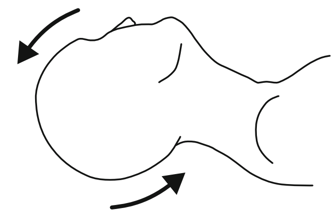


Fig. 2.3.29

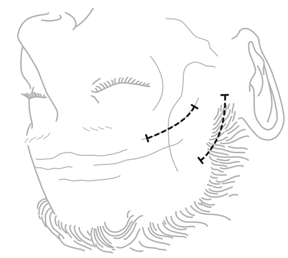


Fig. 2.3.30

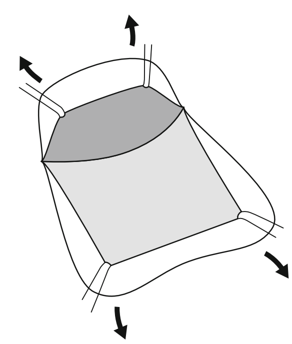


Fig. 2.3.31

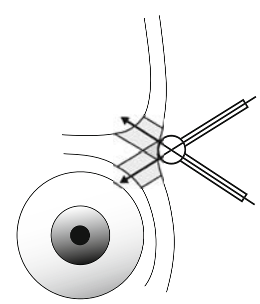


Fig. 2.3.32

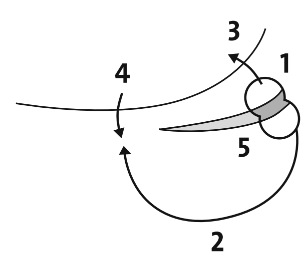


Fig. 2.3.33

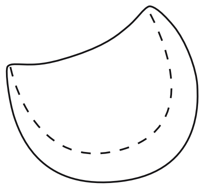


Fig. 2.3.34

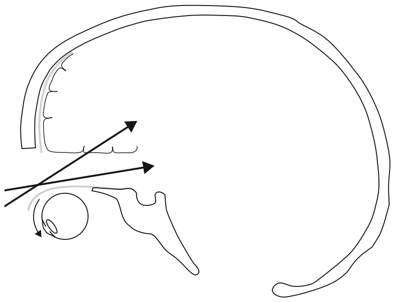


Fig. 2.3.35

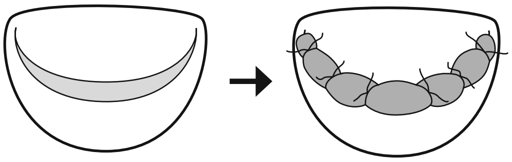
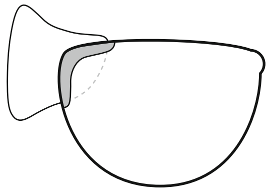


Fig. 2.0.36



bone; 4. dividing the orbital rim; 5. drilling of the lateral aspect of the orbital roof and fracturing the orbital roof.

- Dural opening in a "C" shaped fashion is time-consuming but avoids unnecessary exploration of the frontal lobe (Fig. 2.3.33).
- Using strong dural holding sutures and minimal depression of the orbital structures, a more angled intracranial exploration can be achieved (Fig. 2.3.34).
- To achieve watertight dural closure, a piece of muscle can be sewn into the dural closure (Fig. 2.3.35).
- If the frontal paranasal sinus is penetrated, careful closure is required. Bone wax, a flap of galea or abdominal fat tissue can be used for this purpose (Fig. 2.3.36).
- After completion of the intracranial procedure, the bone flap should be fixed anatomically to achieve optimal cosmetic outcome and to avoid postoperative eye movement disorders (Fig. 2.3.37).
- If present, bony dehiscence should be closed with a mid- or large-sized titanium plate (Fig. 2.3.38).
- The eyebrow incision should be carefully closed with intracutaneous sutures or with sterile adhesive tapes.
- Using limited skin incision and minimal soft-tissue dissection, no suction drain is necessary.

Fig. 2.3.37

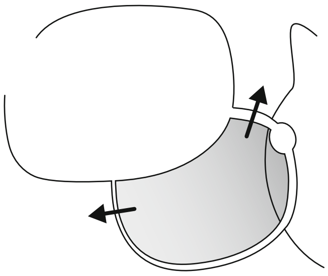
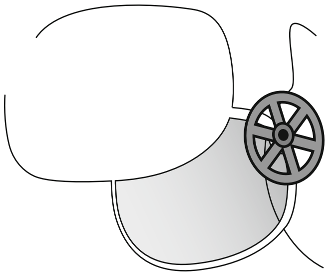


Fig. 2.3.38



3.0
Subtemporal approach

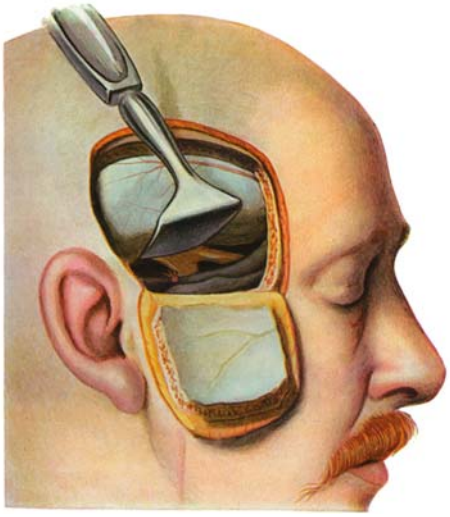


Fig. 3.0.1 *Subtemporal extradural exposure of the Gasserian ganglion in a case of severe tic douloureux, published by* Fedor Krause *in 1911. Differing from modern temporal or subtemporal approaches with careful dissection of anatomical layers, the author created a horseshoe-shaped combined skin-fascia-muscle-bone flap retracted inferiorly over the zygomatic arch. With this extradural exposure, intraoperative damage to the temporal lobe could be effectively minimized.*

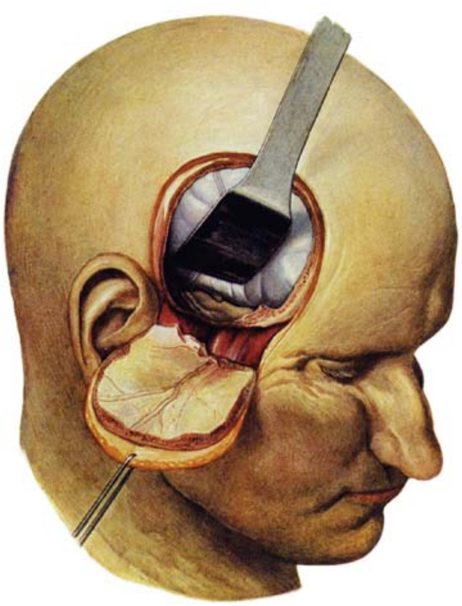


Fig. 3.0.2 *A similar subtemporal extradural approach to the trigeminal ganglion described by* Tandler *and* Ranzi *in 1920 in their illustrated textbook "Surgical Anatomy and Operative Techniques of the Central Nervous System"*

History of subtemporal approaches

In the course of neurosurgical history, techniques using temporal craniotomies for the treatment of trigeminal neuralgia, space-occupying lesions of the middle and posterior cranial fossa and aneurysms of the internal carotid and basilar arteries have been frequently described.

A form of subtemporal approach to the trigeminal ganglion was described by Fedor Krause in 1911 in the second volume of his pioneering work "Surgery of the Brain and Spine" published in Berlin, Germany [Krause 1911]. The first operation for treatment of severe trigeminal neuralgia was carried out in 1892 encouraged by the neurologist Hermann Oppenheim. A pre-auricular subtemporal extradural approach was developed for extirpation of the Gasserian ganglion whereafter the severe tic douloureux of the English captain *Milton Howard* showed marked postoperative improvement. In 1901, the neurologist William Spiller and the surgeon Charles Frazier reported an experimental study and successful surgical outcome on the division of the sensory root of the trigeminus for the relief of trigeminal neuralgia also using a subtemporal exposure [Frazier 1901]. From the beginning of the 1900s, Harvey Cushing also operated on patients suffering from tic douloureux [Cushing 1912]. In 1920, Julius Tandler and E. Ranzi described a subtemporal exposure in their volume "Surgical Anatomy and Operative Techniques of the Central Nervous System" [Tandler & Ranzi 1920]. Many years later, a very similar method was used by Ludwig G. Kempe, who described an osteoclastic extradural approach for the selective retrogasserian rhizotomy of the maxillary and mandibular roots of the trigeminal nerve (Fig. 3.0.3) [Kempe 1968].

A special indication for a subtemporal approach was occlusive hydrocephalus. In 1932, Walter Dandy described a lateral subtemporal approach for a third ventriculostomy [Dandy 1932]. Compared with his initial subfrontal exposure, the subtemporal third ventriculostomy did not require division of the optic nerve for opening the floor of the third ventricle (Fig. 3.0.4). In 1945, Dandy published a series of 92 patients treated in this fashion with a 12% mortality rate and with arrest of the hydrocephalus in 50% of the patients [Dandy 1945].

The temporal approach to an intracranial aneurysm was first published by A.S. Trevani as he was exploring a patient for a tumor within the middle cranial fossa [Trevani 1932]. After performing a large temporal flap extending into the frontal and parietal region, he found a giant aneurysm of the internal carotid artery. William J. Gardner described a case in which a temporal craniotomy was used for a hypophyseal tumor which was also an aneurysm of the internal carotid [Gardner 1936]. After intraoperative rupture, the operating field was filled with gauze which became infected and was removed two years later. Others subsequently used the temporal route for planned operations for aneurysms of the internal carotid artery and its branches. Peter Harris and George B. Udvarhelyi recommended a subtemporal craniectomy instead of craniotomy [Harris and Udvarhelyi 1957]. James L. Poppen in 1960 (Fig. 3.0.5), Jiro Suzuki in 1965, and E. Stephens Gurdjian in 1970 each reported on the subtemporal approach for aneurysms of the PCoA [Poppen 1960, Suzuki 1965, Gurdjian 1970].

The first surgeon to use the temporal-subtemporal route for exposure of basilar aneurysms was F. John Gillingham. In 1958, he reported four cases in which two aneurysms were clipped and two were wrapped with fascia [Gillingham 1958]. The real pioneer in the development of subtemporal approaches for aneurysms of the basilar artery, however, was Charles Drake, who reported his first experiences in 1960 of aneurysms of the basilar tip [Drake 1960]. In 1968, he was able to describe different variations of the subtemporal and temporobasal approaches exposing the basilar bifurcation, the upper and lower basilar trunk, and the terminal vertebral arteries (Fig. 3.0.6). In the due course of time, Drake's flap became smaller and more anterior, demonstrating Drake's personal learning process in reducing surgical traumatization. The large posterior craniotomies were only used to reach lower situated aneurysms in the posterior fossa after sectioning of the petroclinoid ligament and tentorium [Drake 1968, 1978]. Ludwig J. Kempe, E. Stephens Gurdjian, Keiji Sano and Donald H. Wilson subsequently utilized the subtemporal route, albeit with different modifications of skin incision and craniotomy (Fig. 3.0.7). Takeshi Kawase reported on the subtemporal transpetrosal approach for aneurysms of the lower basilar artery after removal of the petrous apex [Kempe 1968, Gurdjian 1970, Sano 1971, Wilson 1971, Kawase 1985].

Exposure of the posterior fossa and internal auditory canal via a subtemporal middle cranial fossa approach was first described

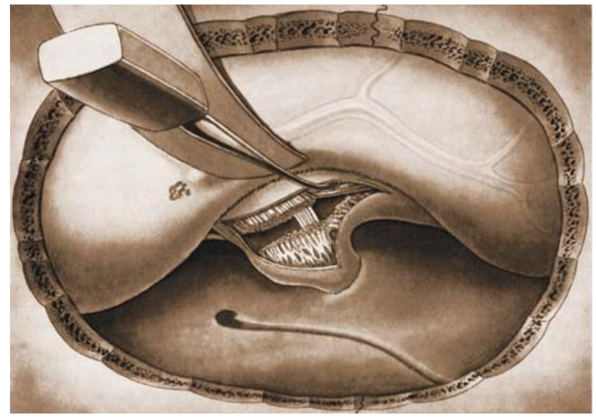
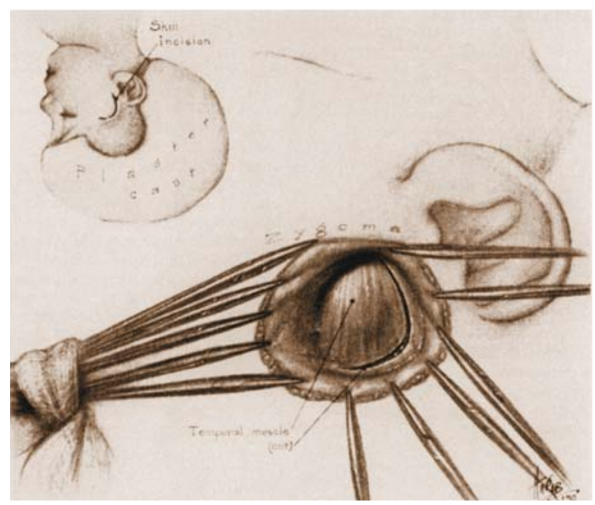


Fig. 3.0.3 *A limited subtemporal osteoclastic extradural exposure for retrogasserian rhizotomy of the maxillary and mandibular roots of the trigeminal nerve in patients suffering from severe trigeminal neuralgia published by Kempe in 1968. Note the selective dissection of the sensory nerve roots and protection of the radix motoria.*



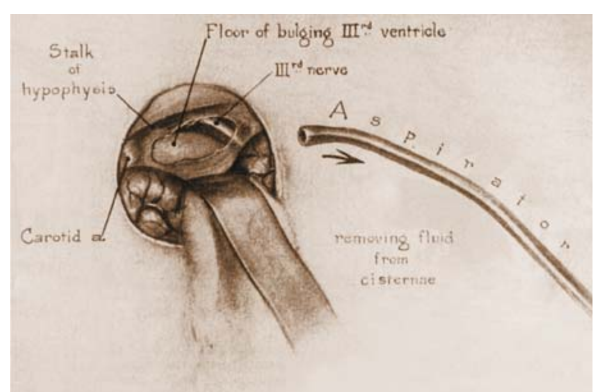


Fig. 3.0.4 *Dandy's temporal exposure for a third ventriculostomy published in 1932. Note the small skin incision and minimal retraction of the temporal lobe. The floor of the enlarged third ventricle was approached between the ICA and CN III.*

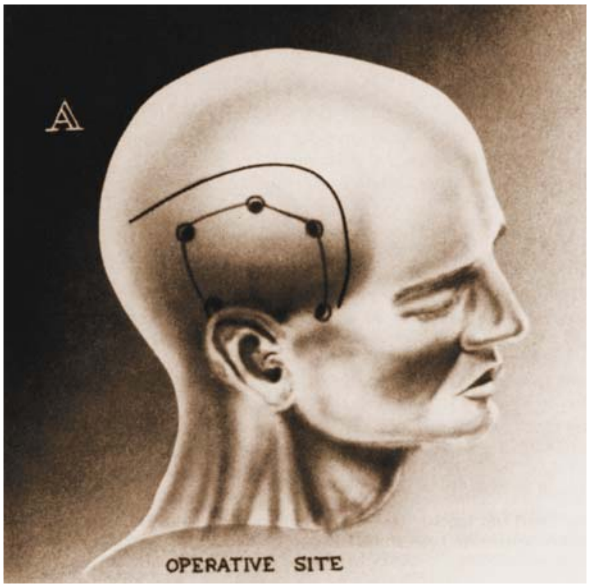


Fig. 3.0.5 *Temporal exposure for aneurysms of the internal carotid artery and their branches according to* Poppen *published in 1960.*

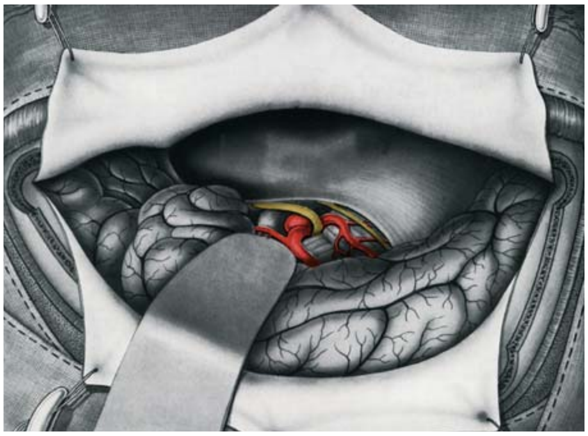


Fig. 3.0.7 *Kempe's temporal flap for basilar artery aneurysms, published in 1968. Note the extended frontal and temporal bone removal.*

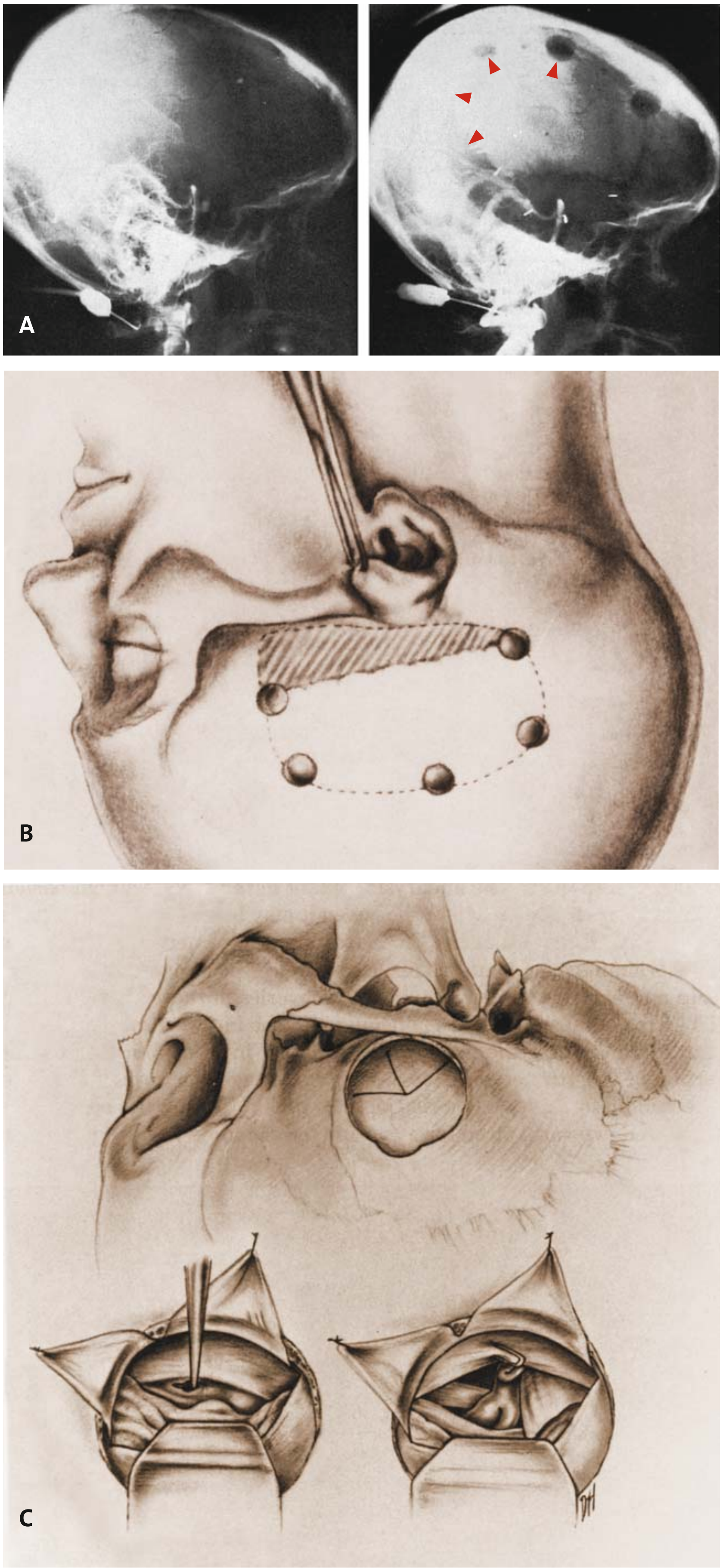


Fig. 3.0.6 *Different subtemporal approaches for treating basilar artery aneurysms published by* Charles Drake *in 1960, 1968 and 1978. Note the frontoparietal extension of the extended 1960 craniotomy (red arrows) to gain exposure to the ventrally situated aneurysm diagnosed by preoperative angiography (A).* Drake*'s subtemporal craniotomy for basilar tip aneurysms, published in 1968 (B). In 1978, he treated a very similar aneurysm via a limited subtemporal exposure demonstrating his personal experience in reducing operative trauma (C).*

by R. H. Parry in 1904. He described a case of tinnitus and vertigo treated by division of the auditory nerve [Parry 1904]. The sentinel work of William F. House in 1961 led to the refinement of this approach for the internal auditory canal and cerebellopontine angle. The approach was used initially for decompression of the internal auditory canal in cases of extensive otosclerosis involving the labyrinthine bone. That indication has been abandoned, but the middle fossa approach has become a workhorse in exposing small vestibular schwannomas when preoperative hearing remains intact [House 1961, Fisch 1968] (Fig. 3.0.8).

The subtemporal petrosal approach for meningeomas of the posterior fossa and petroclival region was described by M. Gazi Yasargil in 1980, Laligam N. Sekhar in 1984, Ossama Al-Mefty in 1988, Madjid Samii in 1989 and Takeshi Kawase in 1991 (Fig. 3.0.9).

Tumorous and vascular lesions of the cavernous sinus were considered to be inoperable before the pioneering work of Dwight Parkinson. Approaches through the lateral wall of the cavernous sinus using subtemporal exposure were published by several experienced surgeons [Parkinson 1965, 1973, Johnston 1979, Umansky 1982, Dolenc 1983, Perneczky 1987]. Extended fronto-temporal and temporo-basal exposures for lesions of the cavernous sinus area and temporal skull base were reported by Laligam N. Sekhar, Vinko Dolenc and Ossama Al-Mefty [Sekhar 1986, Dolenc 1987, Al-Mefty 1988]; however, the damaging approaches such as the pre-auricular infratemporal or orbitozygomatic exposures usually did not influence the extent of resection but resulted in higher postoperative morbidity. Compared with these extended approaches, other authors reported on subtemporal keyhole craniotomies, allowing optimal visualization of the posterior and lateral aspect of the cavernous sinus and the temporal skull base [Perneczky 1988, Knosp 1996, Taniguchi 1997].

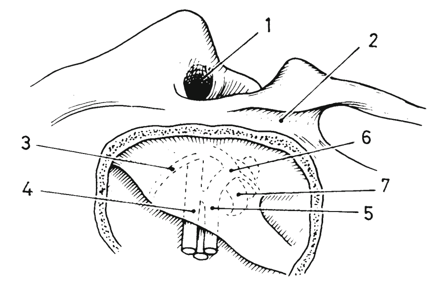


Fig. 3.0.8 *Identification of the internal auditoy canal by the subtemporal approach using the superior semicircular canal as unique landmark, published by Ugo Fisch in 1968. The relationship of the external auditory canal (1), the root of the zygomatic arch (2), the superior semicircular canal (3), the vestibular nerve (4), the facial nerve (5), the geniculate ganglion (6) and the basal term of the cochlea (7) is well demonstrated.*

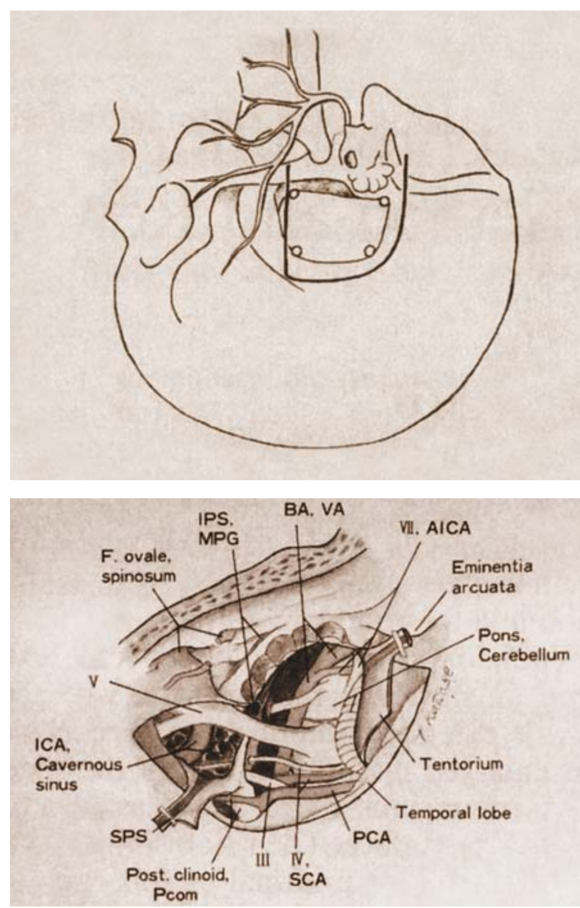
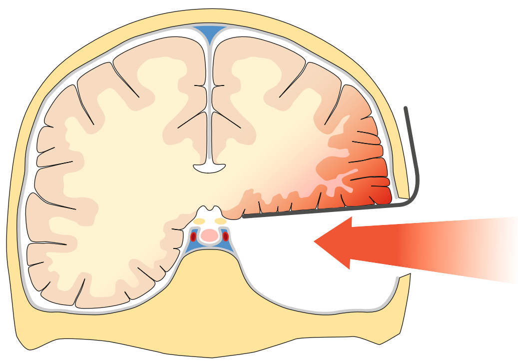


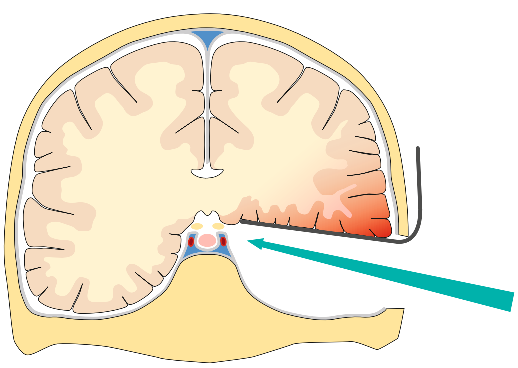
Fig. 3.0.9 *Kawase's subtemporal approach observing lesions of the central skull base. Note the wide exposure of the posterior fossa after removal of the petrous apex.*

General anatomical construction of the middle cranial fossa, the cerebellopontine angle and the suprasellar region

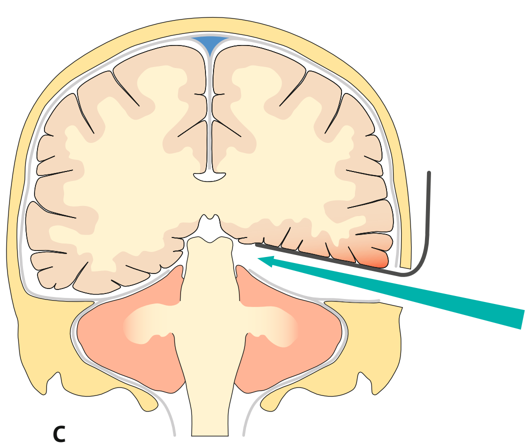
Prior to performing a subtemporal approach, the anatomical characteristics of the middle and anterior cranial fossa should first be considered. The base of the anterior part of the middle cranial fossa is situated deeper than the base of the suprasellar area,



A



B



C

Fig. 3.0.10 *Exposing the supra- and parasellar region through an anterior subtemporal craniotomy, retraction of the temporal lobe must always be included (A). However, due to a basal (B) or posterior (C) placement of the approach, temporal contusion can be effectively minimized.*

represented by the anterior and posterior clinoid processes and the diaphragma sellae [LANG 1981]. This means that approaching this area from a lateral, temporal direction, the anterior part of the temporal lobe obscures access to the important suprasellar structures. Therefore, using the anterior temporal exposure, manipulation and retraction of the temporal lobe must always be included with subsequent injury and contusion of the basal part of the temporal lobe. In order to minimize the retraction of the temporal lobe, the anterior subtemporal craniotomy should be placed as close to the base as possible (Fig. 3.0.10 A, B). In addition, a posterior placement of the craniotomy can effectively minimize temporal retraction (Fig. 3.0.10 C). Early drainage of CSF, adequate positioning of the patient, minimal dural opening and careful surgical dissection are also essential factors to avoid contusion of the temporal lobe.

Using subtemporal craniotomies, a frequently described surgical problem is dealing with the inferior anastomotic vein of Labbé. However, using a limited anterior subtemporal approach, dissection of the posteriorly situated vein must be never included.

The main target regions using the anterior subtemporal approach are the lateral aspect of the suprasellar region, the cavernous sinus and the anterolateral posterior fossa.

As previously described, the suprasellar region can be represented as a virtual pyramid allowing a better constructional image of this area (Fig. 3.0.11). The base of the pyramid is formed by the diaphragma sellae and the lateral plane consists of the ICA, CN II, optic tract, PCoA, AChA, and the CN III. The posterior triangle plane is defined by the ventral surface of the mesencephalon and the BA, PCA and the SCA. The pyramid shows a slight tilt backwards with its axis formed by the infundibulum and pituitary stalk.

The base of the pyramid corresponds to the diaphragma sellae as roof of the bilateral cavernous sinus. From a surgical point of view, the cavernous sinus can be divided into three major anatomical parts (Fig. 3.0.12). The anterior part involves the para-infraclinoidal portion of the ICA and the structures of the superior orbital fissure. The middle part represents the field of the lateral sinus wall consisting of the CN III, CN IV, CN V/1 and the underlying horizontal segment of the ICA with the CN VI. The posterior part involves the region of the petrous bone tip including the Dorello canal with the CN VI, the posterior knee of the ICA and the Gasserian ganglion.

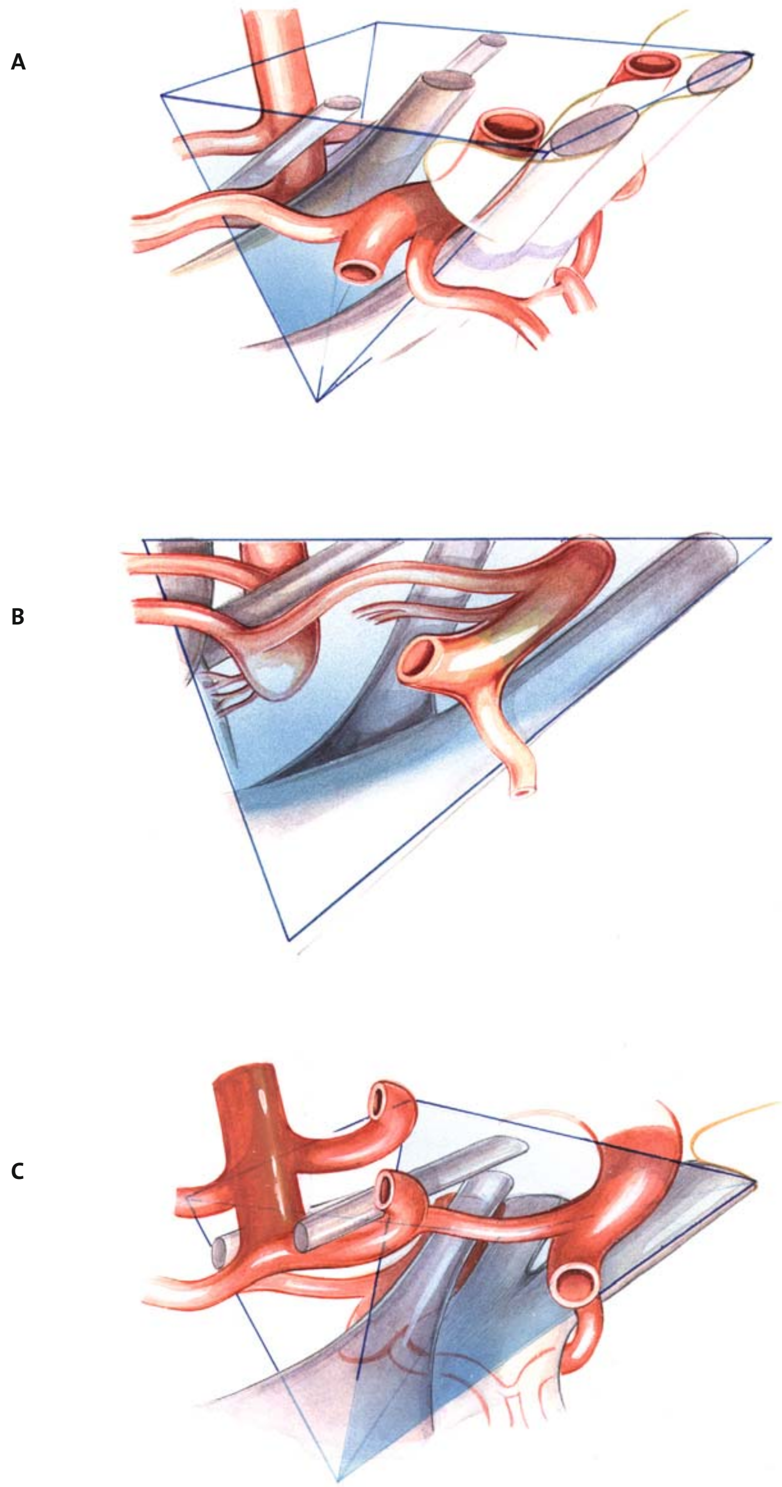


Fig. 3.0.11 *A virtual pyramid construction of the suprasellar region, demonstrating various viewing angles through the A) anterior, B) middle, and C) posterior subtemporal exposures. Note that the same anatomical structures are exposed differently according to diverse surgical visualizations.*

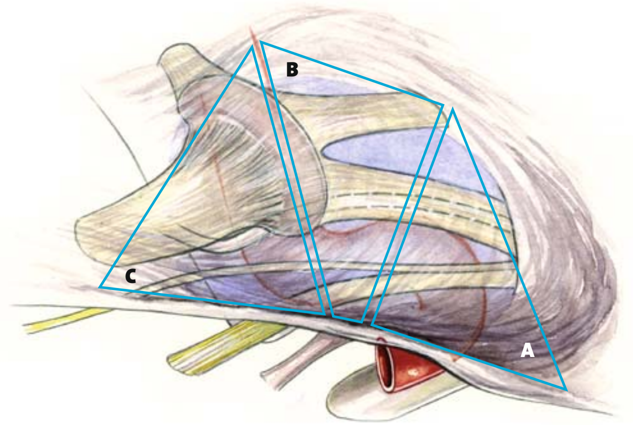


Fig. 3.0.12 *Artist's drawing demonstrating the left cavernous sinus. The venous chamber can be divided into three major parts. The anterior part represents the para-infraclinoidal segments of the ICA (A). The middle part involves the lateral wall of the CS and the horizontal segment of the ICA (B). The posterior part involves the petrous apex and the posterior knee of the ICA (C).*

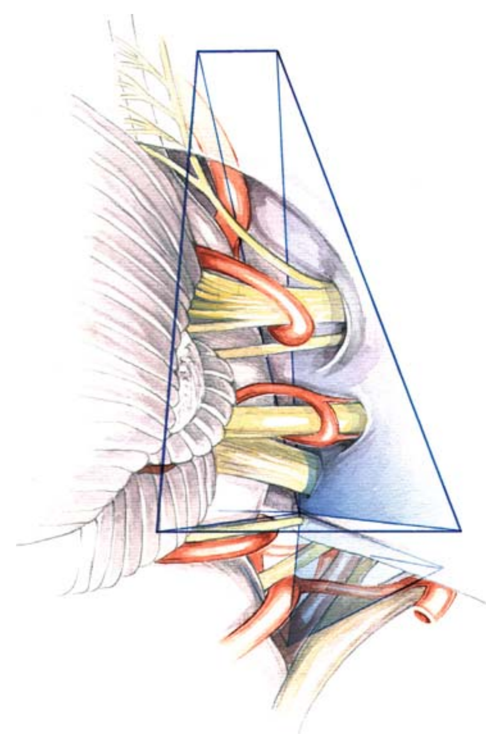


Fig. 3.0.13 *The anterolateral posterior fossa can be exposed using a transtentorial extension of the subtemporal approach. Note that the upper cerebellopontine angle can also be defined as a virtual pyramid, with its apex represented by the posterior clinoid process and the base formed by the anterior surface of the brain stem.*

Using an anterior subtemporal craniotomy, the suprasellar pyramid and the cavernous sinus are approached from a laterobasal aspect; however, with incision of the tentorium and partial removal of the petrous apex, the posterior cranial fossa can also be approached. The anterolateral posterior fossa and the cerebellopontine angle region can also be defined as a pyramid but inclined ventrally with its apex pointing to the posterior clinoid process and the base facing the inner lateral surface of the occipital bone (Fig. 3.0.13). The superior side corresponds to the inferior surface of the tentorium with the CN IV running through it. The inferomedial side includes the VA and the CN XII. The anterior and posterior sides are represented by the posterior surface of the petrous bone and the anterolateral surface of the brain stem and cerebellum, respectively.

Using the anterior subtemporal approach, the upper part of the cerebellopontine pyramid can be entered. After performing a tentorial incision and partial resection of the petrous apex, the view into the cerebellopontine pyramid is divided by the CN V into two major windows. The cranial window offers access to the petroclival region with wide exposure around the anterolateral pontomesencephal junction and structures of the CN III, CN IV, BA, and proximal portions of the PCA and the SCA. Through the caudal window, the middle part of the clivus can be approached including the AICA and the CN VI.

In the following, the basic surgical technique of the anterior subtemporal approach is described as a step-by-step dissection.

Supra-, parasellar	Cavernous sinus	Posterior fossa
Temporobasal skull base Anterior clinoid process Posterior clinoid process Dorsum sellae APcL, Tentorium Diaphragma sellae Infundibulum, Pituitary stalk CN II, optic tract, CN III, CN IV ICA, A1, PCoA, AChA, incl. perforators	CN III, CN IV Gasserian ganglion CN V/1, CN V/2, CN V/3 CN VI ICA incl. intracavernous branches	Upper clivus Anterolateral mesencephalon Anterolateral pons Tentorium CN V, CN VI, CN VII, CN VIII BA, PCA, SCA, AICA, incl. perforators Basal vein of Rosenthal Petrous vein of Dandy

Table 3.0.1 *Anatomical structures approached through the subtemporal craniotomy.*

Surgical technique

1. Patient positioning

The patient is placed supine and the ipsilateral shoulder is raised with a cushion to facilitate head rotation. An electrically motorized operating table offers an additional tilting and intraoperative remodelling of patient positioning. By taking these precautions, a significant head and neck rotation with subsequent compression of the larynx, carotid artery and the internal jugular vein can be avoided. The head is fixed in a three-pin Mayfield holder with the single pin placed in the frontal area to allow free manipulation during the procedure.

Step 1

Initially, the head is elevated above the level of the thorax to facilitate venous drainage and to allow additional decompression of the cervical structures and the ventilation tube (Fig. 3.0.14).

Step 2

In the next stage the head is rotated 60°–100° to the contralateral side. The degree of rotation depends on the precise location of the lesion. Taken as a rough indicator, for lesions of the lateral suprasellar area and upper prepontine region, the zygomatic arch should be in an almost horizontal position with a rotation of ca. 90°. For the petrous apex, posterior fossa and the upper cerebellopontine angle, a head rotation of ca. 75° is required. A rotation of ca. 100° is necessary for exposing the temporopolar skull base (Fig. 3.0.15).

Step 3

Thereafter the head should be lateroflected by ca. 15°–20°. This important maneuvre provides an efficient working position for the surgeon as the steep upward angle of the medial part of the middle cranial fossa is compensated. In addition, lateroflexion supports the gravity-related self-retraction of the temporal lobe which is necessary to avoid forced retraction of the temporal lobe with subsequent temporobasal contusion (Fig. 3.0.16).

Step 4

As a last step, the head may be retroflected by ca. 10° in order not to compress the ventilation tube, larynx and the main cervical vessels (Fig. 3.0.17).

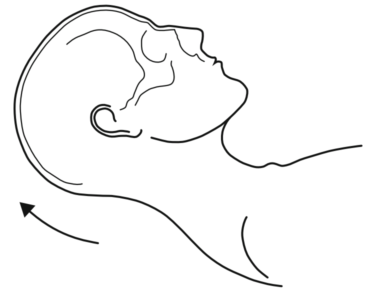


Fig. 3.0.14

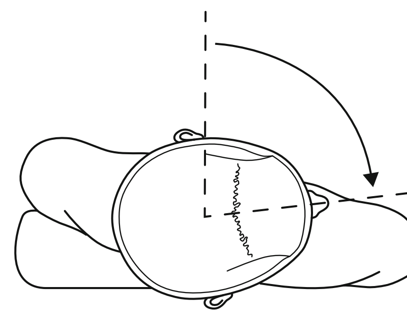


Fig. 3.0.15

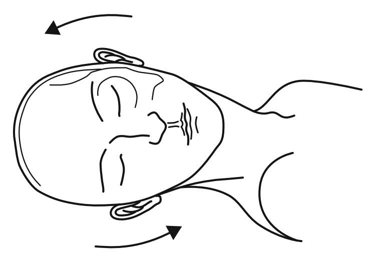


Fig. 3.0.16

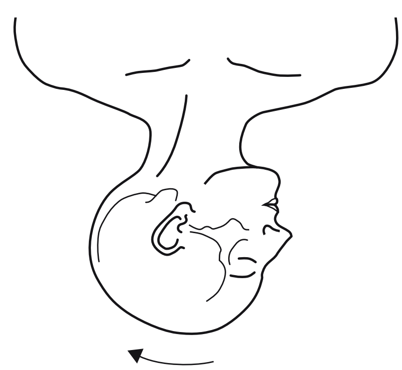


Fig. 3.0.17

2. Anatomical landmarks and orientation

For preoperative orientation, the important anatomical landmarks of the temporal osseous skull such as the lateral orbital rim, frontobasis, impression of the Sylvian fissure, zygomatic arch, articular tubercule, external auditory meatus and the supramastoid crest are precisely defined. Special attention must be given to the course of the superficial neurovascular structures of the pre-auricular temporal region such as the superficial temporal artery, the auriculotemporal nerve, and the temporal branch of the facial nerve (Fig. 3.0.18).

After precise orientation, the borders of the craniotomy are marked with a sterile pen, taking into consideration the target region and the superficial anatomical landmarks. The inferior border of the craniotomy, which usually has a diameter of ca. 15 to 25 mm, corresponds to the level of the zygomatic arch; the posterior border corresponds to the plane of the external auditory canal (Fig. 3.0.18). After definition of the craniotomy, the side hairs are shaved according to the line of a straight skin incision of ca. 40–50 mm in length. The skin is disinfected meticulously and the eyelids are protected with sensitive tape.

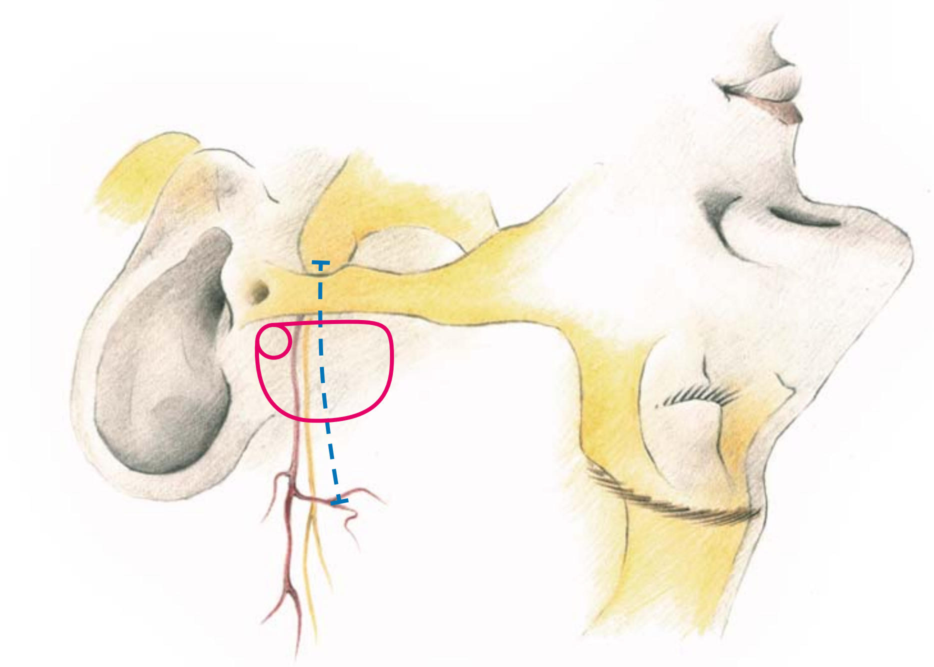


Fig. 3.0.18 *Definition of the craniotomy according to the anatomical landmarks of the temporal region. The skin incision should be made anterior to the superficial temporal artery, approximately at the level of the articular tubercule.*

Fig. 3.0.19

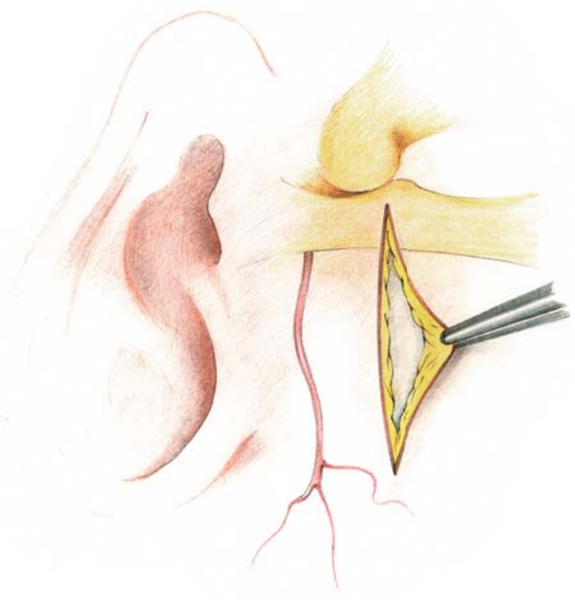


Fig. 3.0.20

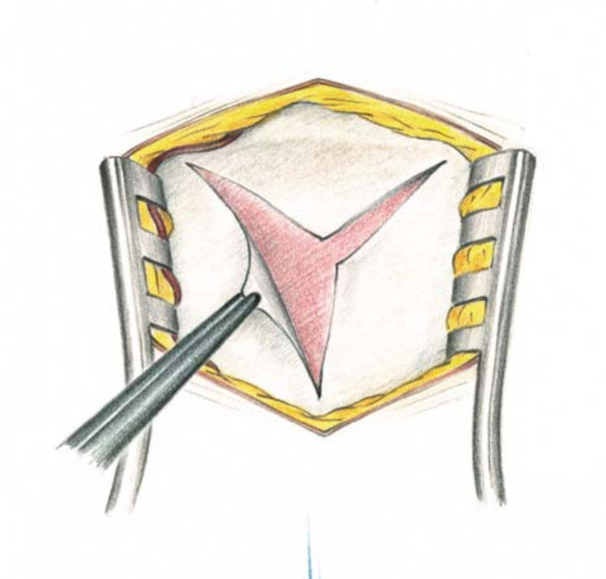
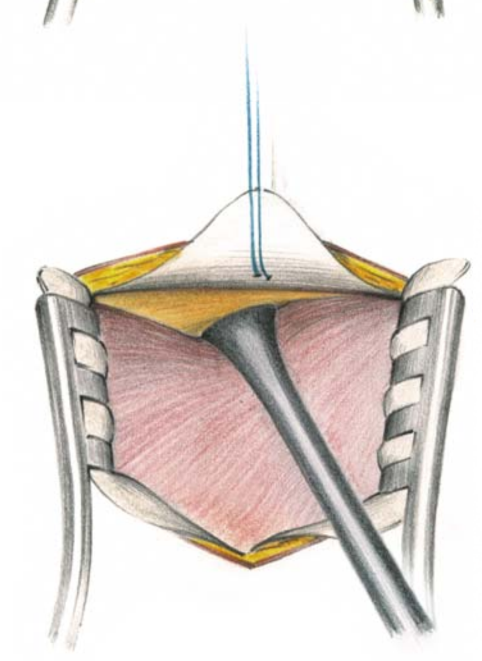


Fig. 3.0.21



3. Craniotomy

Step 1

Left side. After positioning and anatomical orientation, a vertical straight epifascial skin incision is made from the inferior rim of the zygomatic arch at the level of the articular tubercule approximately 10 mm anterior to the external auditory meatus. After performing this preauricular skin incision, the subcutaneous tissue is carefully dissected whilst preserving the superficial temporal artery and auriculotemporal nerve. With this skin incision, injury to the temporal branch of the facial nerve can be avoided (Fig. 3.0.19).

Step 2

After bilateral retraction of the skin, the fascia of the temporal muscle is cut in a Y-shaped fashion. The basal flap of the fascia is reflected upwards over the zygomatic arch. The remaining two flaps of the temporal fascia are dissected bilaterally exposing the temporal muscle (Fig. 3.0.20).

Step 3

The basal flap of the fascia is fixed with holding sutures upwards. Under the zygomatic arch, the inferior margin of the temporal muscle is dissected bluntly and retracted downwards with a dissector exposing the squamous bone. Local hemostasis needs to be performed rapidly and precisely (Fig. 3.0.21).

Step 4

In patients with a thick temporal muscle, complete mobilization of the muscle is not possible, and a short vertical incision at the posterior margin is necessary. However, exposure and mobilization of the temporal muscle can be restricted to the necessary minimum to prevent postoperative problems with mastication and severe temporal atrophy (Fig. 3.0.22).

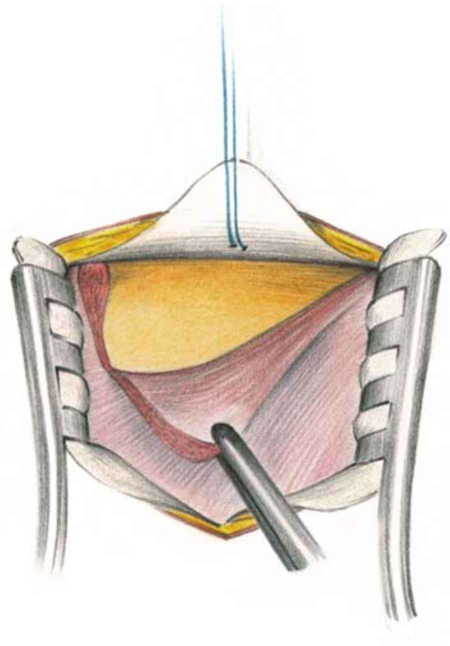


Fig. 3.0.22

Step 5

The temporal muscle is then retracted bilaterally using a wound retractor and the squamous bone is exposed. In some cases, a tiny groove is visible between the protuberances of the medial and inferior temporal gyrus. The craniotomy is started with a burr hole trephination just above the zygomatic pedicle anterior to the level of the external auditory meatus (Fig. 3.0.23).

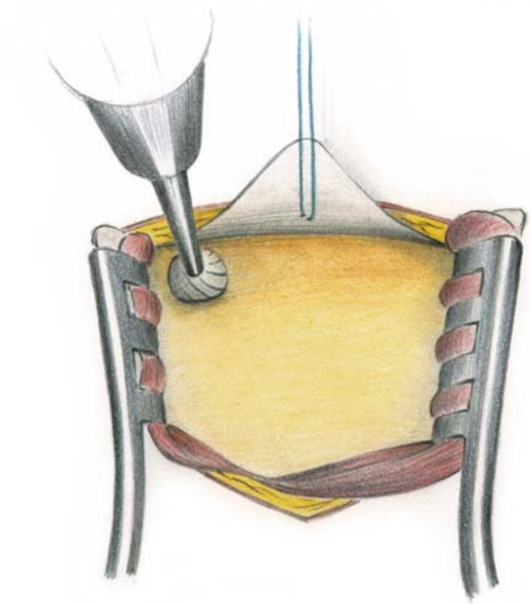


Fig. 3.0.23

Step 6

After minimal enlargement of the hole with fine punches and mobilization of the dura, a straight line is sawed with the craniotome parallel to the zygomatic arch. Thereafter a “C” shaped, curved line is sawed from the burr hole to the anterior border of the previously made temporobasal line, creating a bone flap with a width of ca. 15–25 mm and a height of ca. 15–20 mm (Fig. 3.0.24).

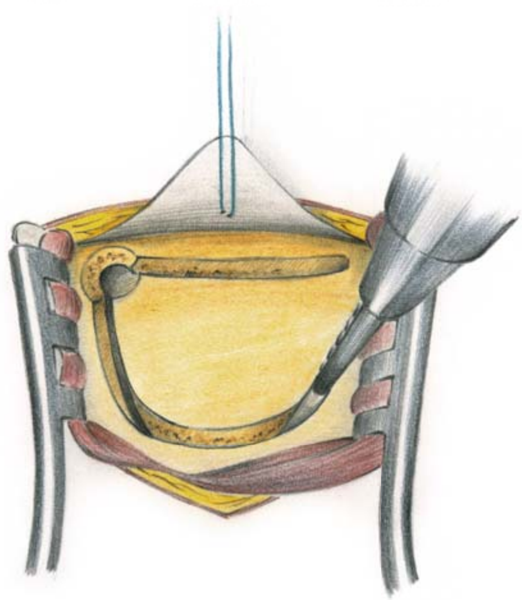
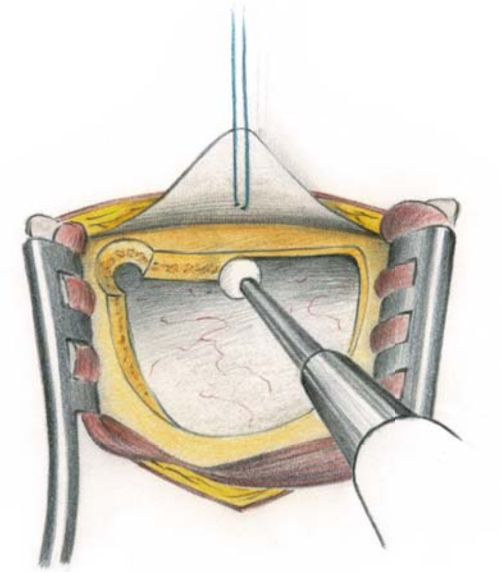


Fig. 3.0.24

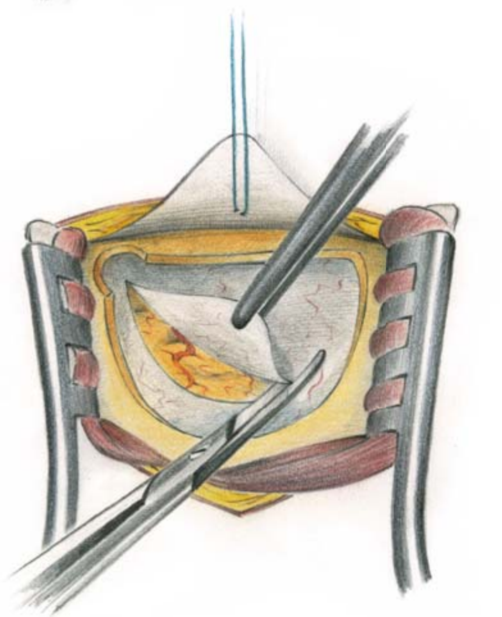
Fig. 3.0.25



Step 7

An osteoplastic craniotomy is carried out in all cases. An important step of the craniotomy, after removal of the bone flap, is the drilling of the inner edge of the temporobasal line under protection of the dura with a high-speed drill. Hemorrhages occurring during the craniotomy can be stemmed using bipolar coagulation and wax (Fig. 3.0.25).

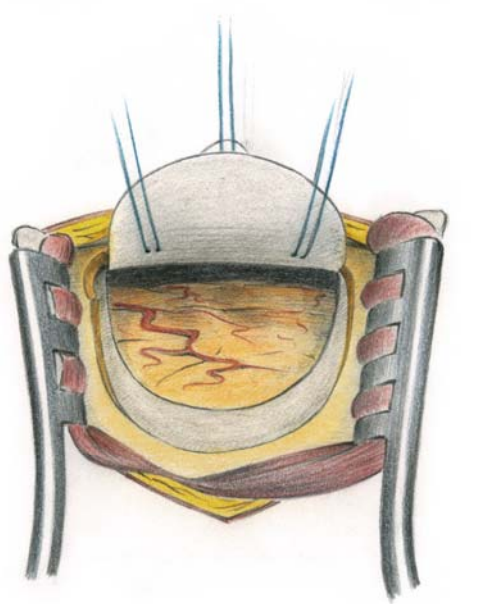
Fig. 3.0.26



Step 8

The dura mater should be opened in a simple semicircular way with its base towards the temporal skull base (Fig. 3.0.26).

Fig. 3.0.27



Step 9

The free dural flap is fixed upwards with two sutures. Other dural elevation sutures are not necessary with this limited craniotomy (Fig. 3.0.27).

4. Intradural dissection

Step 1

Left side. Dissection using fresh human cadaver; arteries filled with colored latex solution. After opening the dura mater, the first step should be provision of CSF drainage. The temporal lobe is gently retracted and the arachnoid membranes of the ambient cistern are opened. With optimal patient positioning, the decreasing ICP supports the gravity-related self-retraction of the temporal lobe. In the case of narrow ventricles and subarachnoid spaces, a lumbar drain can be inserted preoperatively, avoiding contusion of the temporal lobe during first steps of the intracranial procedure. Note the tentorial incisura and temporal lobe. The arachnoid is opened with a microdissector (Fig. 3.0.28).

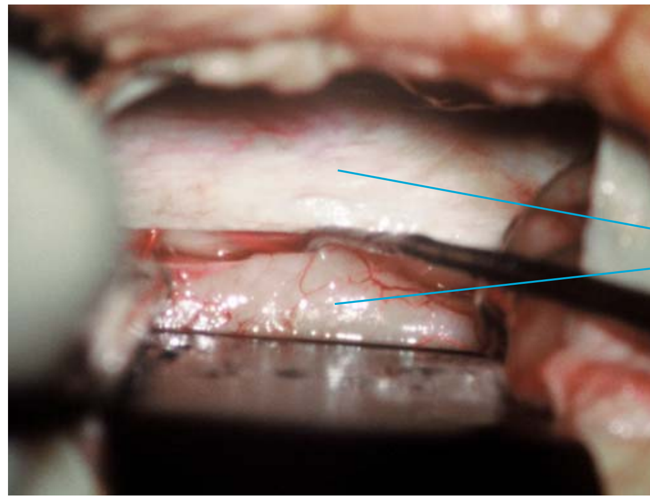


Fig. 3.0.28

Step 2

After opening the subarachnoid spaces and additional removal of CSF, the temporal lobe is sufficiently retracted for visualization of the PCA and CN III. Note the relationship between the anterior petroclinoid ligament and CN III (Fig. 3.0.29).

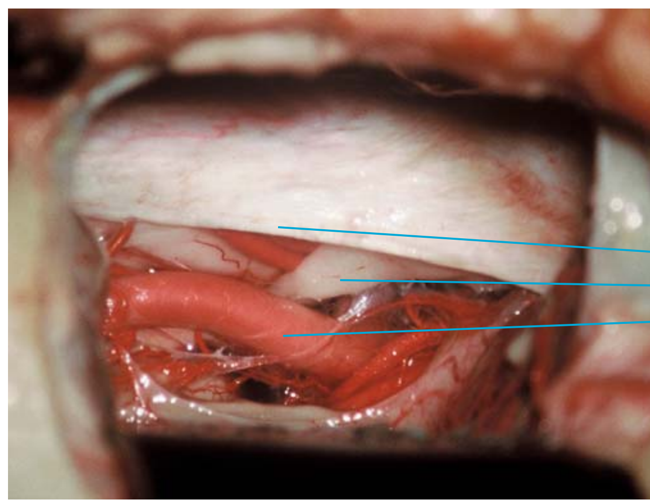


Fig. 3.0.29

Step 3

The anterior petroclinoid ligament is retracted with a microdissector, exposing the posterior petroclinoid ligament and the subarachnoidal segment of the CN III which enters the ponto-mesencephal sulcus between the SCA and PCA. The superior cerebellar artery that arose in this case as a double vessel disappears behind the tentorium. Note the basilar tip within the interpeduncular cistern (Fig. 3.0.30).

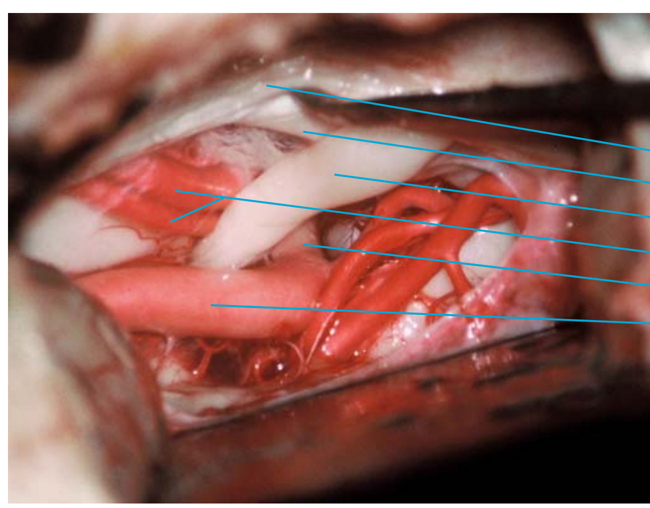


Fig. 3.0.30

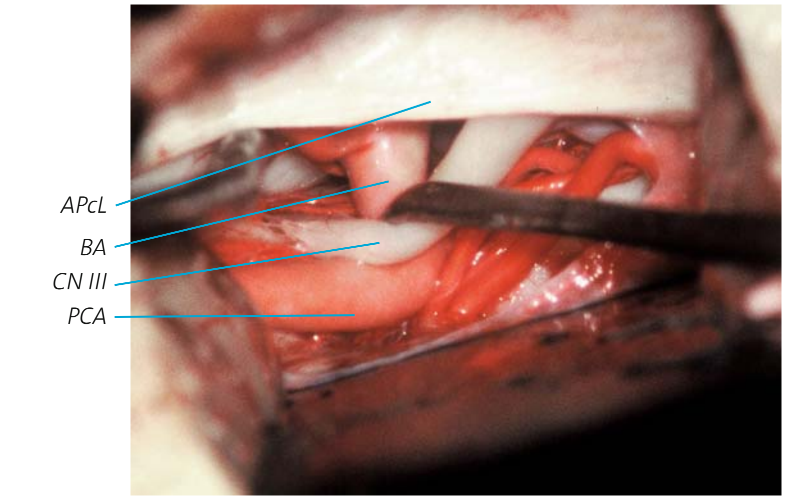


Fig. 3.0.31

Step 4
The CN III is gently retracted observing the distal BA. Note the PCA. The SCA is hidden behind the tentorium (Fig. 3.0.31).

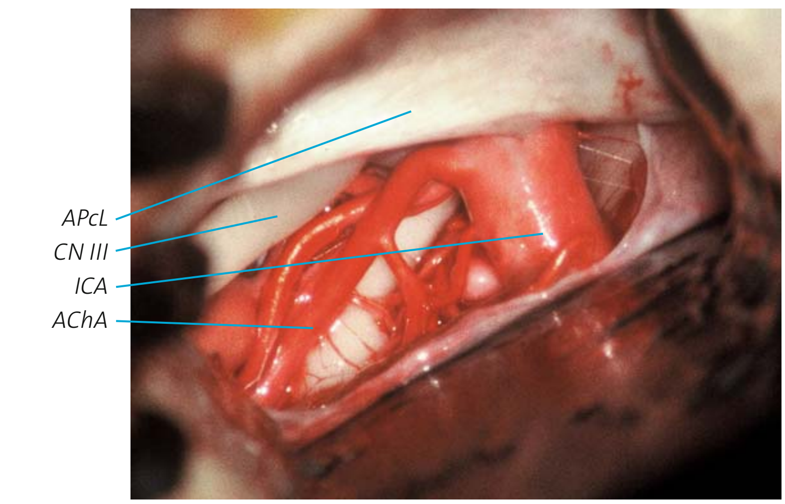


Fig. 3.0.32

Step 5
In an anterior view, the ICA can be approached via the subtemporal route. The supraclinoid segment begins where the ICA passes through the distal dural ring of the cavernous sinus, medial from the anterior petroclinoid ligament. Note the relationship between the CN III and ICA, visualized through the subtemporal craniotomy. Note the AChA (Fig. 3.0.32).

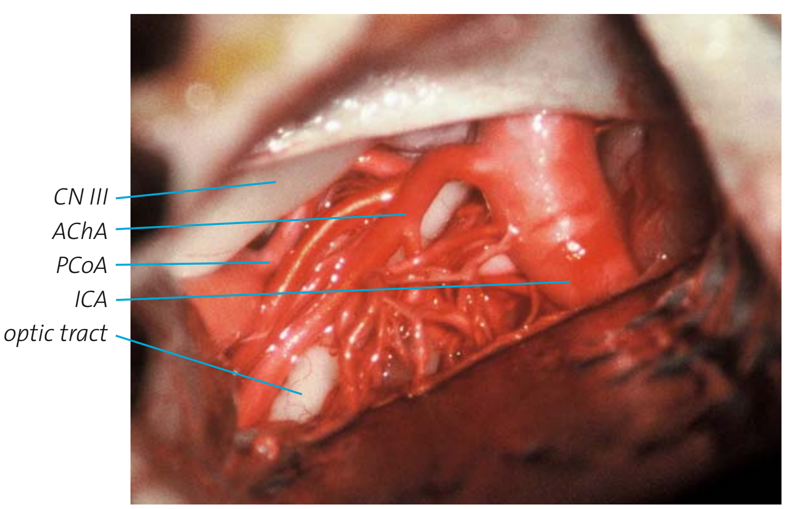


Fig. 3.0.33

Step 6
In an anterior aspect after further retraction of the temporal lobe, perforators of the ICA, AChA and PCoA can be seen supplying the anterior thalamus and hypothalamus. Note the CN III and optic tract (Fig. 3.0.33).

Step 7

In a posterior aspect, the trochlear nerve can be seen. The definition of its entry point into the tentorial notch by splitting of the tentorium is absolutely essential. After careful division of the tentorium, the lateral surface of the pontomesencephal junction and the ambient segment of the SCA can be obseved. Note the PCA (Fig. 3.0.34).

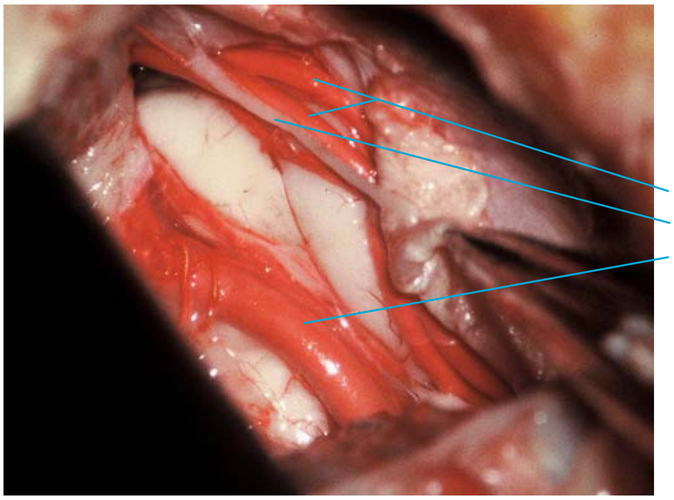


Fig. 3.0.34

Step 8

The tentorium cerebelli is divided posterior from the CN IV and raised to expose the CN V. Note the ambient segment of the SCA at the anterolateral margin of the brain stem running along the lateral surface of the upper pons. The caudal trunk of the SCA forms a loop projected towards the root entry zone of the CN V (Fig. 3.0.35).

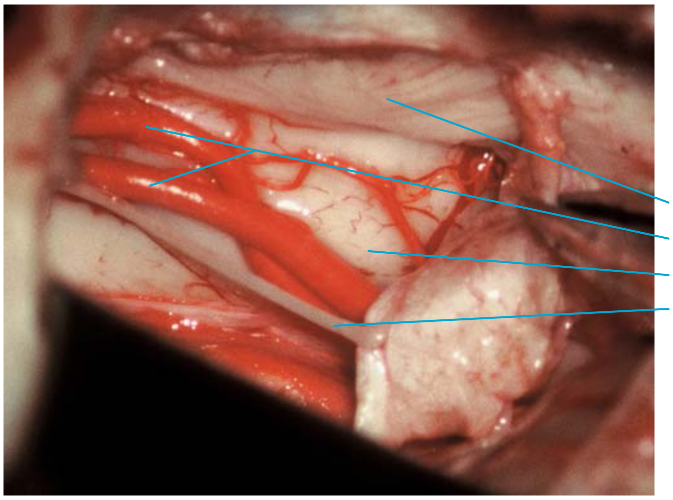


Fig. 3.0.35

Step 9

After partial removal of the tentorium, the retrosellar area with structures of the prepontine and interpeduncular cisterns is approached. Note the BA, SCA, PCA and the CN III (Fig. 3.0.36).

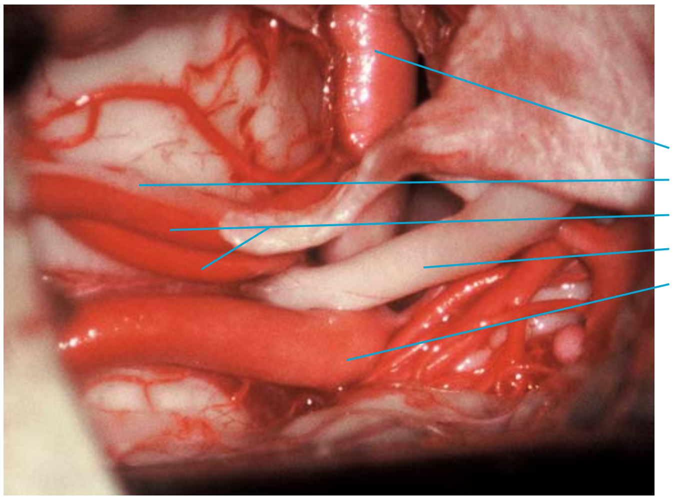


Fig. 3.0.36

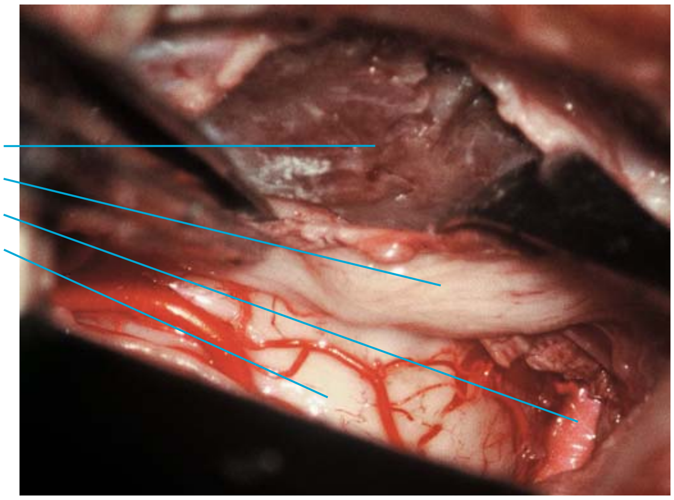


Fig. 3.0.37

Step 10

Focusing on the temporobasal skull base, the dural covering of the petrous apex is removed. The CN V is gently mobilized with a blunt dissector (Fig. 3.0.37).

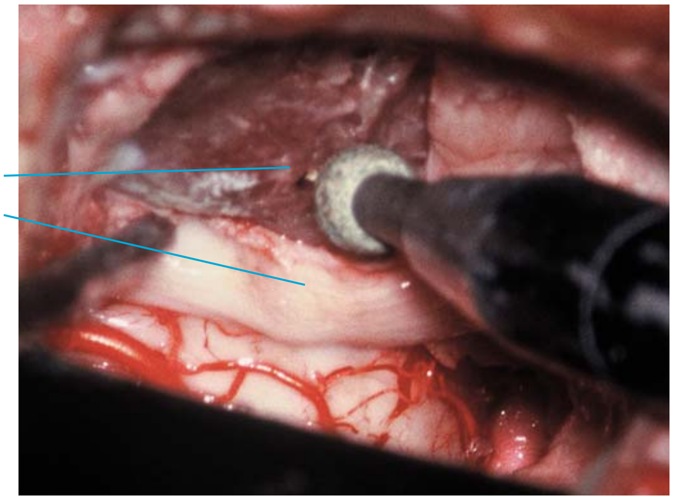


Fig. 3.0.38

Step 11

The petrous apex is removed with a diamond drill under gentle protection of the CN V. Note the trigeminal impression, a shallow depression on the anterior surface of the petrous apex (Fig. 3.0.38).

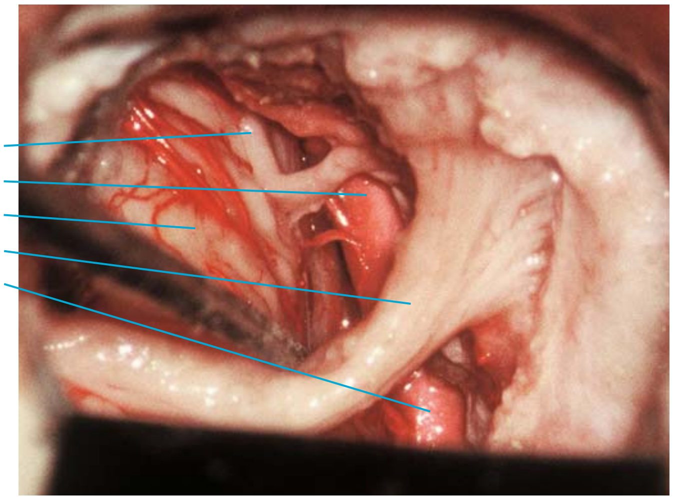


Fig. 3.0.39

Step 12

After resection of the petrous apex, the prepontine-retroclival region and the posterior part of the CS can be exposed. This view into the deep posterior cranial fossa is divided by the CN V into two major parts. The cranial window offers free access to the anterolateral pontomesencephal junction. Through the caudal window, the middle clivus and the prepontine region can be approached. Note the BA, CN V and trigeminal ganglion. The CN VI passes below the CN V running within the Dorello canal into the posterior CS (Fig. 3.0.39).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with Ringer solution at body temperature. The dural incision is closed as usual with watertight running or interrupted sutures. If tension has developed in the dural plane, implantation of small pieces of temporal muscle or plastic material may be necessary. A plate of gelfoam is placed extradurally and the bone flap is fixed with a titanium plate. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with intracutaneous sutures. The limited skin incision and nontraumatic surgical technique do not require the use of a suction drain.

Potential errors and their consequences

- Incorrect preoperative planning and positioning of the patient. Planning and positioning are tasks of the operating surgeon.
- Injury to the superficial temporal artery, auriculotemporal or facial nerve during skin incision.
- Traumatic dissection and retraction of the temporal muscle causing postoperative problems with mastication and later temporal atrophy.
- Overlooked, but often unavoidable injury to the dura mater during craniotomy. The essential watertight dural closure can be achieved using pieces of the temporal muscle or implantation of plastic material.
- Damage to the temporal lobe due to spatula pressure after inadequate removal of CSF.
- Injuries to numerous nerves and vessels in the lateral suprasellar area during surgical dissection with postoperative neurological deterioration.
- Inadequate dural closure with postoperative CSF leak. If mastoid cells were opened during craniotomy, nasoliquorrhea can occur.
- Inadequate hemostasis with postoperative intracranial or soft tissue hematoma.
- Incorrect positioning and fixation of the bone flap.

Tips and tricks

- Take time for preoperative planning and correct positioning. Special attention should be given to the plane of the tentorium demonstrated in the preoperative imaging.

- Make a careful anatomical orientation with definition of the osseous structures and neurovascular structures, placement of the craniotomy and skin incision.

- The temporal fascia should be cut in a Y-shaped fashion with the basal leaflet reflected toward the zygomatic arch. The remaining two flaps are retracted bilaterally leading to adequate exposure of the temporal bone (Fig. 3.0.40).

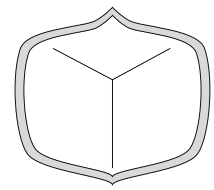


Fig. 3.0.40

- Stages of craniotomy (Fig. 3.0.41): 1. burr hole trephination; 2. temporobasal cutting parallel to the zygomatic arch; 3. sawing in a semilunar curved fashion from the burr hole to the anterior edge of the temporobasal craniotomy line.

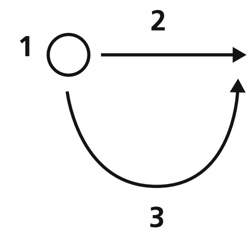


Fig. 3.0.41

- Drilling of the inner edge of the craniotomy after removal of the bone flap is important to ease intradural visualization and manipulation (Fig. 3.0.42).

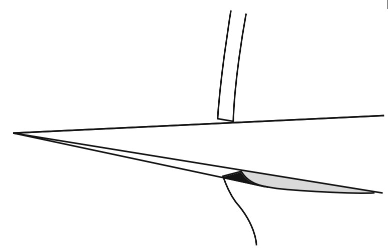


Fig. 3.0.42

- The dura is opened in a simple "C" shaped, semilunar fashion and retracted towards the zygomatic arch with two sutures. Other dural elevation sutures are not required (Fig. 3.0.43).

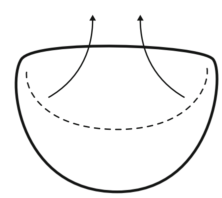


Fig. 3.0.43

- Adequate positioning of the patient, early removal of CSF from the ambient cistern or puncture of the lateral ventricle are required to avoid temporobasal contusion. Alternatively, a lumbar drain can be placed preoperatively.

- After finishing the intracranial procedure, the dural opening should be closed with watertight sutures. If tension has developed in the temporal dura, a small piece of muscle can be sewn into the dural closure. In other instances, plastic material may be used (Fig. 3.0.44).

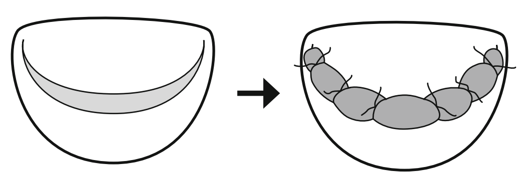


Fig. 3.0.44

Fig. 3.0.45

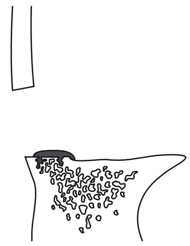
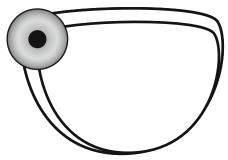


Fig. 3.0.46



- If penetration of the mastoid cells could not be avoided, meticulous closure is necessary. Bone wax or a flap of the temporal muscle can be used for this purpose (Fig. 3.0.45).

- Fixing the bone flap, the burr hole trephination should be closed with a titanium plate (Fig. 3.0.46).

- The skin incision should be closed with intra- or transcutaneous running sutures.

- Because of the limited skin incision and nontraumatic dissection a suction drain is not necessary.

3.1
Posterior variation of the subtemporal craniotomy

A

B

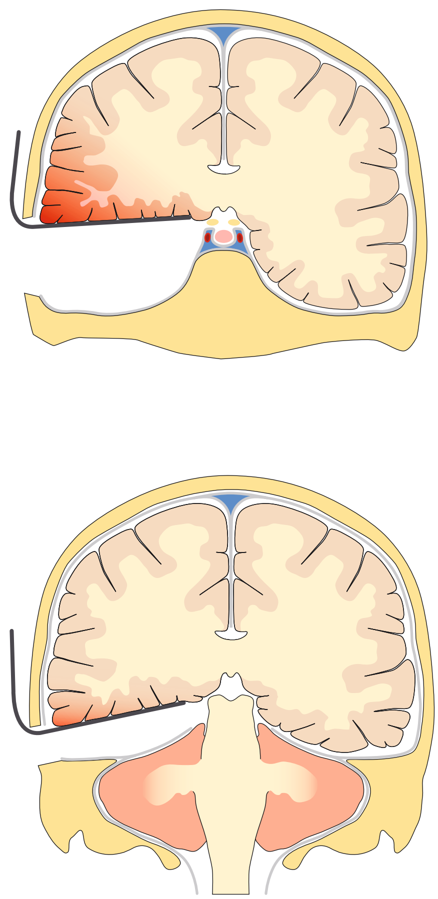


Fig. 3.1.1 *Schematic picture illustrating the advantage of a posteriorly placed subtemporal craniotomy. Compared with the anterior subtemporal route (A), the posterior modification requires significantly less retraction of the temporal lobe, allowing a less traumatic exposure of the posterior suprasellar area and tentorial hiatus (B).*

The advantage of the posterior craniotomy placement is the significantly reduced retraction of the temporal lobe compared to the anterior subtemporal approach. As previously desribed, the anterior subtemporal surgical access requires major retraction of the temporal lobe because the base of the anterior part of the middle cranial fossa is more deeply situated than the level of the suprasellar area. Using the posterior subtemporal approach along the superior border of the petrous bone and the tentorium, the view of the structures around the tentorial incisura is less obscured by the temporal lobe (Fig. 3.1.1).

A challenging problem using posterior subtemporal approaches is to deal with the inferior anastomotic vein of Labbé. In most cases, temporal bridging veins can be carefully dissected away from the cortical surface and from the dural entrance, circumventing occlusion. However, if scarification cannot be avoided, retraction of the temporal lobe must be maximally reduced allowing open flow in the anastomotic veins of the temporal surface. Thus, position and pressure of the brain spatula play a central role.

With the posterior subtemporal craniotomy, the region of the tentorial incisura can be well approached allowing safe dissection within the posterolateral prepontine, ambient, and quadrigeminal cisterns. The elasticity of the tentorium offers wide intracranial exposure. An additional splitting of the tentorium provides access to the posterior cranial fossa and visualization of the tentorial surface of the cerebellum and structures of the cerebellopontine angle.

According to the target structures and the planned surgical corridor, the exact placement and extension of the craniotomy can be varied. The center of these variations of the posterior subtemporal craniotomy corresponds approximately to the junction between the transversal and sigmoid sinuses (Fig.3.1.2). The anterior extension of the posterior subtemporal craniotomy opens a surgical corridor along the upper rim of the petrous bone (Fig.3.1.2A). The posterior extension provides the opportunity to approach the posterior part of the tentorial hiatus (Fig.3.1.2B). The posteroinferior extension of the posterior subtemporal craniotomy is a combina-

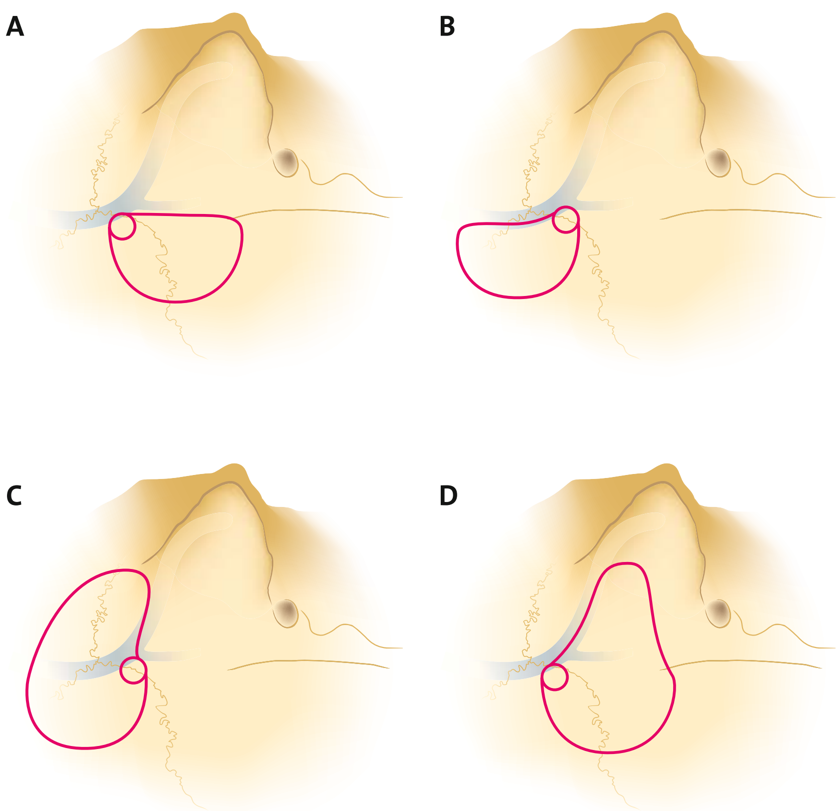


Fig. 3.1.2 *Schematic illustration demonstrating the variants of the posterior subtemporal craniotomy. The anterior variant (A) opens a surgical corridor along the upper rim of the petrous bone. After tentorial splitting, the structures of the posterolateral prepontine, lateral premesencephalic, ambient, upper cerebellopontine and quadrigeminal cisterns can be well exposed. The posterior extension (B) offers exposure of the posterior tentorial hiatus with the ambient and quadrigeminal cisterns. After splitting of the tentorium, the tentorial surface of the cerebellum can be exposed. The culmen and quadrangular lobule correspond to the anterior part and the declive, simple lobule and a part of the superior semilunar lobule correspond to the posterior part of this tentorial surface. The posteroinferior extension (C) represents a combination of the posterior subtemporal approach with the retrosigmoidal exposure. The anteroinferior variation (D) is a presigmoidal extension through the Trautmann triangle allowing wide exposure of the posterior fossa. Of course, these four variants can also be combined with each other and should be tailored according to the individual pathoanatomical situation.*

tion of the subtemporal approach with a retrosigmoidal exposure of the cerebellopontine angle (Fig.3.1.2C). The anteroinferior variation of the posterior subtemporal craniotomy represents a presigmoidal extension of the approach (Fig.3.1.2D).

In the following, details of the basic surgical technique of the anterior modification of the posterior subtemporal approach are given.

Supratentorial	Infratentorial
Posterior clinoid process	Tentorial incisura
Anterior and posterior petroclinoid ligaments	Superior petrosal sinus
Tentorial incisura, superior petrosal sinus	Upper part of the clivus
Lateral aspect of the pontomesencephal junction	Cerebellopontine angle
Lateral pineal region	Anterolateral aspect of the mesencephalon and pons
Optic tract, CN III, CN IV	Tentorial surface of the cerebellum
ICA, PCoA, AChA, PCA, SCA, incl. perforators	CN IV, CN V, CN VI, CN VII, CN VIII
Basal vein of Rosenthal, vein of Labbé	Upper BA, SCA, AICA, incl. perforators
	Basal vein of Rosenthal, vein of Galen

Table 3.1.1 *Anatomical structures approached through the posterior subtemporal craniotomy.*

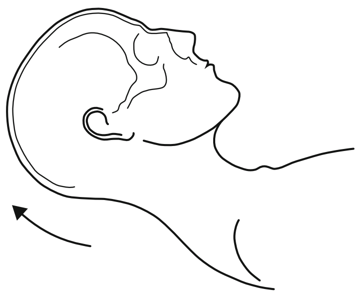


Fig. 3.1.3

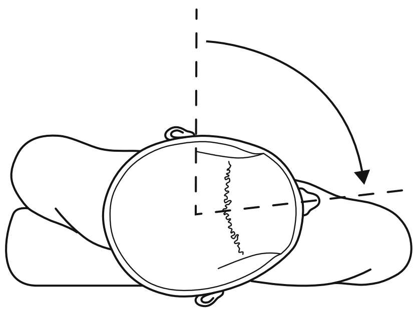


Fig. 3.1.4

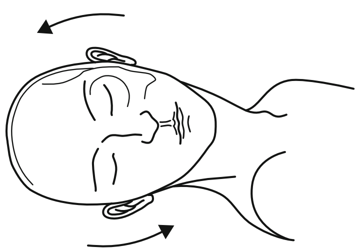


Fig. 3.1.5

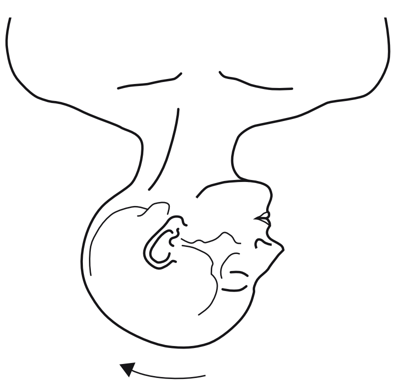


Fig. 3.1.6

Surgical technique

1. Patient positioning

With the patient in the supine position, the head is fixed in a Mayfield holder with the single pin placed in the frontal region allowing free dissection during surgery. The head of the operating table is elevated above the thorax, facilitating cranial venous drainage, and tilted to the opposite side supporting the significant head rotation. In addition, the ipsilateral shoulder is raised with a cushion avoiding compression of the main cervical vessels and the larynx.

Step 1

The head is elevated above the level of the thorax. This maneuvre facilitates additionally the cranial venous drainage and decompresses the larynx, the ventilation tube and the main cervical vessels (Fig. 3.1.3).

Step 2

Thereafter, the head is rotated ca. 80° to 100° to the side opposite to the planned craniotomy. The exact degree of rotation corresponds to the target region and to the direction of the surgical corridor. Approaching the tentorial incisura and the quadrigeminal cistern, a rotation of ca. 80° is required; exposing the anterolateral pontomesencephal junction, the head should be turned ca. 90° to the contralateral side; approaching the cerebellopontine angle through transtentorial path, a rotation of ca. 100° is necessary. As mentioned above, this significant rotation should be done with a sideways tilting of the operating table and with a cushion placed beneath the ipsilateral shoulder (Fig. 3.1.4).

Step 3

In the next step, the head is lateroflected ca. 15° to 20° downwards, supporting the gravity-related self-retraction of the temporal lobe. In this way, a forced retraction of the temporal lobe can be successfully avoided (Fig. 3.1.5).

Step 4

Finally, the head should be retroflected. This slight retroflection of ca. 10° may offer an additional decompression of the cervical structures (Fig. 3.1.6).

2. Anatomical landmarks and orientation

For preoperative orientation, the important anatomical landmarks of the temporoparietal region, e.g., the zygomatic arch, articular tubercule, external auditory canal, supramastoid crest, mastoid process, mastoid incisura, occipitomastoid and lambdoid sutures, asterion, parietomastoid suture, and the squamous suture should be precisely defined. Special care should be taken to define the level of the temporal base according to the supramastoid crest and to the course of the transversal and sigmoid sinuses (Fig. 3.1.7 A).

After anatomical orientation, the borders of the craniotomy and the optimum line of the skin incision should be defined. The basal line of the craniotomy corresponds to the temporal skull base, marked by the supramastoid crest. The posterior border of the craniotomy corresponds to the junction between the transversal and sigmoid sinuses. The center of the craniotomy is approximately at the level of the mastoid process. The straight or slightly curved skin incision should be made after minimal shaving and careful disinfection just behind the ear, allowing exposure of the temporomastoidal bony surface (Fig. 3.1.7 B).

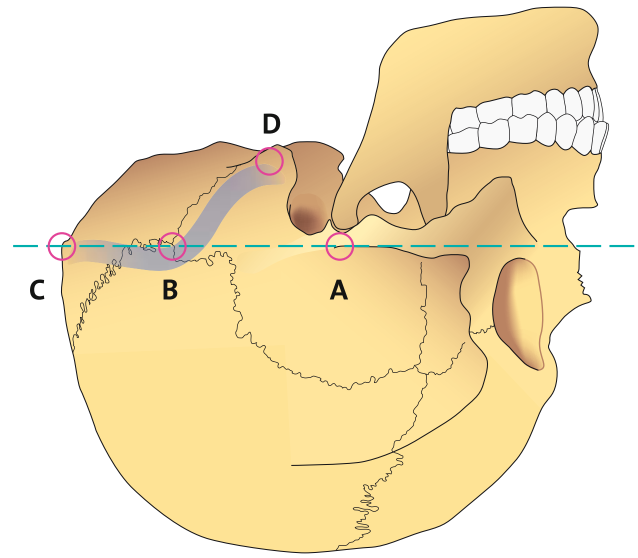


Fig. 3.1.7 A *Definition of the transversal and sigmoid sinus, according to the anatomical landmarks of the retroauricular-retromastoidal region. Note the supramastoid crest (A), asterion (B), external occipital protuberance (C) and the mastoid process (D).*

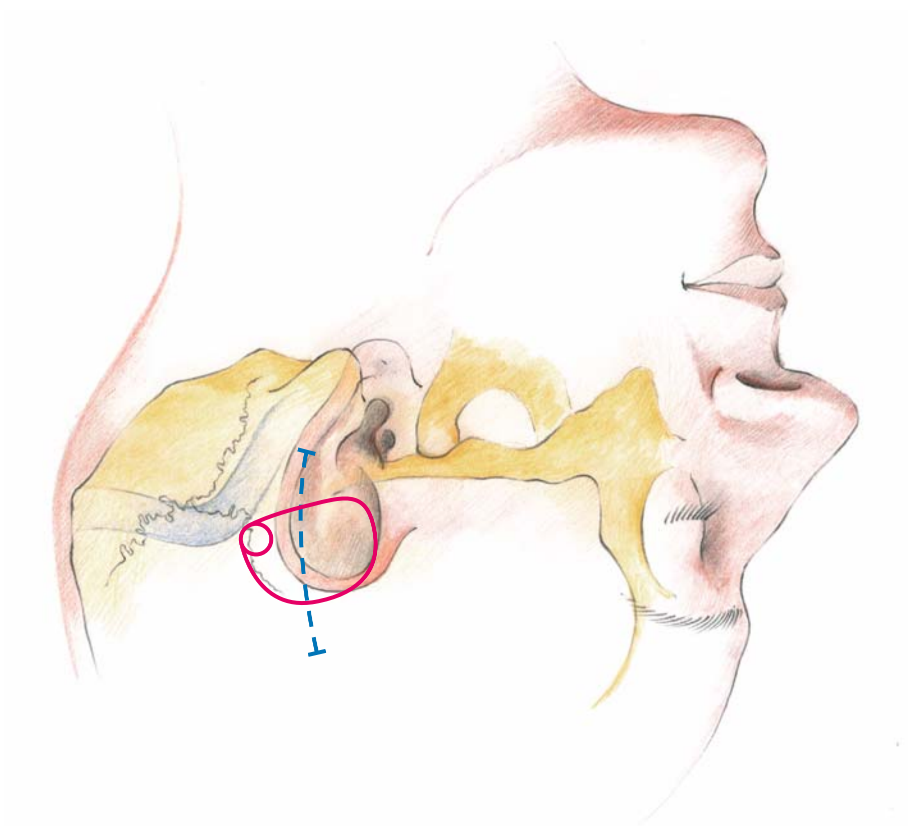


Fig. 3.1.7 B *Definition of the craniotomy, according to the anatomical landmarks of the posterior temporal region. Special attention must be given to the course of the transversal and sigmoid sinuses and to the level of the temporal skull base. Note the occipitomastoidal, lambdoid, parietomastoidal and squamosal sutures allowing exact determination of the trephination.*

3. Craniotomy

Step 1

Left side. After patient positioning, anatomical orientation, and minimal hair shaving, the skin is prepared with an alcohol solution. A straight or slightly curved epifascial skin incision of approximately 50 mm is then made just behind the ear at the level of the mastoid process (Fig. 3.1.8).

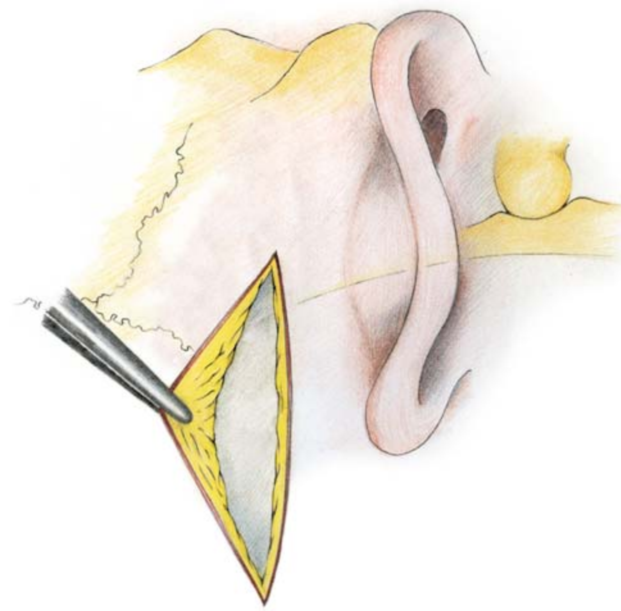


Fig. 3.1.8

Step 2

After bilateral retraction of the skin, the temporal muscle is moved from the supramastoid crest using a blunt dissector; the subgaleal fascia and periosteum is incised in the direction of the mastoid process (Fig. 3.1.9).

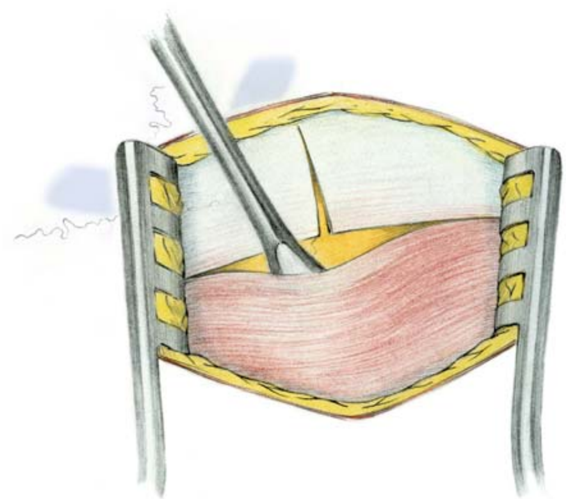


Fig. 3.1.9

Step 3

The basal leaflet of the fascia is held upwards with a strong holding suture. Using a wound retractor, the posterior flap of the fascia is retracted in a posterior direction and the temporal muscle in an anterior direction, gaining exposure to the junction between the mastoid process, temporal and parietal bones. Observing the bony surface, two anatomical structures, the supramastoid crest and the junction between the parietomastoidal and squamosal sutures, should be located precisely to avoid injury to the sigmoid sinus and to enter exactly the middle cranial fossa. The easily palpable supramastoid crest marks the level of the temporal skull base. The 90° junction between the parietomastoidal and squamosal sutures corresponds to the optimal placement of the burr hole trephination just in front of the junction between the transversal and sigmoid sinuses (Fig. 3.1.10).

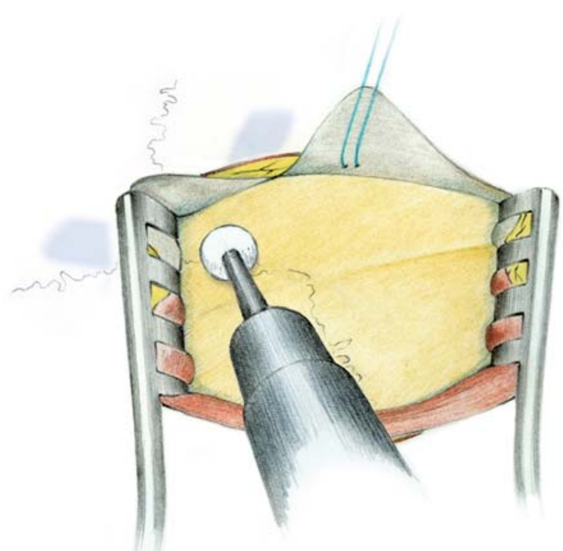
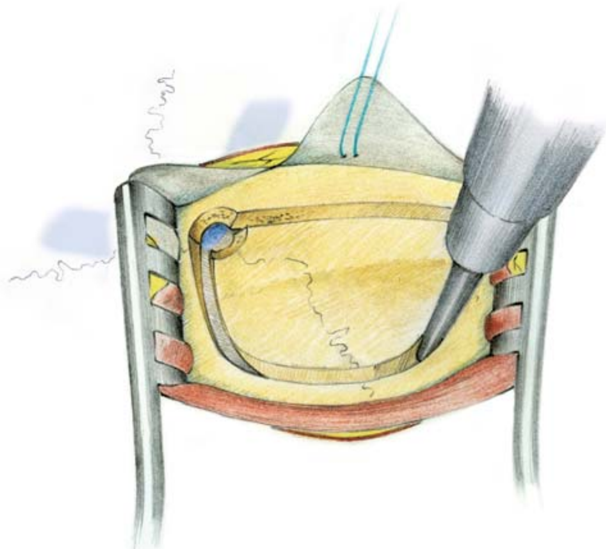


Fig. 3.1.10

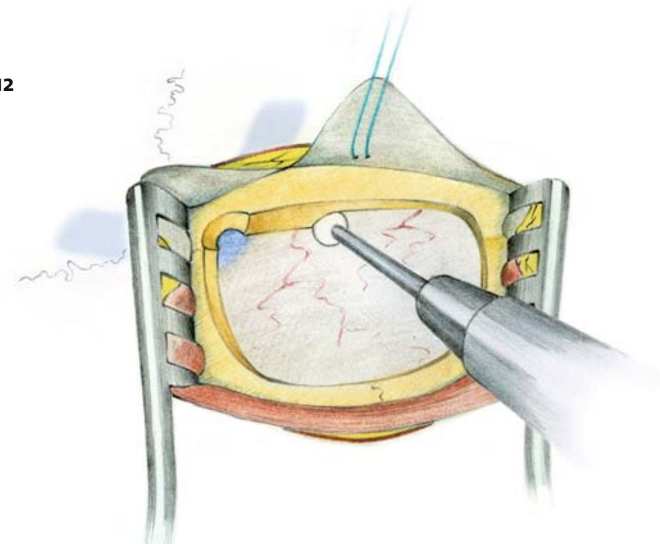
Fig. 3.1.11



Step 4

After minimal enlargement of the hole with fine punches and mobilization of the dura, the anterior border of the sigmoid sinus and the level of the temporal skull base are seen. Thereafter, a straight line is sawed with the craniotome in an anterior direction according to the level of the temporal skull base. Next, a "C" shaped, curved line is sawed from the burr hole to the anterior border of the previously formed temporobasal line, thus creating a bone flap with a width of ca. 15 to 25 mm and a height of ca. 20 mm (Fig. 3.1.11).

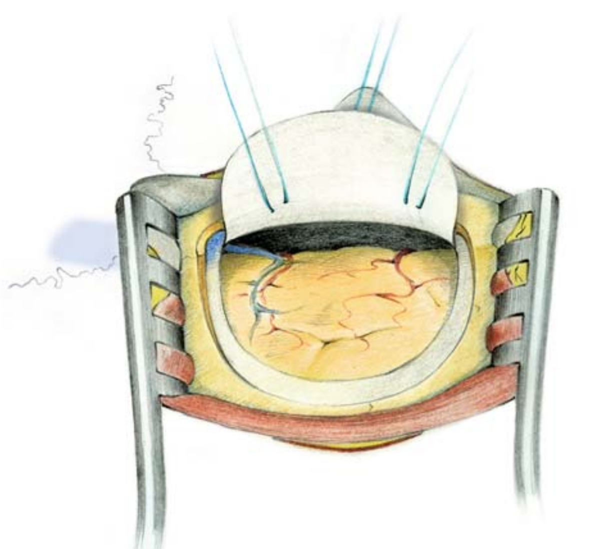
Fig. 3.1.12



Step 5

After removal of the bone flap, the inner edge of the temporobasal craniotomy line is removed using a high-speed drill providing a significantly increased intracranial view. In the posterior part of the craniotomy, injury to the transversal and sigmoid sinuses should be meticulously avoided (Fig. 3.1.12).

Fig. 3.1.13



Step 6

The dura should be opened in a curved fashion with its base towards the temporal skull base. The free dural flap is fixed downwards with two sutures. With this limited dural opening, other elevation sutures are not recommended (Fig. 3.1.13).

4. Intradural dissection

Step 1

Left side. Dissection using a fresh human cadaver; arterial vessels are prepared with red, veins partially with blue colored latex solution. After opening the dura mater, the surface of the posterior temporal lobe with the inferior anastomotic vein of Labbè are observed. If occlusion of the bridging vein cannot be avoided, retraction of the temporal lobe must be as minimal as possible allowing open flow within the anastomotic vessels of the temporal surface (Fig. 3.1.14).

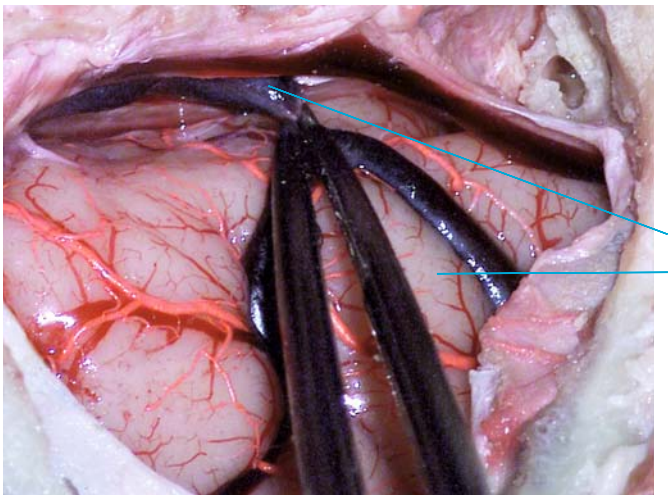


Fig. 3.1.14

Step 2

The temporal lobe is carefully raised. The first step of the intracranial dissection should be the opening of the subarachnoid spaces with sufficient CSF drainage. This supports the gravity-related self-retraction of the temporal lobe avoiding contusion of the temporobasal cortical surface. After gentle retraction of the tentorium with a microsucker, the surface of the cerebellum and the posterolateral brain stem are exposed. The CN IV appears within the posterior part of the ambient cistern (Fig. 3.1.15).

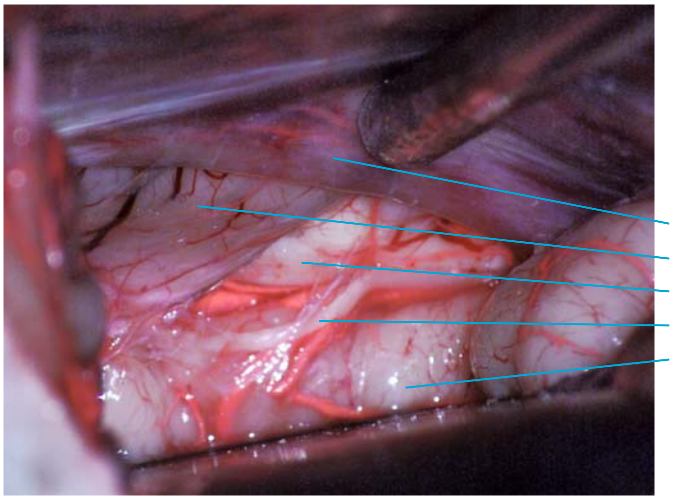


Fig. 3.1.15

Step 3

Looking in the anterior direction, the CN III can be seen disappearing into the roof of the cavernous sinus. Note the SCA, PCA and the anterolateral surface of the pontomesencephalic junction. In the posterior subtemporal view, the basilar tip is hidden behind the brain stem and cannot be exposed without retraction of sensitive structures. Note the anterior petroclinoid fold and behind the CN III the posterior clinoid process. Note the PCoA connecting the ICA and PCA (Fig. 3.1.16).

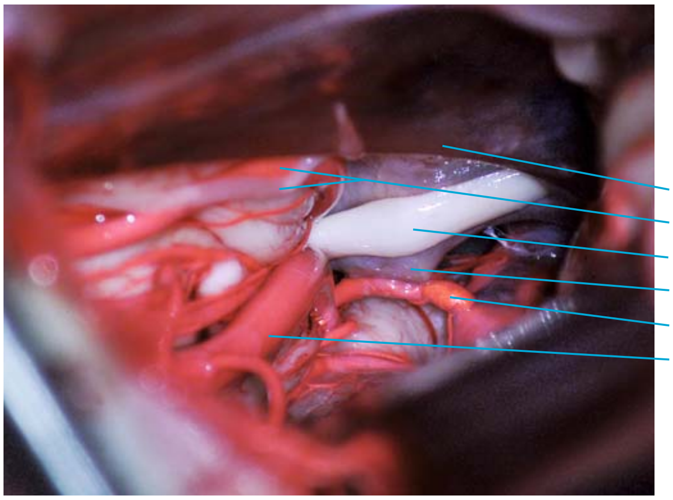


Fig. 3.1.16

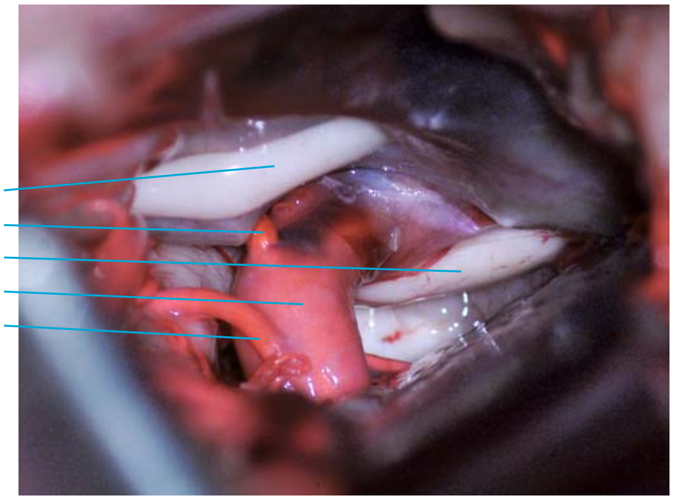


Fig. 3.1.17

Step 4

Continuing the anterior observation, the suprasellar region can be approached from the posterior subtemporal surgical corridor. Note the branches of the ICA, e.g., the posterior communicating and the anterior choroidal arteries. The optic nerve can also be well seen (Fig. 3.1.17).

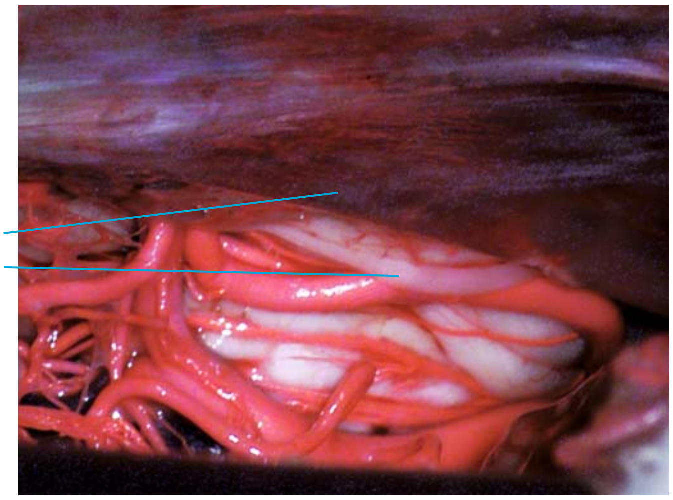


Fig. 3.1.18

Step 5

Observing again the tentorial notch, the posterior part of the ambient cistern is approached. After gentle retraction of the temporal lobe, the microscopic view is focused on the temporal surface of the tentorium. In the background, countless branches of the superior cerebellar and posterior cerebral arteries can be observed. Note the CN IV disappearing behind the tentorial notch (Fig. 3.1.18).

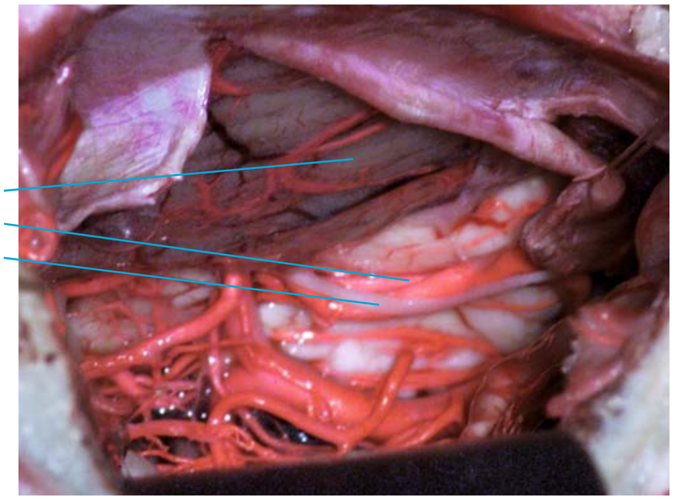


Fig. 3.1.19

Step 6

Exposure of the tentorial surface of the cerebellum after splitting the tentorium. In the background, we can see the structures of the ambient and quadrigeminal cisterns; note the intracisternal course of the CN IV close to the SCA (Fig. 3.1.19).

Step 7
After retraction of the divided tentorium, the dissection is orientated in a more posterior direction approaching the quadrigeminal cistern. Note the basal vein of Rosenthal and the pineal gland (Fig. 3.1.20).

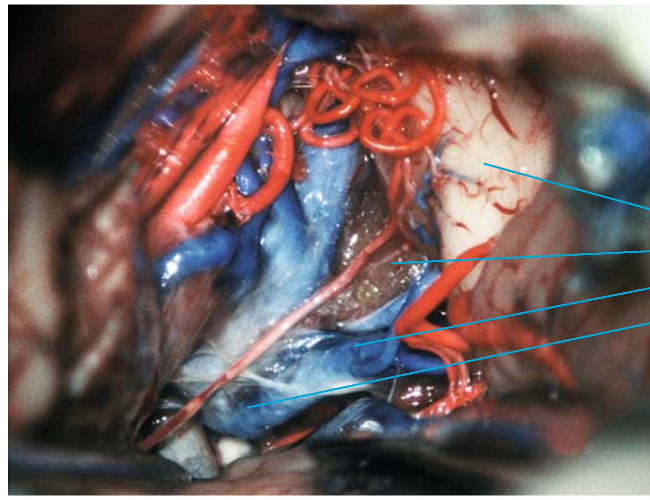


Fig. 3.1.20

Step 9
The posterior variation of the subtemporal craniotomy provides the opportunity to approach the upper cerebellopontine angle and the retroclival part of the posterior fossa. After retraction of the tentorium with strong holding sutures, the surgical corridor along the upper rim of the petrous bone is opened. Note the CN III, CN IV, and the CN V. According to the posteriorly placed craniotomy, the BA is hidden behind the brain stem (Fig. 32.1.21).

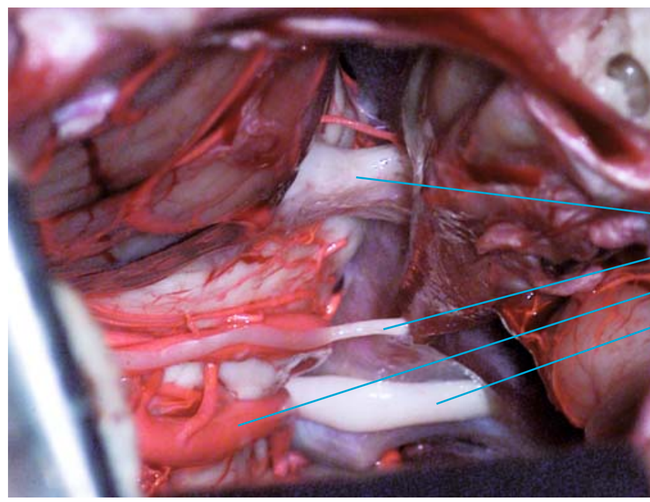


Fig. 3.1.21

Step 10
The anterior cerebellopontine and prepontine cisterns are approached via the subtemporal transtentorial pathway observing the facial and vestibulocochlear nerves. Note the posterior dural surface of the petrous bone and the clivus. A loop of the AICA appears close to the CN VII and CN VIII (Fig. 3.1.22).

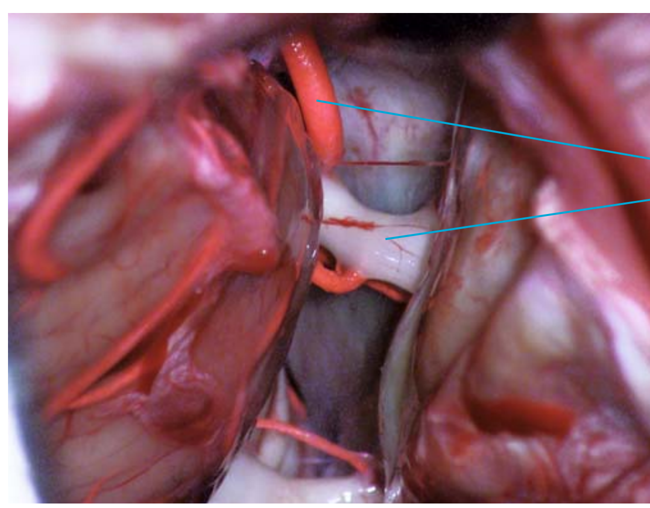


Fig. 3.1.22

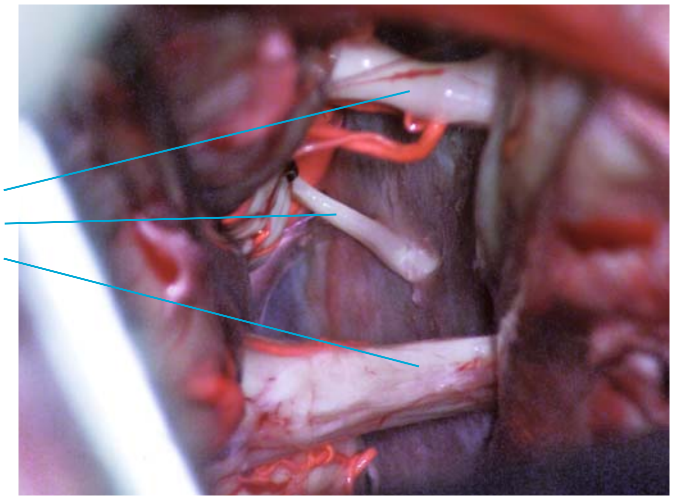


Fig. 3.1.23

Step 11

After further mobilization of the cerebellum, the CN VI is approached between the trigeminal and vestibulocochlear nerves. Note that the CN VI enters the dura of the clivus, running into the Dorello canal (Fig. 3.1.23).

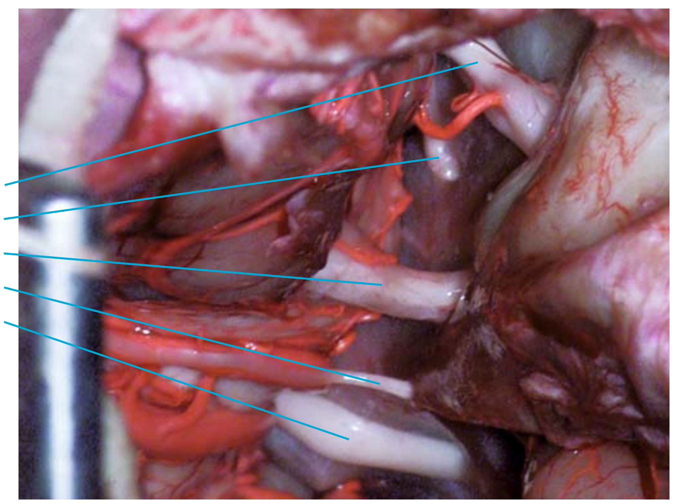


Fig. 3.1.24

Step 12

Overview of the middle and posterior fossa through the posterior subtemporal transtentorial approach. Note the CN III, CN IV, CN V, CN VI, CN VII and the CN VIII (Fig. 3.1.24).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with Ringer solution and the dural incision is closed as usual with running or interrupted sutures. If necessary, pieces of the temporal muscle or plastic material can be used for watertight closure. A plate of gelfoam is placed extradurally and the bone flap is fixed with a titanium plate. If possible, this plate should close the burr hole trephination. After final verification of hemostasis, the subgaleal and muscular layers are closed with interrupted sutures and the skin with intracutaneous sutures. Due to the small cutaneous incision and nontraumatic surgical dissection, the use of a suction drain is unnecessary.

Potential errors and their consequences

- Inadequate preoperative planning and positioning of the patient with subsequent deterioration in surgical access.
- Often unavoidable opening of the mastoid cells during craniotomy. The opening should be closed meticulously to avoid a postoperative CSF fistula.
- Injury to the transversal or sigmoid sinus during burr hole trephination. With precise anatomical orientation, this severe complication can be successfully avoided.
- Injury to the dura mater during craniotomy. In most cases, the dural dehiscence can be closed with a galeal flap or small pieces of the temporalis muscle. In other cases, implantation of plastic material is necessary.
- Injury to the vein of Labbé. Minimal dural opening and limited brain retraction can minimize this often problematic complication.
- Damage to the temporal lobe due to spatula pressure. Limited dural opening, adequate positioning of the patient and early removal of CSF from the ambient cistern can adequately minimize temporal compression.
- Injuries to numerous nerves and vessels in the lateral tentorial and suprasellar area during surgical dissection causing postoperative neurological deficits.
- Inadequate dural closure with postoperative CSF fistula. In cases of opened mastoid cells, nasoliquorrhea may occur with a potential risk of postoperative meningitis.
- Inadequate hemostasis during wound closure with intracranial or extracranial soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and correct positioning.
- Study the plane of the tentorium when performing surgical planning, it is important for positioning of the patient (Fig. 3.1.25).
- Compared with the subtemporal craniotomy, the posterior subtemporal approach requires more head rotation. This significant rotation can be supported with a cushion beneath the ipsilateral shoulder and with tilting of a motorized operating table (Fig. 3.1.26).
- Possible variations of the posterior subtemporal craniotomy: anterior extension (A); posterior extension (B); posteroinferior extension (C); anteroinferior extension (D) (Fig. 3.1.27).
- The temporal muscle should be moved with a blunt instrument; the fascia should be incised in the direction of the mastoid process allowing adequate exposure of the squamous bone (Fig. 3.1.28).
- Note the supramastoid crest, marking the level of the temporal skull base, and the 90° junction of the parietomastoidal and squamosal sutures defining the optimal placement of the burr hole trephination and the craniotomy (Fig. 3.1.29).

Fig. 3.1.25

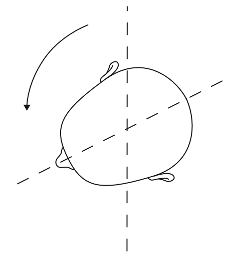


Fig. 3.1.26

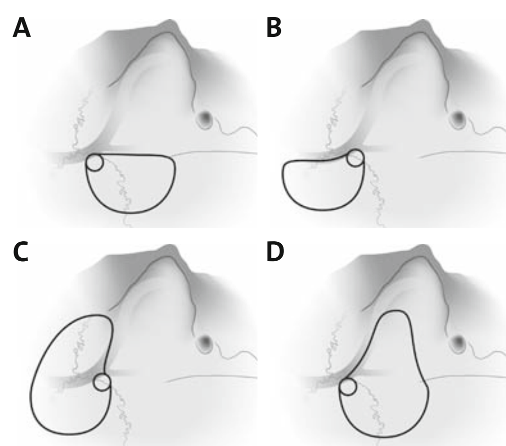


Fig. 3.1.27

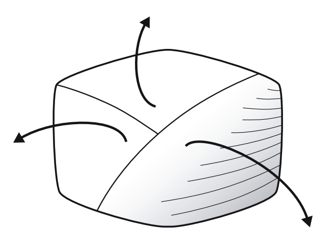


Fig. 3.1.28

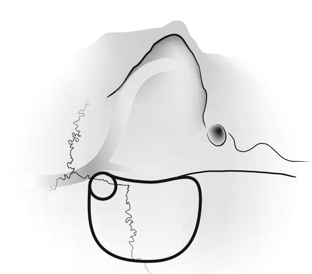


Fig. 3.1.29

- Stages of craniotomy (Fig. 3.1.30): 1. burr hole trephination at the junction of the parietomastoidal and squamosal sutures; 2. temporobasal cutting according to the temporal skull base; 3. sawing in a semilunar fashion from the burr hole to the anterior edge of the first craniotomy line.

- Drilling of the inner edge of the temporobasal craniotomy line after removal of the bone flap is important to facilitate intradural visualization and manipulation (Fig. 3.1.31).

- If penetration of the mastoid cells could not be avoided, meticulous closure is required (Fig. 3.1.32).

- The dural opening should be performed in a simple "C" shaped, semilunar fashion. The dural flap is held towards the temporal skull base with two sutures; other dural elevation sutures are not required (Fig. 3.1.33).

- After ending the intracranial procedure, the dural opening should be closed in a watertight fashion. If tension has developed in the temporal dura, a small piece of muscle can be sewn into the dural closure; in other cases plastic material should be used (Fig. 3.1.34).

- The burr hole trephination may be closed with a titanium plate providing an optimal fixation of the bone flap (Fig. 3.1.35).

- No suction drain is necessary.

Fig. 3.1.30

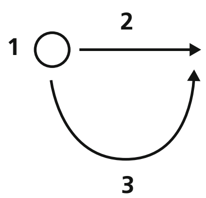


Fig. 3.1.31

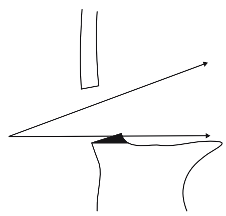


Fig. 3.1.32

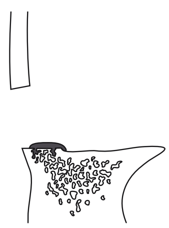


Fig. 3.1.33

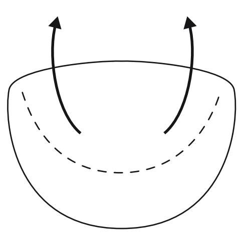


Fig. 3.1.34

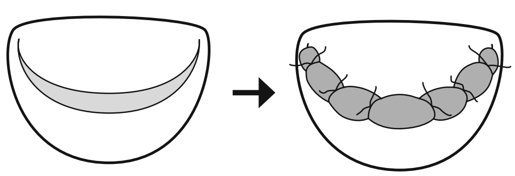
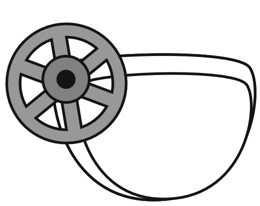


Fig. 3.1.35



3.2
The combined posterior subtemporal-presigmoidal approach

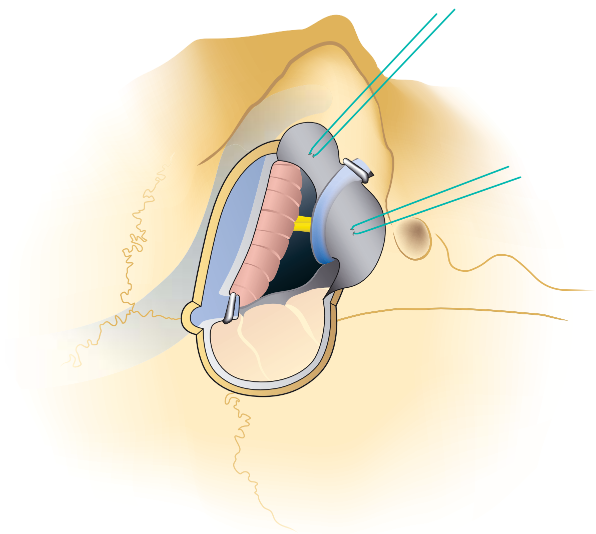


Fig. 3.2.1 *Schematic illustration demonstrating the objective of the presigmoidal extension of the subtemporal craniotomy: after a partial mastoidectomy and tentorial incision, the anterior part of the cerebellopontine angle can be effectively approached according to a combined supra- and infratentorial dissection.*

The posterior subtemporal craniotomy can be effectively extended in an anteroinferior direction. The essence of the combined posterior subtemporal-presigmoidal approach is the broad supra- and infratentorial exposure after performing a limited anterior mastoidectomy and opening the subtemporal and presigmoidal dura mater.

A challenging problem using combined posterior subtemporal-presigmoidal approaches is to deal with the inferior anastomotic vein of Labbé. In most cases, temporal bridging veins can be carefully dissected away from the cortical surface and from the dural entrance, circumventing occlusion. However, if scarification can not be avoided, retraction of the temporal lobe must be maximally reduced allowing open flow in the anastomotic veins of the temporal surface. Thus, position and pressure of the brain spatula play a central role.

This combined subtemporal-presigmoidal approach allows wide supra- and infratentorial visualization around the postero-superior surface of the petrous bone. The supratentorial subtemporal part of the approach corresponds to a variation of the posterior subtemporal craniotomy, allowing exposure of the posterolateral tentorial incisura. The infratentorial presigmoid part of the approach is centered on the mastoid process, performing varying degrees of mastoid and labyrinthine resection. Through the presigmoid dural opening, according to the Trautmann triangle, the cerebellopontine angle and the lateral cerebellomedullar region can be observed from the tentorial incisura into the craniocervical junction. We describe here a limited presigmoid dissection without destruction of the labyrinth and without displacement of the facial nerve. As a real retrolabyrinthine modification, in cases of narrow anatomical spaces, the approach may incorporate identification of the bony capsules of the lateral and posterior semicircular canals and skeletonizing the Fallopian canal. A more extensive degree of mastoid dissection with partial or entire resection of the semicircular canals and the vestibule does not allow significantly increased intracranial visualization of the deep-seated cerebellopontine structures and, in our opinion, should be avoided.

Supratentorial	Petrous bone	Infratentorial
Superior petrosal sinus Tentorial incisura Anterior and posterior petroclinoid ligament Posterior clinod process Posterior part of the cavernous sinus Lateral aspect of the pontomesencephal junction Lateral pineal region Optic tract, CN III, CN IV ICA, PCoA, AChA, PCA, SCA, incl. perforators Basal vein of Rosenthal, vein of Labbé	Fallopian canal Lateral semicircular canal Posterior semicircular canal	Trautmann triangle Superior petrosal sinus Tentorial incisura Upper part of the clivus Cerebellopontine angle Lateral aspect of the mesencephalon Lateral aspect of the pons Tentorial surface of the cerebellum CN IV, CN V, CN VI, CN VII, CN VIII CN IX, CN X, CN XI, CN XII AICA, PICA, VA, BA, SCA, incl. perforators Basal vein of Rosenthal, vein of Galen

Table 3.2.1 *Anatomical structures approached via the combined posterior subtemporal-presigmoidal craniotomy.*

In the following, the surgical technique of the subtemporal presigmoid approach is described.

Fig. 3.2.2

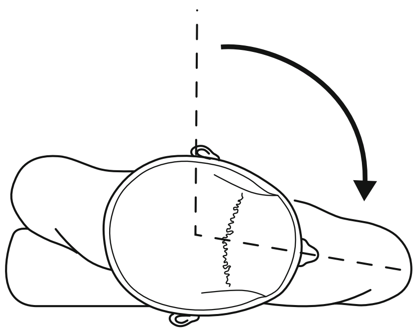


Fig. 3.2.3

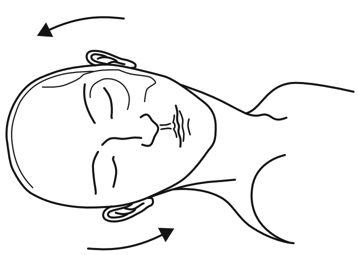


Fig. 3.2.4

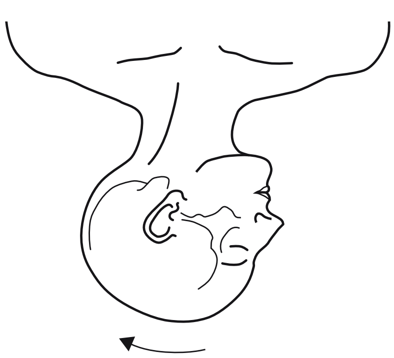


Fig. 3.2.5

Surgical technique

1. Patient positioning

With the patient in a supine position, the head is fixed in a Mayfield holder with the single pin placed in the forehead behind the hairline, allowing a free and comfortable position for surgery. According to the significant head rotation, the ipsilateral shoulder is elevated with a cushion, and, if necessary, the operating table can be tilted sideways.

Step 1

The elevation of the head above the level of the thorax facilitates cranial venous drainage and offers effective decompression of the cervical structures. Compared to the anterior and posterior subtemporal craniotomies, more elevation of the head offers optimal and ergonomic access to the cerebellopontine angle (Fig. 3.2.2).

Step 2

Thereafter, the head is carefully rotated about 90°–100° to the contralateral side. As mentioned above, this extreme rotation can be successfully supported with a cushion beneath the ipsilateral shoulder and by tilting the operating table. Special attention should be given to the ventilation tube, larynx and to the main cervical vessels. Compared to the anterior and posterior subtemporal approaches, the presigmoid modification requires more rotation to allow optimal access to the cerebellopontine angle (Fig. 3.2.3).

Step 3

The head should be lateroflected about 10°, supporting the gravity-related self-retraction of the temporal lobe. Compared to the anterior and posterior subtemporal approaches, the presigmoid variation needs less lateroflexion, providing optimal access to the cerebellopontine angle (Fig. 3.2.4).

Step 4

Similar to the posterior subtemporal approach, the head should be retroflected about 10°, providing a comfortable working position for the surgeon. The retroflexion also offers additional decompression of the ventilation tube, larynx and the cervical vessels (Fig. 3.2.5).

2. Anatomical landmarks and orientation

Before performing the skin incision, the anatomical landmarks of the lateral osseous skull such as the lateral orbital corner, zygomatic arch, articular tubercule, external auditory canal, supramastoid crest, mastoid process and the mastoid incisura are precisely palpated. Note the occipitomastoid, lambdoid, parietomastoid and squamosal sutures and definition of the asterion. Special attention should be given to the course of the transversal and sigmoid sinuses and to the level of the temporal skull base (Fig. 3.2.6 A).

After definition of the craniotomy, the individual optimum line of the skin incision is marked and placed about 10 mm in a retroauricular position at the level of the mastoid process (Fig. 3.2.6 B). After minimal shaving, the skin should be carefully disinfected with alcohol solution.

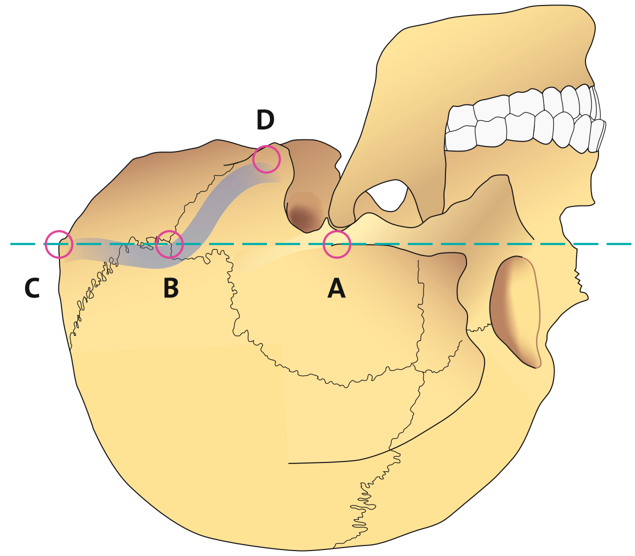


Fig. 3.2.6 A *Definition of the transversal and sigmoid sinus, according to the anatomical landmarks of the retro-auricular-retromastoidal region. Note the supramastoid crest (A), asterion (B), external occipital protuberance (C) and the mastoid process (D).*

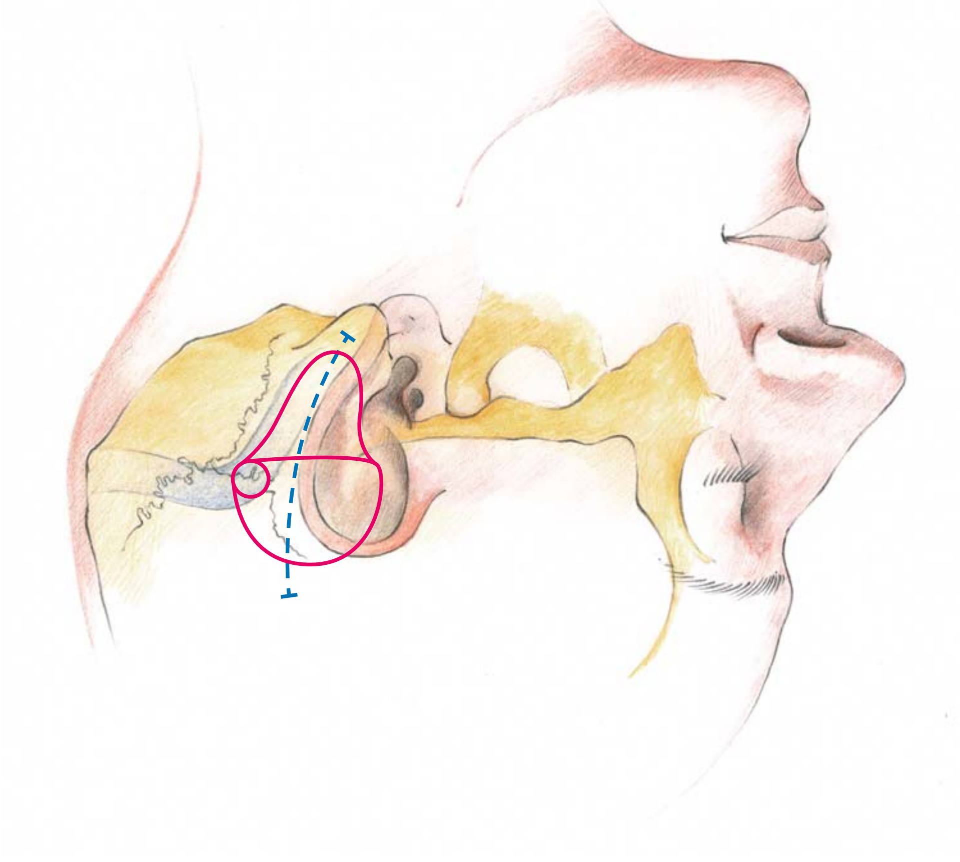


Fig. 3.2.6 B *Definition of the craniotomy and skin incision according to the anatomical landmarks of the temporo-occipital and mastoid regions. Note the posterior placement of the subtemporal craniotomy: the burr hole trephination should be performed at the junction of the parietomastoid and squamous sutures, just anterior to the sigmoid sinus. The base of the craniotomy corresponds to the supramastoid crest. The presigmoid extension of the craniotomy corresponds to a partial mastoidectomy, exposing the Trautmann triangle. The straight or slightly curved skin incision should be made at the level of the mastoid process.*

3. Craniotomy

Step 1

Left side. The slightly curved skin incision is made ca. 10 mm behind the external auditory canal. The incision begins at the tip of the mastoid process and extends with a length of about 60 mm into the temporoparietal area. The subcutaneous layer is dissected sideways exposing the posterior part of the temporal muscle and the surface of the mastoid process. Note schematic illustration of the sigmoid sinus according to the anatomical landmarks (Fig. 3.2.7).

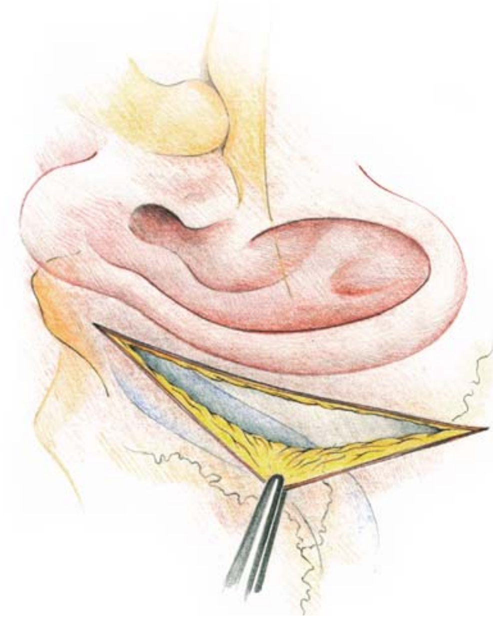


Fig. 3.2.7

Step 2

The periosteal layer, together with the fascia of the sternocleidomastoid muscle, is incised in a straight fashion and the temporal muscle is freed bluntly from the supramastoid crest (Fig. 3.2.8).

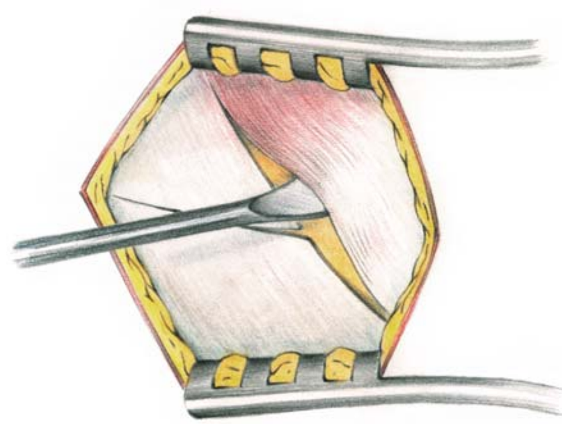


Fig. 3.2.8

Step 3

Using a wound retractor, the fascia of the mastoid process and the temporal muscle are forcibly retracted. Note the important anatomical landmarks of the temporomastoidal region: the supramastoid crest, and the transition between the squamosal and parietomastoidal sutures. The supramastoid crest corresponds to the posterior part of the temporal line and marks the level of the temporal skull base; the junction between the squamosal and parietomastoidal sutures corresponds to the optimal placement of the burr hole trephination avoiding injury to the sigmoidal sinus (Fig. 3.2.9).

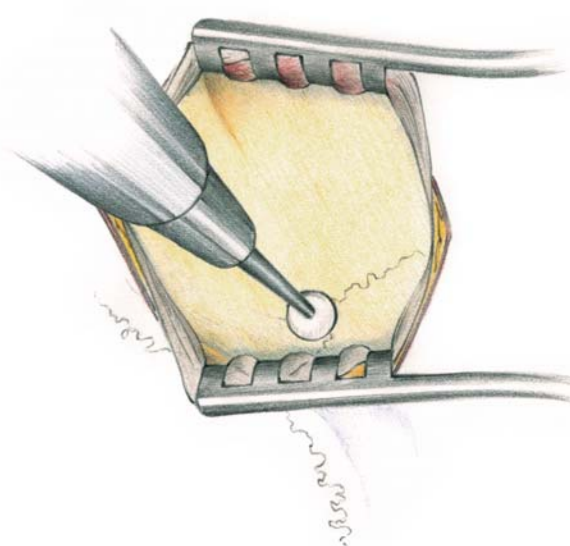
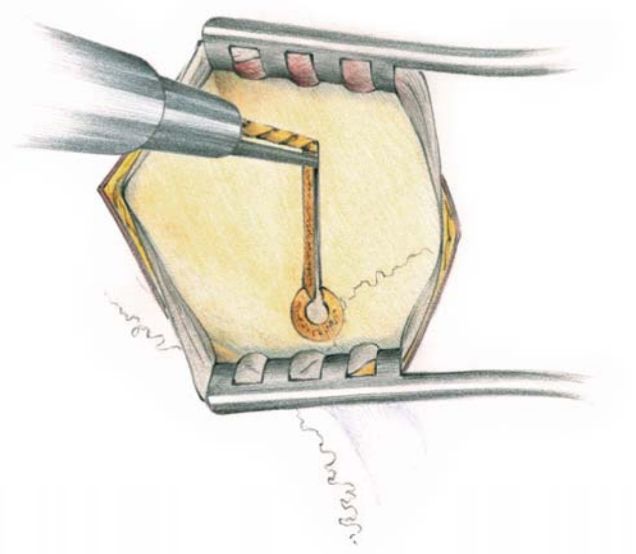


Fig. 3.2.9

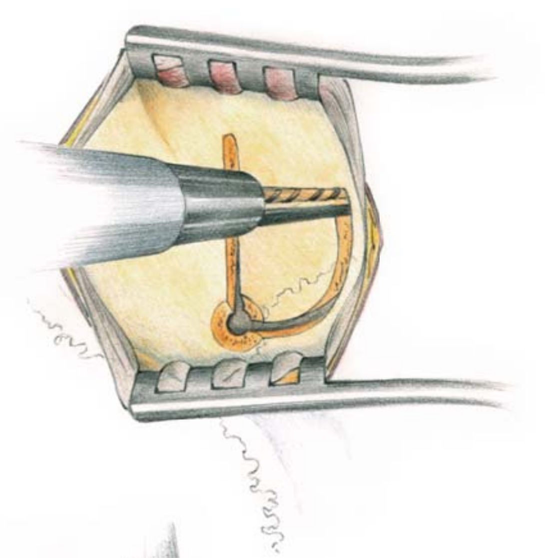
Fig. 3.2.10



Step 4

The combined posterior subtemporal-presigmoidal approach corresponds to a partially osteoplastic and partially osteoclastic craniotomy. After burr hole trephination, the temporobasal dura is seen just anterior to the sigmoid sinus. With the high-speed craniotome, a straight line is then sawed in a posterior to anterior direction at the level of the supramastoid crest, according to the temporal skull base (Fig. 3.2.10).

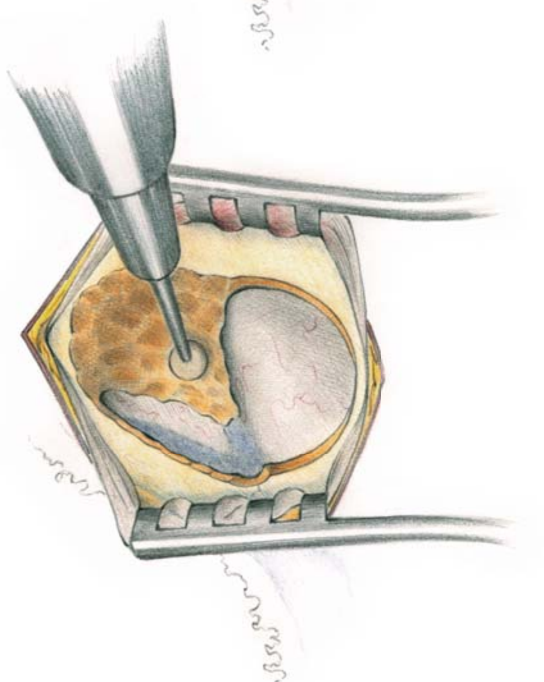
Fig. 3.2.11



Step 5

Thereafter, a "C" shaped, curved line is sawed to the anterior border of the previously performed temporobasal line, using a high-speed drill. Thus, a limited posterior subtemporal craniotomy is created with a width of ca. 25 mm and a height of ca. 15 mm (Fig. 3.2.11).

Fig. 3.2.12



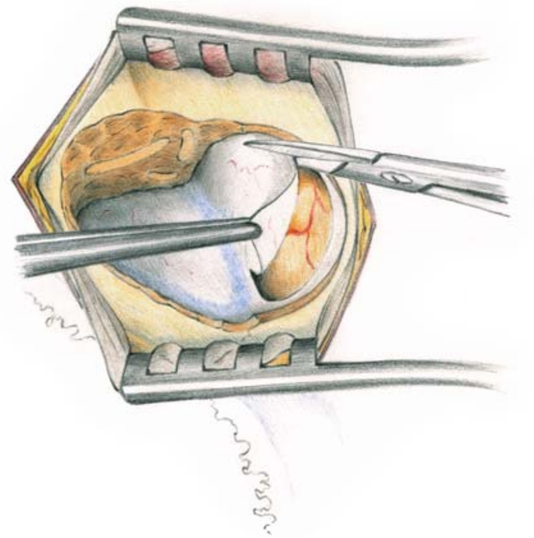
Step 6

After completing the subtemporal craniotomy, the anterior part of the sigmoid sinus is skeletonized, and a limited mastoidectomy is performed, using a high-speed drill. In the case of a narrow presigmoid space, the sigmoid sinus can be freed and gently retracted, allowing optimal exposure of the presigmoid dura mater. Special attention should be given to the Fallopian canal with the facial nerve and to the posterior and lateral semicircular canals (Fig. 3.2.12).

Step 7

The posterior subtemporal craniotomy and a limited mastoidectomy are performed. The facial canal and the middle and inner ear structures are kept intact. The dura mater of the posterior cranial fossa, anterior to the sigmoid sinus, corresponds to the Trautmann triangle. After craniotomy and partial mastoidectomy, the subtemporal dura mater is incised in a semilunar, curved fashion along the base of the temporal craniotomy. Note the superior petrosal sinus and the observed anterior edge of the sigmoid sinus (Fig. 3.2.13).

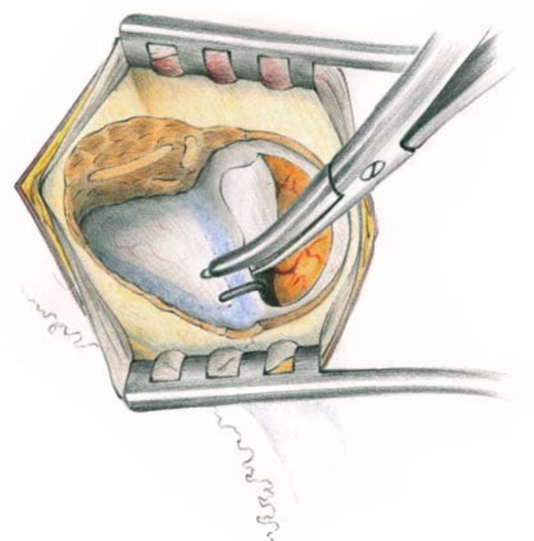
Fig. 3.2.13



Step 8

An important step of the dural opening is to divide the superior petrosal sinus. The closure and division of the sinus should be performed at its connection to the sigmoid and transversal sinuses corresponding to the apex of the Citelli angle. For this reason, the use of hemoclips can be recommended (Fig. 3.2.14).

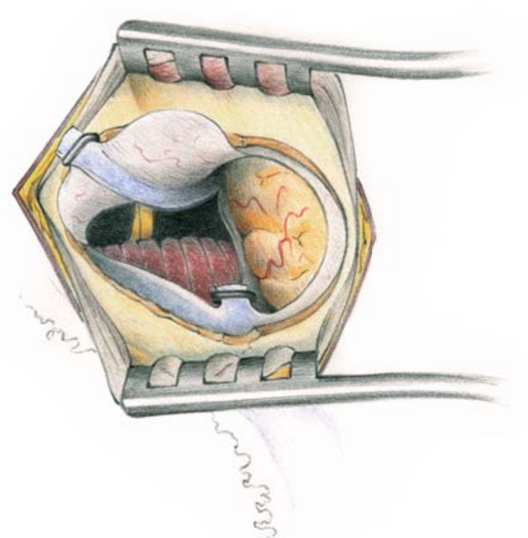
Fig. 3.2.14



Step 9

After division of the superior petrosal sinus, the dura mater of the posterior cranial fossa is opened anterior to the sigmoid sinus according to the posterior margin of the Trautmann triangle. According to the surgical corridor, the tentorium is incised without damaging the structures of the posterior tentorial incisura. The tentorium, the dura of the posterior fossa and the dura of the temporal convexity are then retracted anteriorly using elevating sutures (Fig. 3.2.15).

Fig. 3.2.15



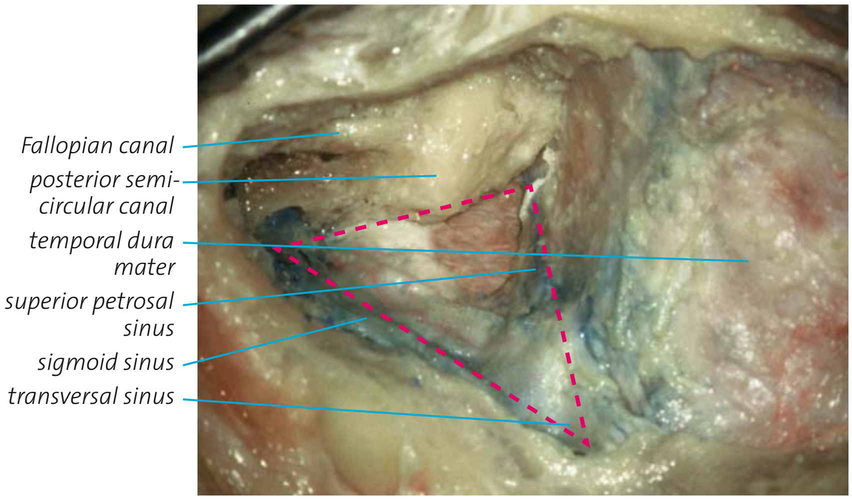


Fig. 3.2.16

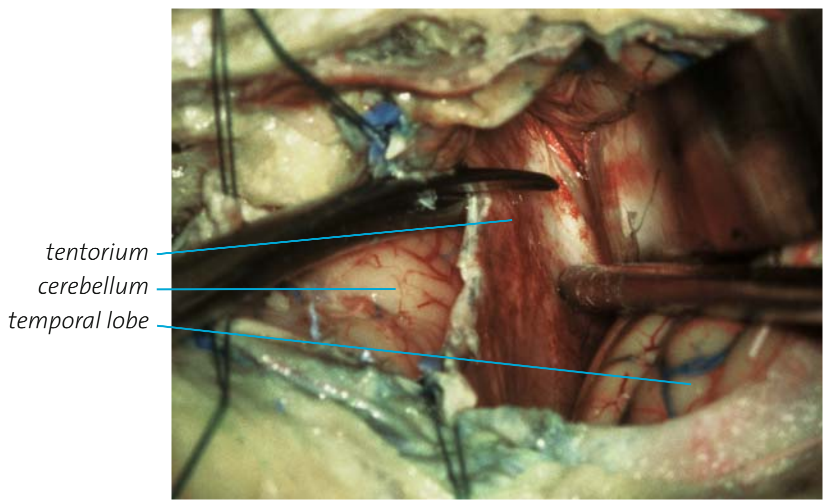


Fig. 3.2.17

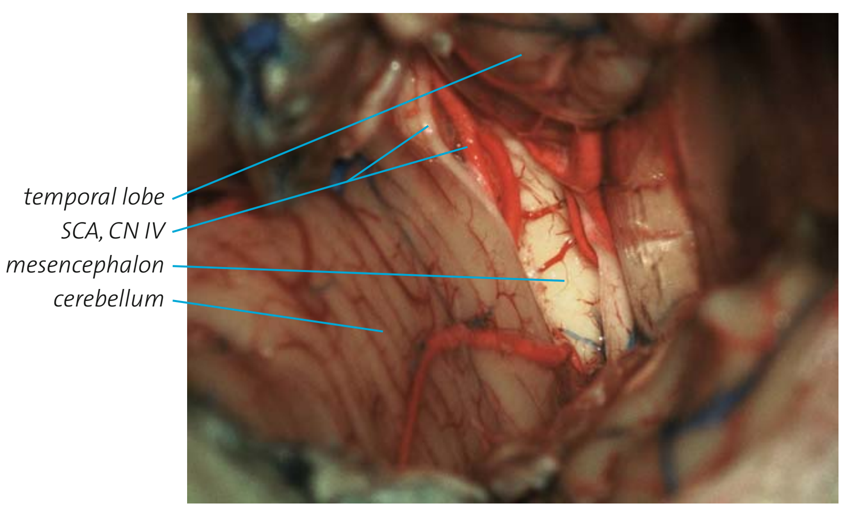


Fig. 3.2.18

4. Dural opening, intradural dissection

Step 1

Left side. Fresh human cadaver, used for intradural dissection. Arteries are filled with red, veins with blue colored latex solution. Note the dural surface, after performing a subtemporal craniotomy and partial mastoidectomy. The Fallopian canal and the posterior semicircular canal are skeletonized, avoiding damage to the sensitive neuro-otological structures. The Trautmann triangle is marked with red lines. The angle between the Trautmann triangle and the temporobasal dura mater corresponds to the Citelli angle, which identifies the position of the superior petrosal sinus. Note the course of the transversal and sigmoid sinuses (Fig. 3.2.16).

Step 2

After opening the dura mater according to the Trautmann triangle and the subtemporal region, the superior petrosal sinus is divided. The temporal lobe is gently retracted with a brain spatula and the tentorium cut with scissors. In this case, no prominent vein of Labbé is present. Note the dural holding sutures exposing the cerebellar surface in the posterior fossa (Fig. 3.2.17).

Step 3

After identifying the posterior part of the ambient cistern, the arachnoid membranes are opened for sufficient CSF drainage. After retraction of the temporo-occipital region, the transition between the ambient and quadrigeminal cisterns with branches of the posterior cerebral and superior cerebellar arteries can be seen. Close to the SCA, the CN IV can be observed and in the background, the posterolateral surface of the mesencephalon appears (Fig. 3.2.18).

Step 4
The parahippocampal gyrus is retracted and the ambient cistern is dissected with a microscissor. The cisternal course of the CN IV is followed in an anterior direction and separated from arachnoidal adhesions. Note the lateral mesencephalic segment of the SCA. In the background the lateral surface of the mesencephalon can be seen (Fig. 3.2.19).

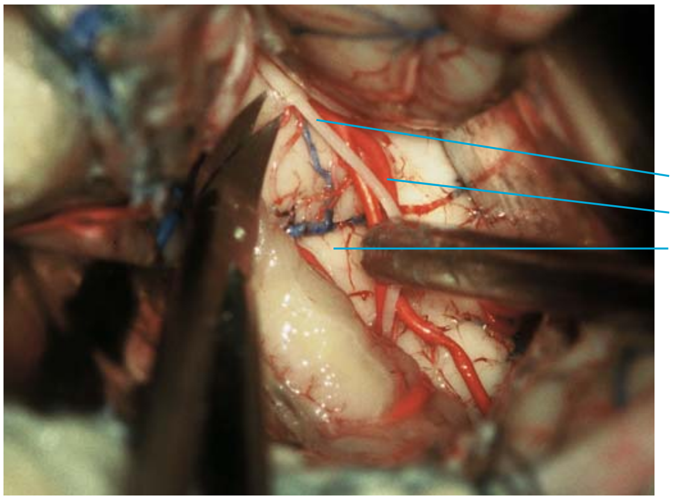


Fig. 3.2.19

Step 5
In a more anterior view, the CN IV disappears within the dural fold of the tentorium. Note the premesencephalic segment of the SCA. With the posteriorly situated craniotomy, the BA is hidden behind the brain stem. Note the CN III (Fig. 3.2.20).

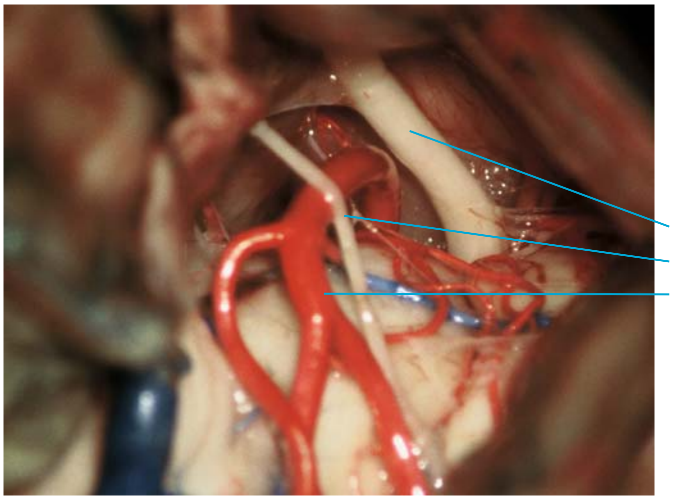


Fig. 3.2.20

Step 6
The retro- and suprasellar area, observing from the posterior subtemporal direction. Note the optic tract and the supraclinoid segment of the ICA with its branches. From the posterior view, the basilar trunk cannot be seen. The CN III lies between PCA and SCA (Fig. 3.2.21).

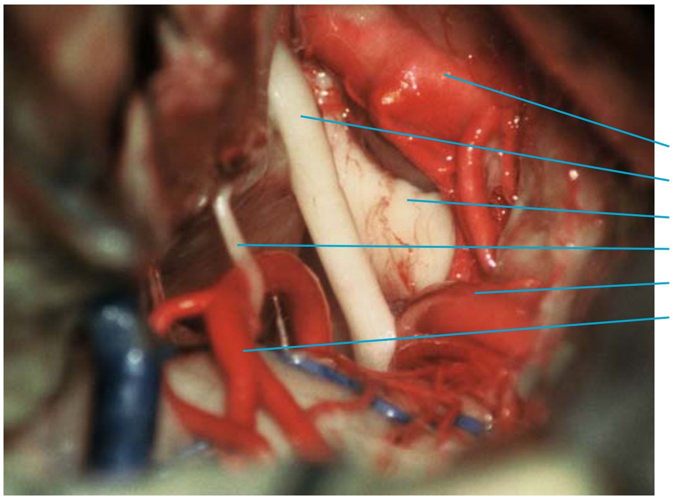


Fig. 3.2.21

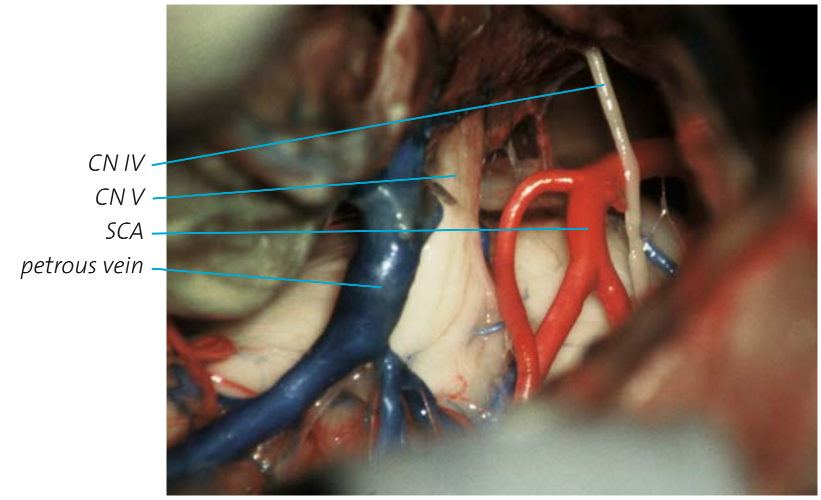


Fig. 3.2.22

Step 7

Dissecting in caudal direction from the CN IV, the CN V appears close to a branch of the SCA. With the combined supra- and infratentorial approach, structures of the middle and posterior fossa can also be observed. Note the petrous vein of Dandy, leading into the superior petrosal sinus. The tentorium is retracted forcibly in an anterior direction (Fig. 3.2.22).

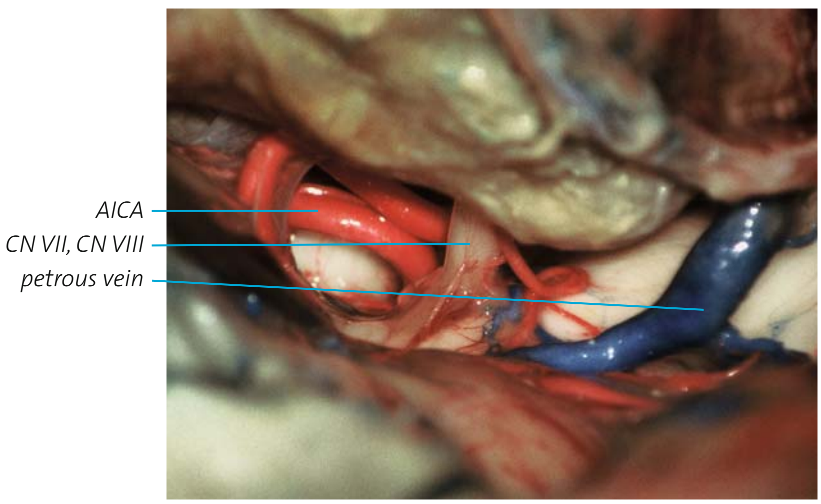


Fig. 3.2.23

Step 8

The cerebellum is freed from the petrous bone, allowing observation of the cerebellopontine angle through the presigmoid surgical corridor. The complex of the facial and vestibulocochlear nerves appears caudal from Dandy's petrosal vein. The flocculus is retracted with a dissector allowing observation of the entry zone of the CN VIII. Note the loop of the AICA close to the CN VII (Fig. 3.2.23).

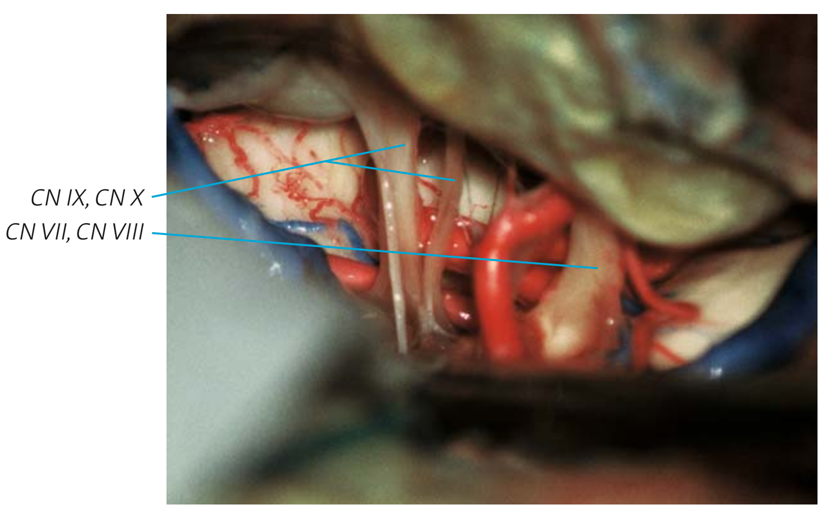


Fig. 3.2.24

Step 9

Dissecting more downward, the CN IX and CN X can be observed. Note the ventrolateral surface of the pontomedullar junction (Fig. 3.2.24).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the dura is closed with interrupted or continuous sutures. In several cases, watertight closure of the presigmoid dura is difficult. The mastoid cells are closed with abdominal fat tissue or with a flap of the temporalis muscle. The subtemporal bone flap is fixed with one or two titanium plates. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with interrupted or running intracutaneous sutures. To avoid a postoperative CSF fistula, use of a suction drain is not recommended. If nasal liquorrhea occurs, lumbar drainage is necessary to avoid postoperative meningitis.

Potential errors and their consequences

- According to the technically sophisticated approach, self-made planing and positioning is especially important.
- With the presigmoidal osteoclastic craniotomy, mastoid cells will be opened while performing the partial mastoidectomy. The opening should be closed meticulously to avoid a postoperative CSF fistula and meningitis.
- Injury to the dura mater during craniotomy. Dural closure is difficult, especially in the presigmoid area.
- Injury to the sigmoid sinus during presigmoid mastoidectomy. This complication with subsequent severe bleeding should definitely be avoided.
- Damage to the temporal lobe and cerebellum due to spatula pressure. Limited dural opening, adequate positioning of the patient and early removal of CSF from the ambient and cerebellopontine cisterns are important.
- Injury to the vein of Labbé with subsequent temporal venous infarction and intracerebral bleeding.
- Injuries to numerous nerves and vessels within the lateral tentorial, cerebellopontine and cerebellomedullar regions during surgical dissection, causing postoperative neurological deficits.
- Inadequate hemostasis in the surgical site with subsequent intracranial rebleeding.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate hemostasis during wound closure with soft tissue hematoma. To avoid a CSF fistula, the use of a suction drain is not required.

Tips and tricks

- Take time for preoperative planning and correct positioning of the patient. Note the form and plane of the tentorium in preoperative imaging. Self-made orientation on anatomical structures is mandatory to avoid damage of the sensitive neuro-otological structures and to allow sufficient intracranial visualization.

- Compared to the anterior and posterior subtemporal approaches, the subtemporal-presigmoidal approach requires more head rotation (A), more elevation (B) and less lateroflexion (C), allowing optimal exposure of the posterior cranial fossa (Fig. 3.2.25).

- The temporal muscle should be freed bluntly and the fascia cut straight allowing exposure of the posterior squamous bone (Fig. 3.2.26).

- Note the important anatomical landmarks: the supramastoid crest, marking the level of the temporal skull base, and the junction between the parietomastoidal and squamosal sutures, showing the optimal placement of the burr hole trephination (Fig. 3.2.27).

- Steps of the posterior subtemporal-presigmoidal craniotomy (Fig. 3.2.28): 1. posterior temporobasal burr hole trephination; 2. temporobasal cutting according to the supramastoid crest; 3. sawing in a semilunar, curved fashion from the burr hole to the anterior edge of the first craniotomy line; 4. partial mastoidectomy.

Fig. 3.2.25

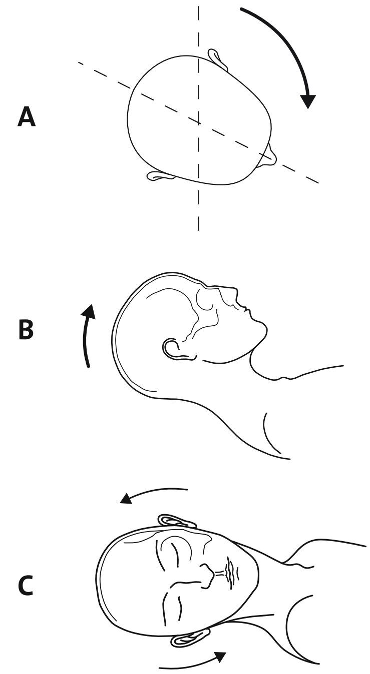


Fig. 3.2.26

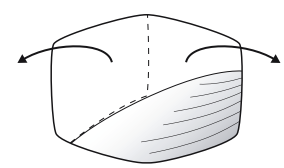


Fig. 3.2.27

Fig. 3.2.28

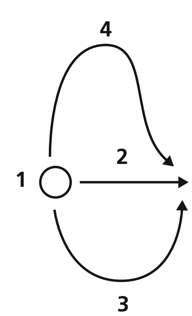
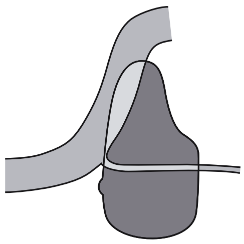


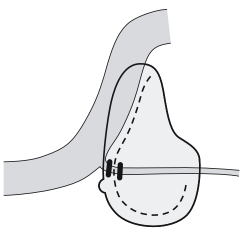
Fig. 3.2.29



- Skeletonization and, in some cases, gentle freeing of the sigmoid sinus is necessary to gain access to the Trautmann triangle of the posterior fossa dura (Fig. 3.2.29).

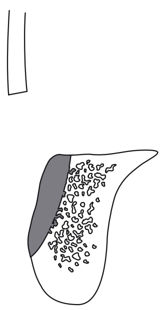
- The dura of the Trautmann triangle should be opened along the sigmoid sinus and the subtemporal dura in a semicircular fashion. The superior petrosal sinus should be closed using hemoclips and divided with a microscissor (Fig. 3.2.30).

Fig. 3.2.30



- To avoid injury to the vein of Labbé, limited dural opening and careful dissection of the vein from the dura and from arachnoidal membrane is important. If closure of the Labbé vein is unavoidable, retraction of the temporal lobe must be restricted to a minimum in order not to compress important anastomotic venous pathways.

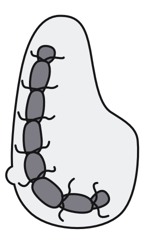
Fig. 3.2.31



- After dural closure, the opened mastoid cells should be closed with abdominal fat tissue or with a flap of the temporal muscle (Fig. 3.2.31).

- To avoid postoperative nasoliquorrhea, meticulous dural closure is mandatory. Watertight closure of the presigmoid dura is difficult; in these cases a piece of temporal muscle can be sewn into the dural dehiscence (Fig. 3.2.32).

Fig. 3.2.32



- To avoid postoperative CSF fistula, use of suction drain is not recommended.

- If postoperative nasoliquorrhea occurs, the use of lumbar drainage is recommended.

3.3
Extradural modification of the subtemporal craniotomy exposing the internal auditory canal

Extended trans-petrous-apex modification exposing the posterior fossa

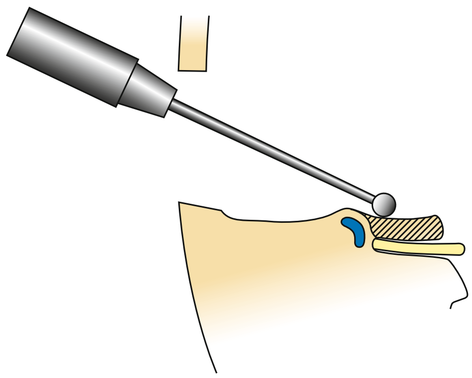


Fig. 3.3.1 *Schematic drawing illustrating the exploration of the internal auditory canal via a subtemporal craniotomy. With careful drilling of the roof of the internal auditory canal, the facial, superior vestibular, cochlear, and the inferior vestibular nerves can be efficiently approached.*

This technique corresponds to an extradural approach to the superior surface of the temporal bone through a limited subtemporal craniotomy. The aim of this modification of the subtemporal approach is the opening of the IAC, exposing the facial, superior vestibular, cochlear, and inferior vestibular nerves (Fig. 3.3.1). After careful identification of the greater superficial petrosal nerve and the superior semicircular canal at the arcuate eminence, the course of the internal auditory canal can be exactly determined, avoiding damage to the sensitive vestibulocochlear structures. Many techniques have been described for this purpose; we prefer the "blue line" method described by William F. House and Ugo Fisch [House 1961, Fisch 1969]. Using a diamond drill with continuous irrigation, the superficial bony layer at the arcuate eminence covering the superior semicircular canal should be partially removed. The blue line of the canal, together with the greater petrosal nerve, determines the course of the internal auditory canal (Fig. 3.3.2).

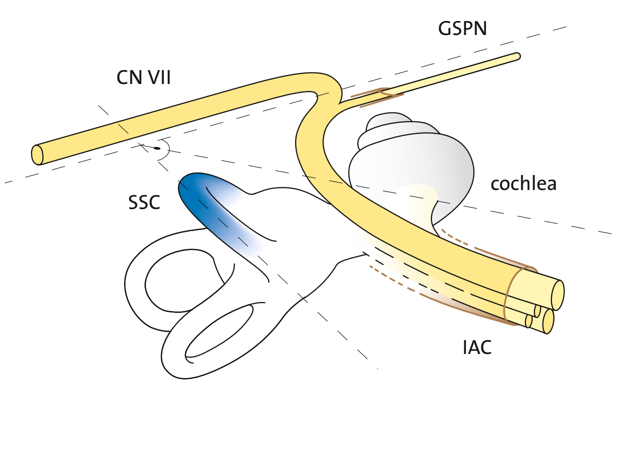


Fig. 3.3.2 *After identification of the GSPN and definition of the superior semicircular canal with the "blue line" technique, the course of the IAC can be precisely determined (left side).*

This approach is indicated for removal of small intrameatal acoustic neurinomas with less than 5 mm extension into the cerebellopontine angle; in particular, tumors which fill the internal auditory canal. The goal is to achieve total removal of the tumor with preservation of hearing at the preoperative level and normal facial function. In certain cases, worthwhile vestibular function can also be preserved.

As mentioned above, the advantage of the subtemporal approach is that it provides access to the internal auditory canal which is otherwise difficult to reach. However, this limited skull base exposure can be extended in an anterior direction, after opening of the temporobasal dura mater, exposing the suprasellar and cerebellopontine structures.

In the following, the surgical technique of the extradural subtemporal approach is described. In addition, the anterior skull base extension of the approach is given in detail.

Extradural dissection	Anterior extra- and intradural extension
Temporobasal skull base Foramen spinosum with the MMA GSPN Arcuate eminence Superior semicircular canal IAC CN VII Superior vestibular nerve Cochlear nerve Inferior vestibular nerve Labyrinthine artery AICA	Petrous apex Lateral aspect of the clivus Posterior clinoid process Tentorial incisura Superior petrosal sinus Meckel cave Dorello canal Posterior part of the cavernous sinus Lateral aspect of the pontomesencephal junction Optic tract CN III, CN IV, CN V, CN VI, CN VII, CN VIII ICA, PCoA, AChA, BA, PCA, SCA, AICA, incl. perforators Petrosal vein of Dandy

Table 3.3.1 *Anatomical structures approached via the modified subtemporal craniotomy.*

Surgical technique

1. Patient positioning and intraoperative monitoring

After anesthetic administration, a lumbar drainage should be placed. In the initial phase of the extradural approach, removal of CSF minimizes compression of the temporal lobe. A different practical solution is to perform a minimal dural opening before extradural elevation of the temporal lobe. Using a limited arachnoidal incision, continuous CSF removal can also be achieved thus minimizing compression of the temporal lobe.

Continuous facial nerve EMG monitoring is essential and facilitates safe exposure of the dura of the internal auditory canal. Facial nerve identification is usually easy anatomically; however, monitoring further insures nontraumatic facial nerve dissection during tumor removal.

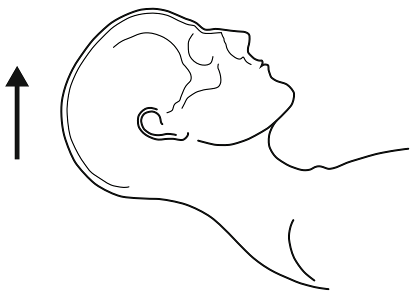


Fig. 3.3.3

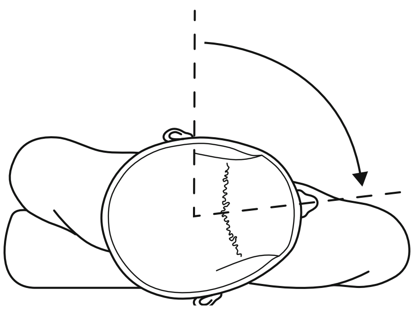


Fig. 3.3.4

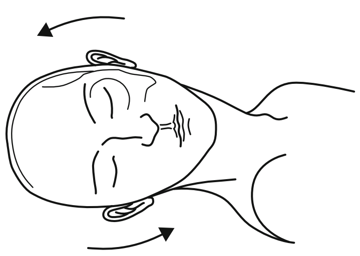


Fig. 3.3.5

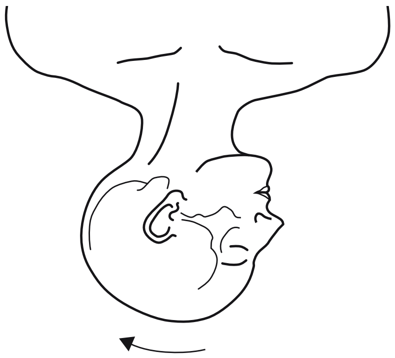


Fig. 3.3.6

The patient should be positioned supine with the head of the operating table elevated above the level of the thorax and the ipsilateral shoulder raised with a cushion. The head is fixed in a Mayfield holder; the single pin is placed in the forehead to allow undisturbed surgery.

Step 1
As the first step, the head is elevated above the level of the thorax to facilitate cranial venous drainage and to provide an effective decompression of the cervical structures. Compared to the anterior and posterior subtemporal craniotomies, more elevation of the head offers optimal and ergonomic access to the IAC (Fig. 3.3.3).

Step 2
Thereafter, the head is rotated 80° to the opposite side of the craniotomy. In this position, the direction of the IAC corresponds to a vertical line, allowing safe anatomical orientation and comfortable surgical access (Fig. 3.3.4).

Step 3
The head should be lateroflected by ca. 10° to 15°, supporting the gravity-related self-retraction of the temporal lobe. Compared to the anterior and posterior subtemporal craniotomies, the extradural variation requires less lateroflexion, allowing optimal exposure of the IAC (Fig. 3.3.5).

Step 4
Similar to the anterior and posterior subtemporal approaches, the head should be retroflected about 10°, allowing a comfortable working position for the surgeon. In addition, due to the slight retroflexion, severe compression of the ventilation tube, larynx and the cervical vessels may be avoided (Fig. 3.3.6).

2. Anatomical landmarks and orientation

For precise planning of the craniotomy, the important anatomical landmarks of the temporal and zygomatic region such as the lateral orbital rim, zygomatic arch, articular tubercule, external auditory canal, mastoid process and the supramastoid crest are accurately defined. Note the course of the auriculotemporal nerve and the superficial temporal artery (Fig. 3.3 7).

After anatomical orientation, the borders of the craniotomy and the optimum line of the skin incision should be defined. The basal line of the craniotomy corresponds to the supramastoid crest, the center of the craniotomy corresponds to the EAC. The extension of the craniotomy is ca. 25 x 25 mm, allowing exposure of the IAC. The straight skin incision with a length of ca. 50 mm should be made just anterior to the ear avoiding destruction of the auriculotemporal nerve and the superficial artery (Fig. 3.3.7). Note a minimal shaving of the hair and careful disinfection of the skin.

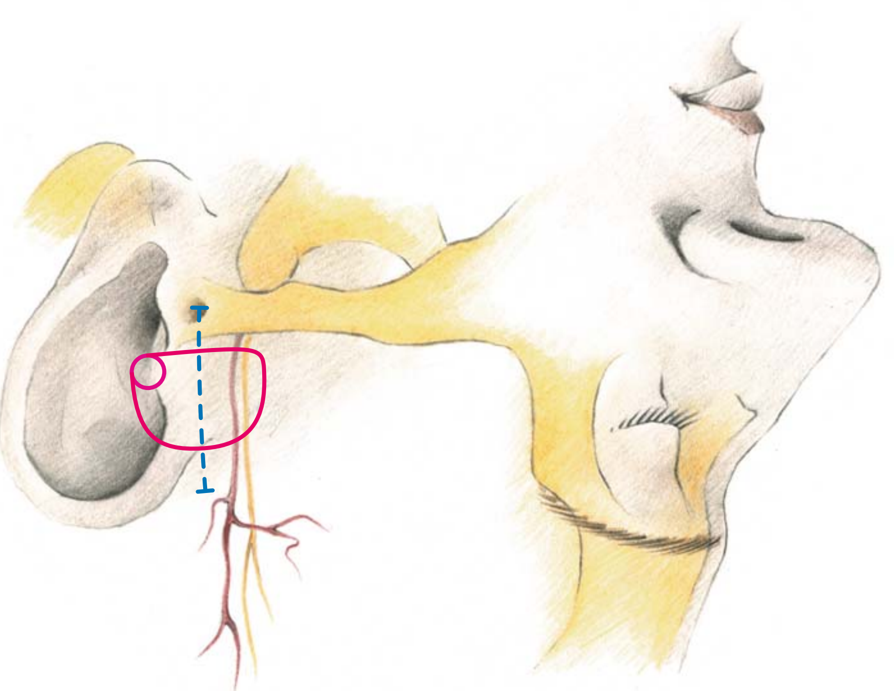


Fig. 3.3.7 *Definition of the craniotomy according to the anatomical landmarks of the temporal and zygomatic region. The center of the craniotomy should be placed exactly at the level of the EAC and the skin incision is made just anterior to the ear, posterior to the superficial temporal artery.*

3. Craniotomy

Step 1

Left side. After patient positioning, anatomical orientation, and minimal hair shaving, the skin is prepared with an alcohol solution. A straight epifascial skin incision is then made just anterior to the tragus. The superficial temporal artery and the auriculotemporal nerve are dissected and moved in an anterior direction preserving the neurovascular structures (Fig. 3.3.8).

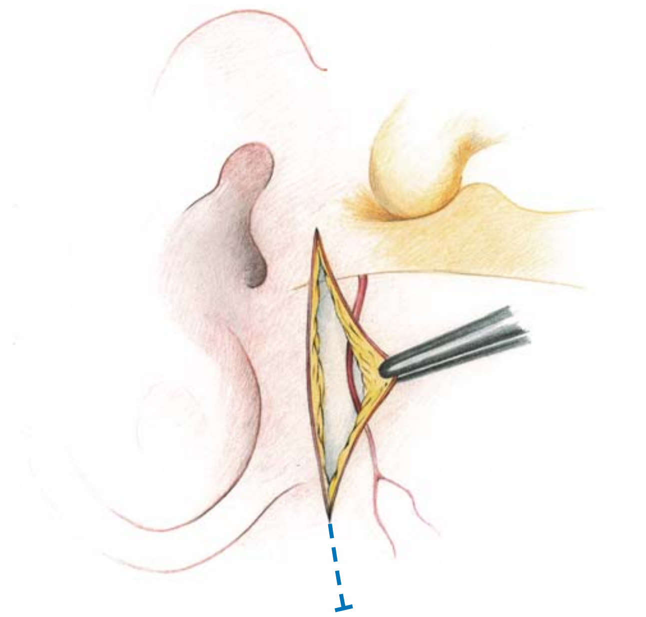


Fig. 3.3.8

Step 2

After bilateral skin retraction, the fascia of the temporal muscle is cut in a Y-shaped fashion optimally exposing the temporal muscle. Note the superficial temporal artery moved and retracted in an anterior direction (Fig. 3.3.9).

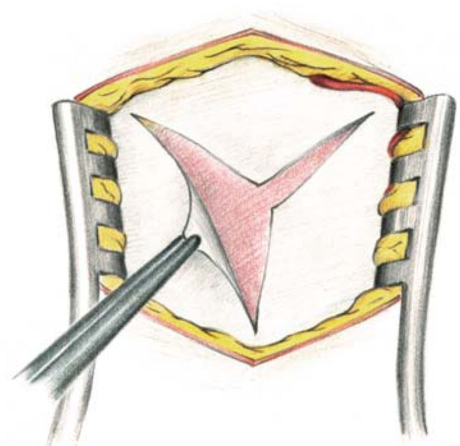


Fig. 3.3.9

Step 3

The basal leaflet is forcibly retracted over the zygomatic pedicle with a strong suture and the remaining two flaps of the temporal fascia are retracted bilaterally exposing the temporal muscle (Fig. 3.3.10).

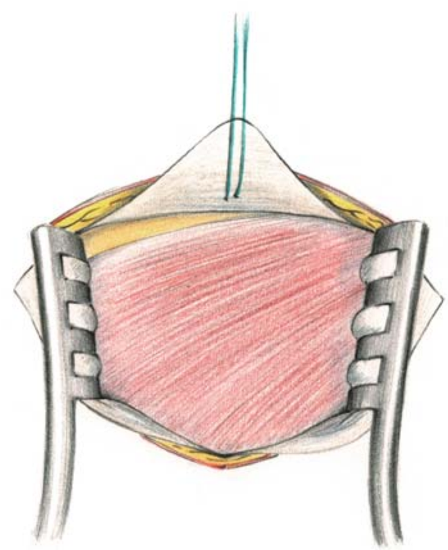
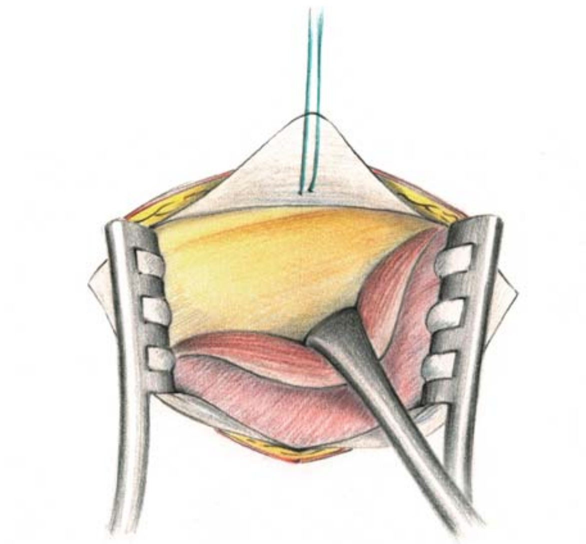


Fig. 3.3.10

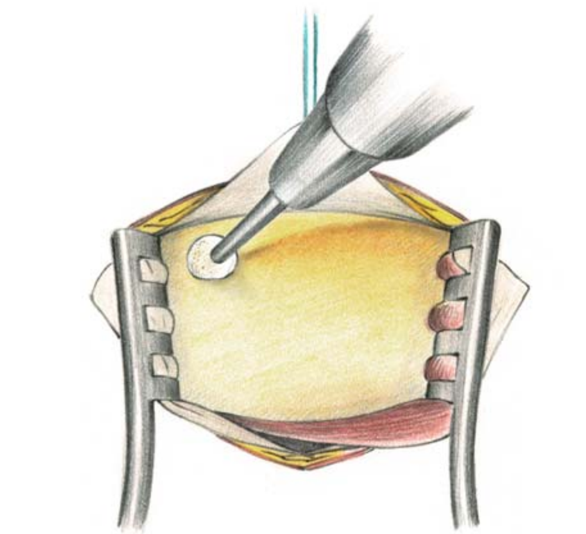
Fig. 3.3.11



Step 4

With a dissector, the inferior margin of the temporal muscle is moved bluntly from the supramastoid crest and from the posterior zygomatic arch revealing the squamous bone. This posterior aspect of the temporalis muscle is thin and incision of the muscle is usually not necessary to gain adequate exposure of the bony surface (Fig. 3.3.11).

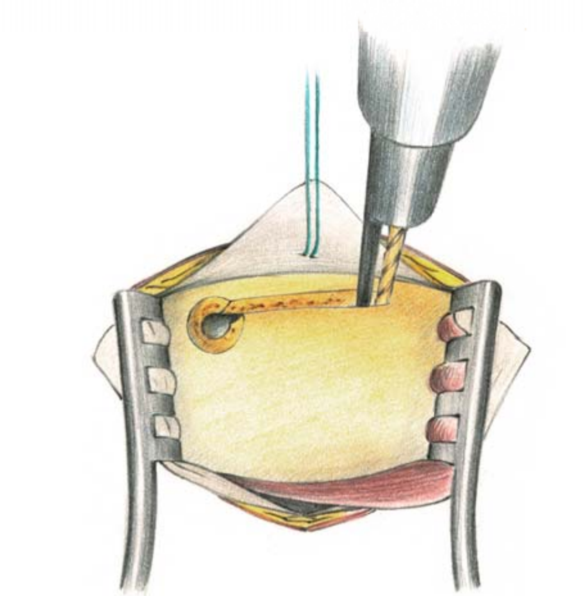
Fig. 3.3.12



Step 5

After exposing the squamous bone, a single burr hole is placed posteriorly at the level of the supramastoid crest, opening the middle cranial fossa (Fig. 3.3.12).

Fig. 3.3.13



Step 6

After minimal enlargement of the hole with fine punches and mobilization of the dura, a straight line is sawed with the craniotome parallel to the zygomatic arch in a posterior to anterior direction (Fig. 3.3.13).

Step 7
Thereafter a "C" shaped line is sawed from the burr hole to the anterior border of the previously performed temporobasal craniotomy line, thus creating a bone flap with a width of ca. 25 mm and a height of ca. 25 mm. The height of 2.5 cm is necessary to gain access to the internal auditory canal. In all cases, an osteoplastic craniotomy is carried out. Care must be taken not to lacerate the dura either with the craniotome or when lifting the bone flap (Fig. 3.3.14).

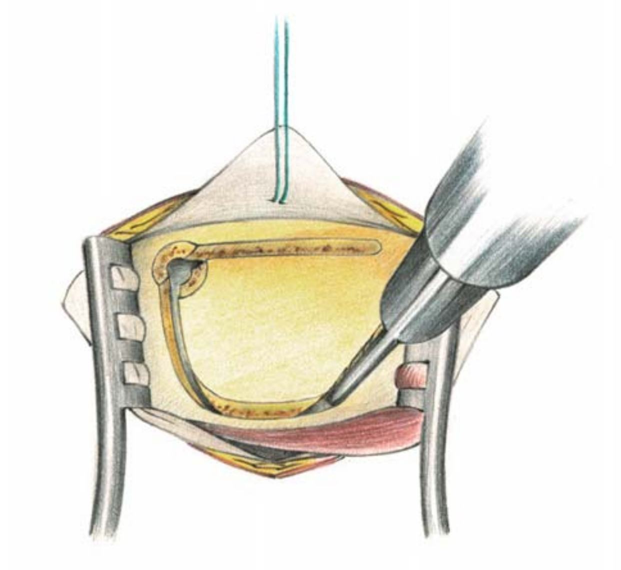


Fig. 3.3.14

Step 8
If a lumbar drainage was not placed preoperatively, an important step is to perform a limited dural incision with opening of the cortical subarachnoid space. Using this simple technique, compression of the temporal lobe can be effectively minimized. After removal of the bone flap, the temporobasal inner edge of the craniotomy is drilled under protection of the dura with high-speed drill, thus increasing the angle for intracranial inspection and manipulation. If mastoid cells are opened, they should be occluded (Fig. 3.3.15).

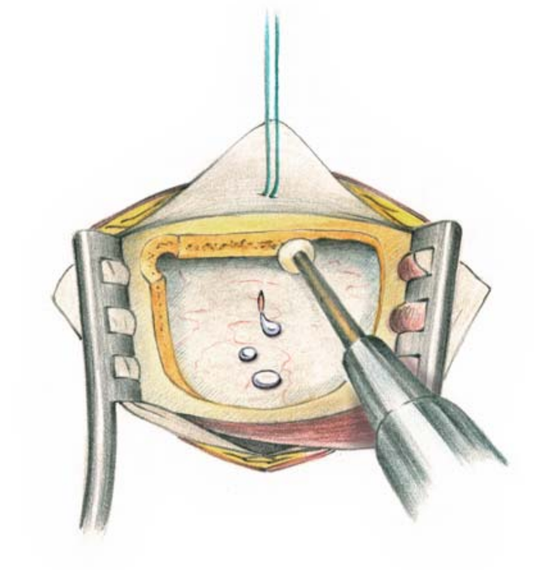


Fig. 3.3.15

Step 9
The dura is separated from both the inferior and lateral borders of the craniotomy and raised carefully from the base of the middle fossa (Fig. 3.3.16).

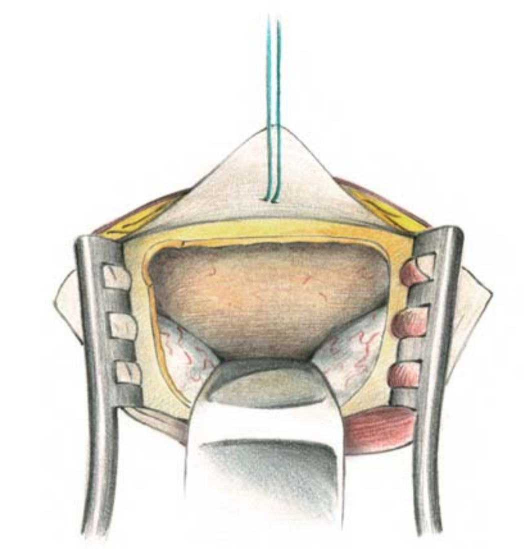


Fig. 3.3.16

4. Extra- and intradural dissection

Step 1

Left side. Dissection by using a fresh human cadaver. The arteries are prepared with red, veins with blue colored solution. The dura mater is raised exposing the greater superficial petrosal nerve. The GSPN is carefully dissected from dural adhesions. The foramen spinosum with the MMA can be seen in the anterior aspect (Fig. 3.3.17).

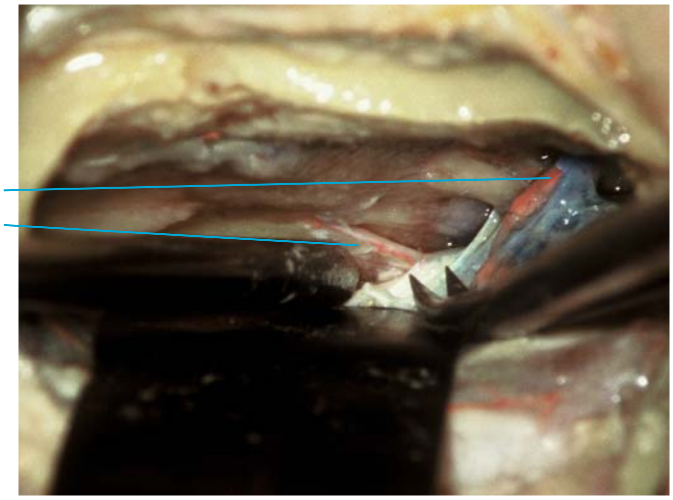


Fig. 3.3.17

Step 2

With further elevation of the temporal dura, the petrous ridge and the arcuate eminence are seen. Using a diamond drill, the thin bony layer above the superior semicircular canal should be partially removed, allowing exact orientation. The blue line of the canal, together with the greater petrosal nerve, determines very accurately the course of the internal auditory canal (Fig. 3.3.18).

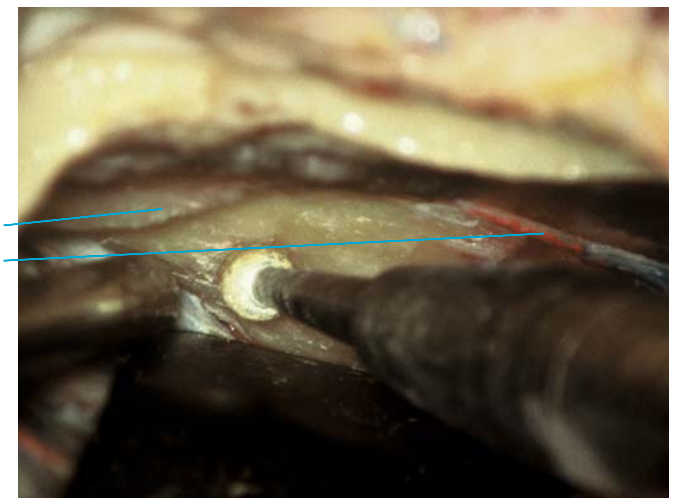


Fig. 3.3.18

Step 3

According to the above-mentioned anatomical orientation, the IAC is opened with a high-speed diamond drill. Note the relationship of the blue line, the GSPN and the direction of drilling (Fig. 3.3.19).

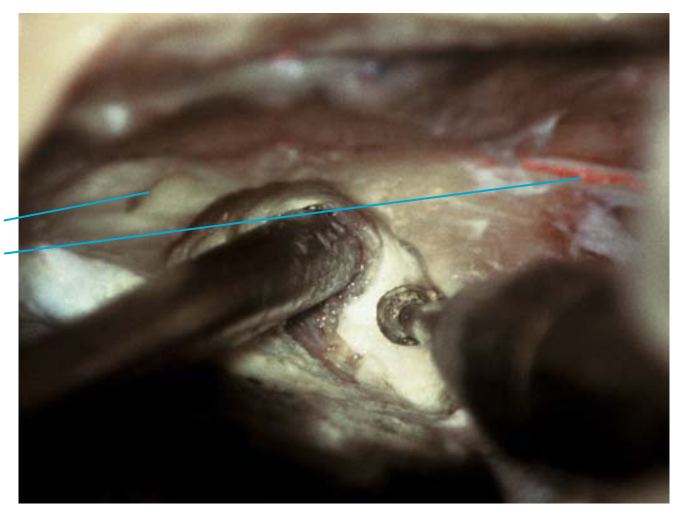


Fig. 3.3.19

Step 4
The dura mater of the IAC and the posterior fossa is exposed and the deepest layer of the bone is removed with a fine Kerrison punch (Fig. 3.3.20).

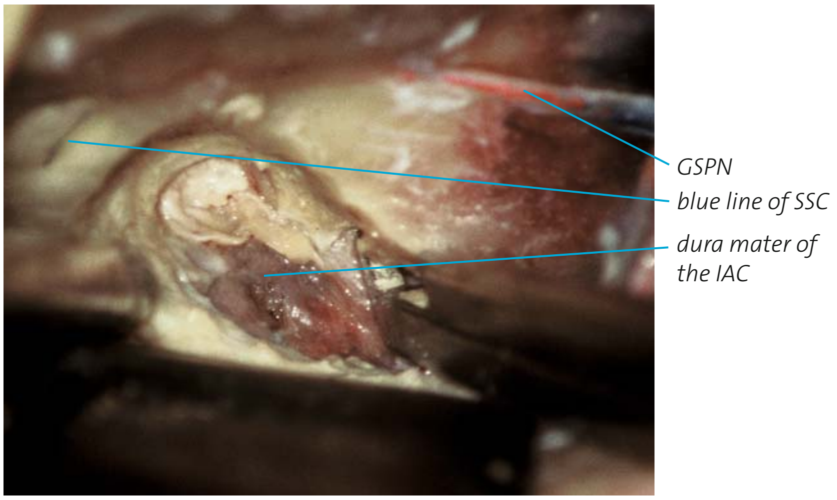


Fig. 3.3.20

Step 5
After dural opening, the facial and superior vestibular nerves can be observed. Note the loop of the AICA; the surface of the brain stem can be seen in the background. The subtemporal approach allows a most advantageous exposure of the IAC and its contents (Fig. 3.3.21).

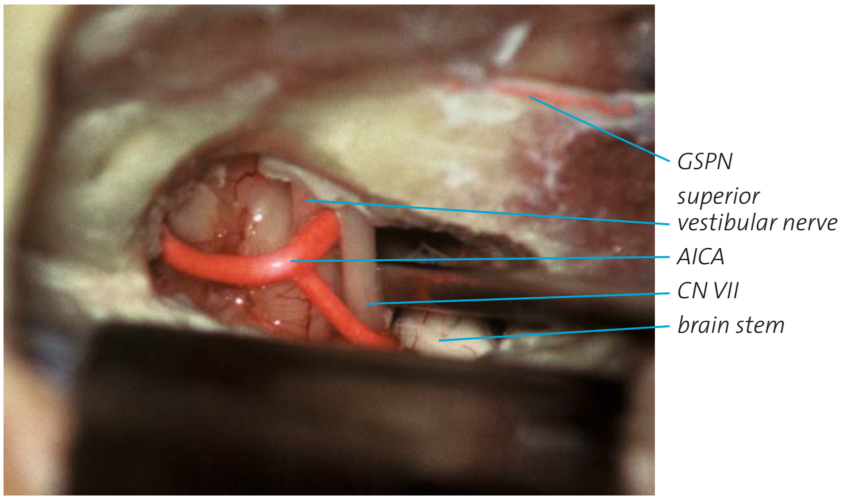


Fig. 3.3.21

Step 6
With further removal of the petrous apex in an anterior direction, the lateral surface of the brain stem can be observed. Note the CN VI running into the Dorello canal. Special care should be taken not to damage the cochlea (Fig. 3.3.22).

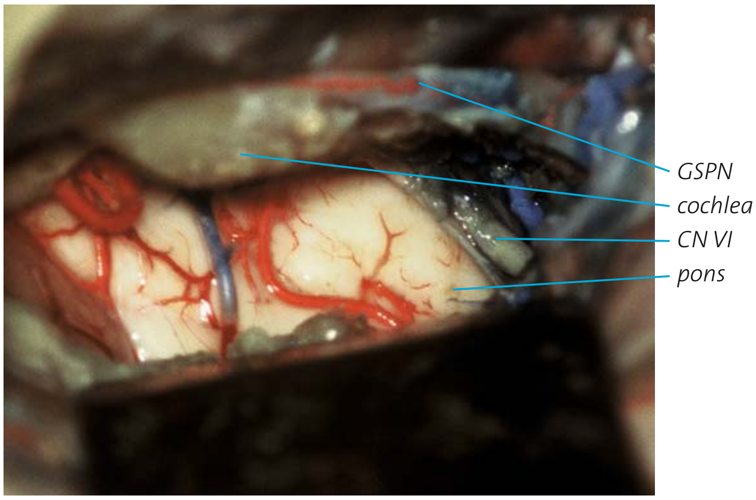


Fig. 3.3.22

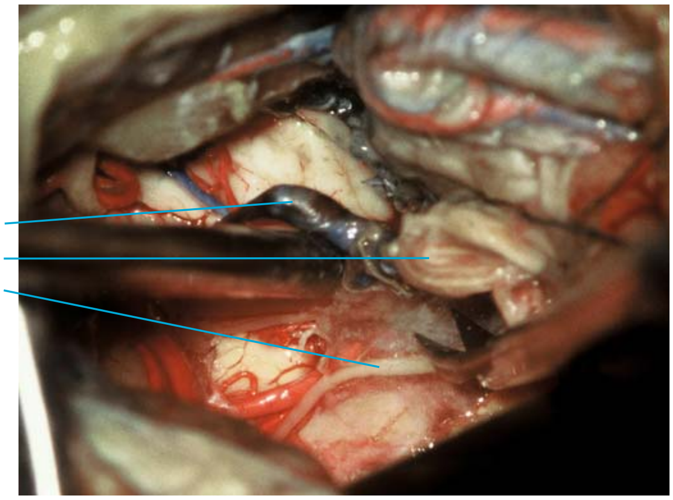


Fig. 3.3.23

Step 7

After subtemporal dural opening and incision of the tentorium, the structures of the ambient cistern can be extensively approached. Note the petrous vein of Dandy, retracted with a microsucker. Arachnoid membranes around the CN IV are opened with microscissors (Fig. 3.3.23).

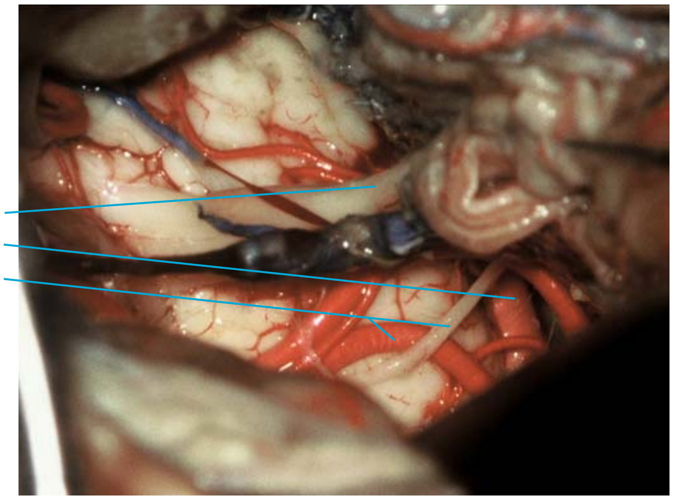


Fig. 3.3.24

Step 8

Dissecting more anteriorly, the ventrolateral surface of the pons can be approached. Note CN IV, CN V, and in the background the BA (Fig. 3.3.24).

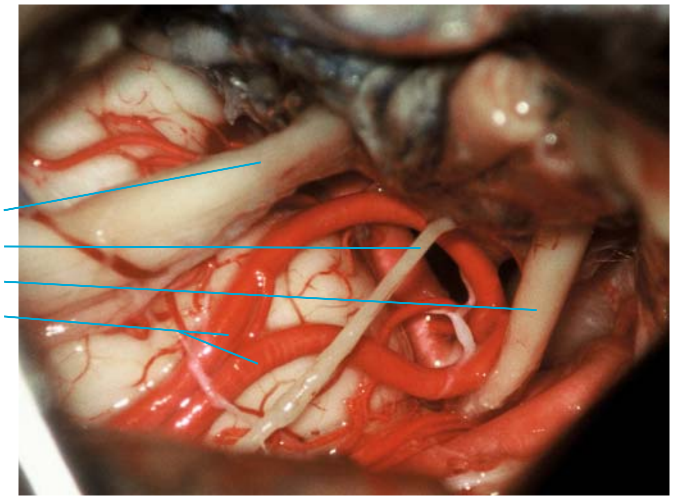


Fig. 3.3.25

Step 9

The petrous vein is removed allowing free anatomical visualization of the CN III, CN IV and the CN V. Note the basilar trunk and the double superior cerebellar arteries (Fig. 3.3.25).

Step 10

Pinpoint the region of the basilar apex with the first segments of the PCA and SCA. Note the CN III and CN IV, disappearing within the dura mater (Fig. 3.3.26).

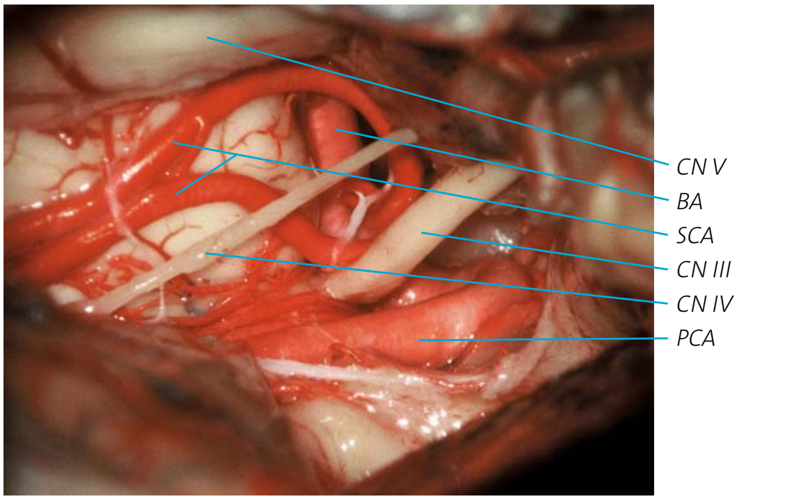


Fig. 3.3.26

Step 11

Extended subtemporal approach to the anterolateral pons after removal of the petrous apex and division of the tentorium. Note the excellent view of the basilar trunk from the AICA to the SCA, the CN III, CN IV, CN V and the cisternal course of the CN VI (Fig. 3.3.27).

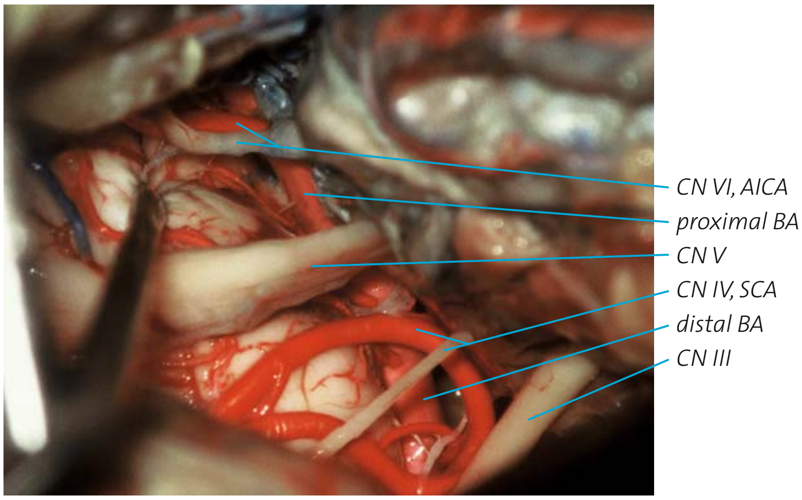


Fig. 3.3.27

Step 12

Exposing again in the posterior direction, the relation of the CN V, CN VI and CN VII can be well visualized (Fig. 3.3.28).

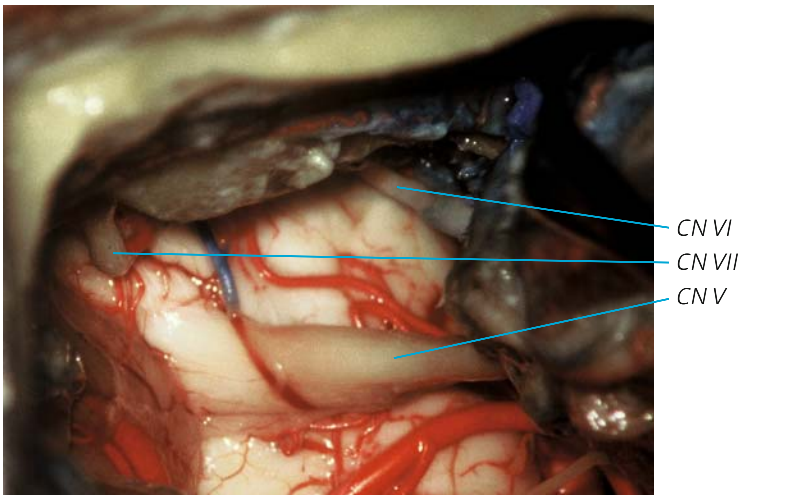


Fig. 3.3.28

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with Ringer solution. In most cases, a watertight dural closure is impossible; however, fine sutures can be used to re-approximate the posterior fossa dura. A postoperative CSF fistula can effectively be avoided with a flap of temporal muscle or fascia, occluding the bony defect of the internal auditory canal. In other cases, abdominal fat tissue should be placed extradurally. The bone flap is fixed with a titanium plate. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with running or interrupted sutures. Due to the small skin incision and nontraumatic soft tissue dissection, a suction drain is not necessary and also not recommended to avoid a postoperative CSF fistula.

Potential errors and their consequences

- Incorrect preoperative planning and positioning of the patient with inadequate exposure of the lesion.
- Injury to the preauricular neurovascular structures.
- In some cases, opening of mastoid cells is unavoidable during craniotomy. The opening should be closed meticulously to avoid postoperative nasoliquorrhea and meningitis.
- Injury to the dura mater during craniotomy, especially in elderly patients. No severe sequelae; however, extradural dissection can be complicated. After completion of the intracranial procedure, the dura must be closed with interrupted or running sutures.
- Damage to the temporal lobe due to spatula pressure. With adequate positioning of the patient and early removal of CSF through the cortical subarachnoid space or through the previously inserted lumbar drainage, temporal compression can be minimized.
- Injury to the lesser or greater superficial petrosal nerves during dural elevation although without severe neurological consequence.
- Injury to the superior semicircular canal causing vestibular disturbance with temporary nausea and vomiting. Cochlear injury causes postoperative ipsilateral anacusis.
- Injury to the facial nerve within the IAC with subsequent postoperative facial palsy.
- Injuries to numerous nerves and vessels in the middle and posterior cranial fossa during surgical dissection causing postoperative neurological deficits.

Fig. 3.3.29

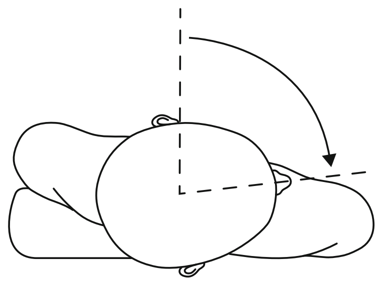


Fig. 3.3.30

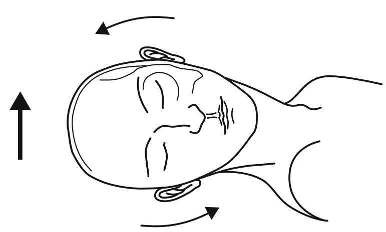


Fig. 3.3.31

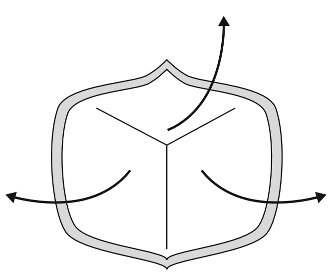


Fig. 3.3.32

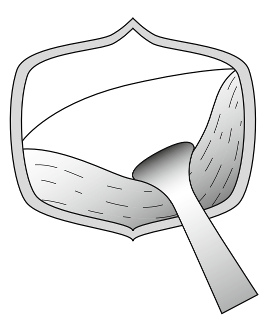
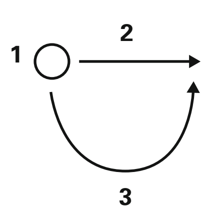


Fig. 3.3.33



- Inadequate intracranial hemostasis with postoperative rebleeding.
- Inadequate dural closure with postoperative CSF fistula. In the case of opened mastoid cells, postoperative nasoliquorrhea can occur.
- Inadequate hemostasis during wound closure with soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning.

- The head should be rotated ca. 80° for adequate visualization of the IAC (Fig. 3.3.29). Compared with the anterior and posterior subtemporal approaches, the extradural modification requires less lateroflexion and more elevation during patient positioning (Fig. 3.3.30).

- Make careful orientation by approach-planning: osseous and neurovascular structures; placement of the craniotomy; skin incision.

- A straight skin incision should be performed just anterior to the ear, preserving the superficial temporal artery and the auriculotemporal nerve.

- The temporal fascia should be incised in a Y-shaped fashion with the basal leaflet deflected over the zygomatic arch. After completing the intracranial procedure, this flap can also be used for dural closure. The remaining two flaps are retracted bilaterally providing adequate exposure of the temporal muscle (Fig. 3.3.31).

- In most cases, blunt movement of the temporal muscle is possible without incision of the muscle exposing the squamous bone (Fig. 3.3.32).

- Stages of craniotomy (Fig. 3.3.33): 1. burr hole trephination; 2. temporobasal cutting parallel to the supramastoid crest and zygomatic arch; 3. sawing in a curved, semilunar fashion from the burr hole to the anterior edge of the previous craniotomy line.

- Creating the craniotomy, a height of 2.5 cm measured from the zygomatic arch is necessary to gain unhindered access to the internal auditory canal (Fig. 3.3.34).
- Drilling of the inner edge of the temporobasal craniotomy border after removal of the bone flap is important to facilitate intradural visualization and manipulation (Fig. 3.3.35).
- If invasion of the mastoid cells could not be avoided, meticulous closure is required. The opened cells should be closed with bone wax; a flap of the fascia or the temporal muscle can also be used for this purpose (Fig. 3.3.36).
- For minimizing compression of the temporal lobe, the cortical subarachnoid space should be opened after limited dural opening. Alternatively, preoperative lumbar drainage can be used (Fig. 3.3.37).
- The course of the internal auditory canal can be accurately defined using the "blue line" technique (Fig. 3.3.38).
- The extradural approach to the IAC can be successfully extended after subtemporal dural opening and division of the tentorium. An additional removal of the petrous apex offers wide exposure of the middle and posterior cranial fossae.
- If possible, the dural opening should be closed with watertight sutures. The dural closure within the posterior fossa can be achieved with a muscle flap or with abdominal fat tissue.
- In the case of postoperative nasoliquorrhae, a lumbar drain should be used.
- The burr hole trephination can be closed with a titanium plate (Fig. 3.3.39).
- To avoid a postoperative CSF leak, the use of a suction drain is not recommended.

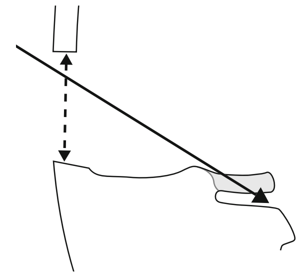


Fig. 3.3.34

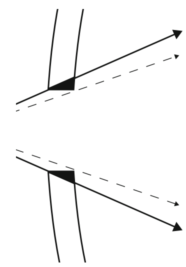


Fig. 3.3.35

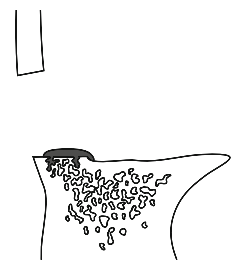


Fig. 3.3.36

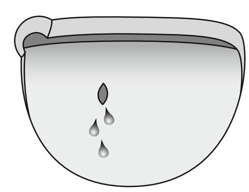


Fig. 3.3.37

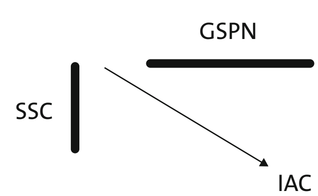


Fig. 3.3.38

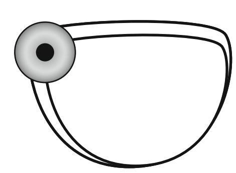


Fig. 3.3.39

4.0 Retrosigmoidal approach

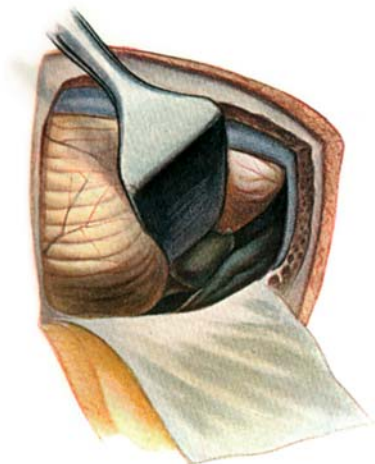


Fig. 4.0.1 *In 1903, KRAUSE described a unilateral exposure for skull base tumors and his name has been identified with the unilateral suboccipital approach, regardless of the many modifications that followed. Note the placement of the craniotomy exposing the transversal and sigmoidal sinus.*

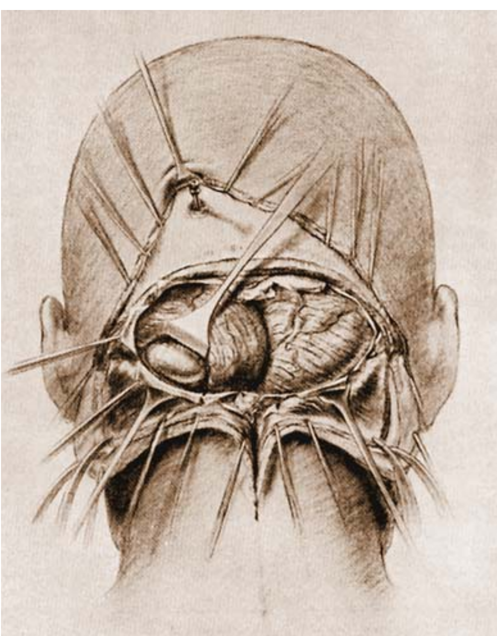


Fig. 4.0.2 *CUSHING's operation for approaching an acoustic neurinoma. His bilateral exposure through a crossbow incision allowed effective decompression of the posterior fossa. Note the puncture of the left lateral ventricle avoiding increased intracranial pressure during surgery.*

History of the lateral suboccipital approaches

The suboccipital method of gaining access to the lateral posterior fossa and cerebellopontine angle was first used successfully by SIR CHARLES BALLANCE in 1894, who operated on a *"fibrosarcoma of the meninges"* attached to the dural covering of the posterior surface of the petrous bone. The operation was carried out in two stages and the tumor was extracted by finger dissection between the sensitive neurovascular structures. The patient survived with residual trigeminal and facial nerve injury [BALLANCE 1894].

Nevertheless, the surgical treatment of cerebellar and extracerebellar tumors was characterized by a very high mortality rate due to the rough and crude procedures used. During the early period of neurosurgery, other attempts at removal of space-occupying lesions within the lateral posterior fossa were so unsuccessful that surgeons were reluctant to undertake these operations. In 1893, ALLEN STARR published 15 cases of cerebellar tumors with only one instance of complete tumor removal and neurological recovery of the patient. On account of these frustrating results, HERMANN OPPENHEIM classified cerebellar lesions as inoperable and reported a more than 70% mortality rate [STARR 1893, OPPENHEIM 1902].

Concerning extracerebellar lesions of the cerebellopontine angle such as acoustic neurinomas and meningeomas, the prevailing mortality for an operation in the hands of most skilled surgeons ranged from 58% by VICTOR HORSLEY to 83.8% by FEDOR KRAUSE as presented at the International Neurological Congress in 1913. Such failures have been attributed to several factors including the undeveloped preoperative diagnostic tools, limited optical control, and the use of fingers in enucleating the neoplasm. KRAUSE also advocated a blunt finger dissection causing associated injury to several sensitive neurovascular structures (Fig. 4.0.1). His crude surgical technique resulted in a mortality rate ranging from 67% to 88% [KRAUSE 1913].

At the beginning of the 20th century, surgeons sought a safe and less invasive approach to the cerebellopontine angle, especially for removal of benign acoustic neurinomas (Fig. 4.0.2). HARVEY CUSHING, in 1905, described a bilateral exposure of the cerebellar hemispheres through a "crossbow incision" resulting in avoidance of brain stem compression during surgery. On the basis of his experience on cadaver dissection, Charles H. Frazier, in 1905, also recommended a bilateral approach, exposing the unilateral posterior fossa with resection of the outer part of the cerebellar lobe [Cushing 1905, Frazier 1905].

As a means to preserve the brain stem and vital vessels, Cushing introduced the palliative concept of intracapsular subtotal removal of tumors of the cerebellopontine angle. His first encounter with an acoustic neurinoma was in 1906. Later he described this frustrating experience as the *"gloomy corner in neurologic surgery"*. However, using his developed techniques in 187 patients suffering from acoustic neurinomas, he was able to lower the previously unacceptable mortality rate to a more reasonable level of 13%. However, an additional 40% of patients eventually died within 5 to 10 years because of subsequent tumor recurrence after subtotal resection [Cushing 1932].

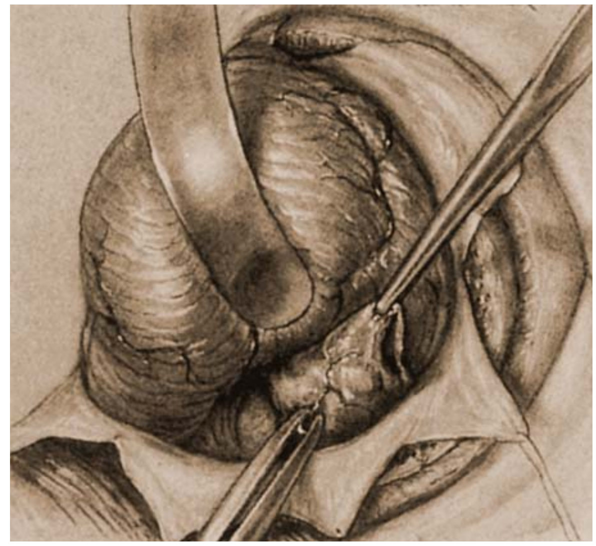


Fig. 4.0.3 *Unilateral access to an acoustic tumor described by Dandy in his article "An operation for the total removal of cerebellopontine (acoustic) tumors", published in 1925. His approach illustrated "the method by which traction on the excavated capsule of the lower pole strips the remaining tumor from the brain stem and brings into view the vessels which cross from the brain stem".*

In 1917, the same year in which Cushing presented his classical monograph on „Tumors of the Nervus Acusticus", Walter E. Dandy, impressed by the potential curability of benign tumors, described a more aggressive surgical approach for total removal (Fig.4.0.3). His approach consisted of a unilateral suboccipital craniectomy, internal tumor decompression and complete removal of the encapsulated neurinoma [Dandy 1925]. In 1941, Dandy published his series of 46 patients with a mortality rate of 11%; however, all patients lost their hearing on the operated side and 95% had an additional facial paralysis [Dandy 1941]. In 1939, Gilbert Horrax, another of Cushing's assistants, and James L. Poppen reported their results with a 5-year mortality rate of 18%; however, 65% of the surviving individuals were neurologically intact after complete removal of the acoustic neurinomas [Horrax & Poppen 1939]. In Herbert Olivecrona's series, which totalled 415 cases, complete recovery of the facial nerve was observed in 29% with small tumors compared with only 7% with large neurinomas [Olivecrona 1949]. E. Stephens Gurdjian and Ludwig J. Kempe reported very similar results, approaching the cerebellopontine angle through a unilateral suboccipital exposure (Fig. 4.0.4, 4.0.5) [Gurdjian 1964, Kempe 1970].

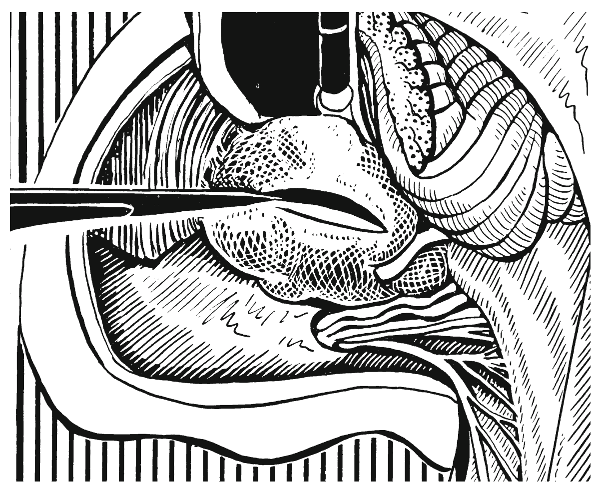


Fig. 4.0.4 *Gurdjian's unilateral suboccipital approach to a cerebellopontine tumor after partial resection of the cerebellar hemisphere. Note the use of an illuminated retractor of a type suggested by Frazier in 1928, allowing better visualization of the surgical field.*

A tremendous development in preoperative assessment and the revolutionary use of microneurosurgical techniques after introduction of the surgical microscope resulted in a marked improvement in postoperative results. Using a transmeatal retrosigmoidal approach, Robert W. Rand and Theodore Kurze reported in their series of 140 patients operated between 1964 and 1980, 100% preservation of the facial nerve in cases with small acoustic tumors [Rand & Kurze 1980]. Also other pioneers of modern microneurosurgery published their first results of acoustic neurinomas operated with a lateral suboccipital approach [Yasargil 1976, Koos 1976, Samii 1981].

At that time, not only neurosurgeons but also otological surgeons were familiar with operative removal of acoustic neurinomas. In 1968, William House reported 133 cases in which a lateral suboccipital translabyrinthine approach was used for moderate and large tumors. Ugo Fisch, another proponent of the microotologic technique, published his results using pre- and retrosigmoidal approaches in the early 1970s [House 1968, Fisch 1970].

The lateral suboccipital approach was also used by the above-mentioned authors for other space-occupying lesions of the lateral posterior fossa such as meningeomas, epidermoids, chordomas, chondromas. By different variations, lesions of the tentorium [Samii 1981], petrous bone [Yasargil 1980], clivus [Hakuba 1977], and foramen magnum [Perneczky 1986] were successfully treated.

In 1934, Walter E. Dandy postulated that arterial compression and distortion of the trigeminal nerve might be the cause of the trigeminal neuralgia [Dandy 1934]. Employing a unilateral suboccipital craniectomy, he exposed the sensory root of the trigeminal nerve at the root entry zone into the pons (Fig. 4.0.6). He described

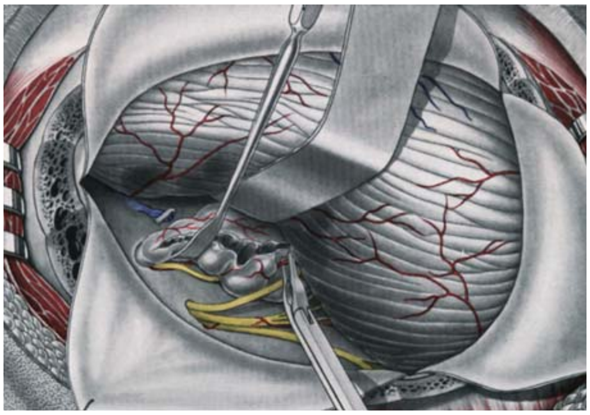


Fig. 4.0.5 *Macrosurgical removal of an acoustic neurinoma, as demonstrated by Kempe in 1970. Note the careful dissection of the facial nerve.*

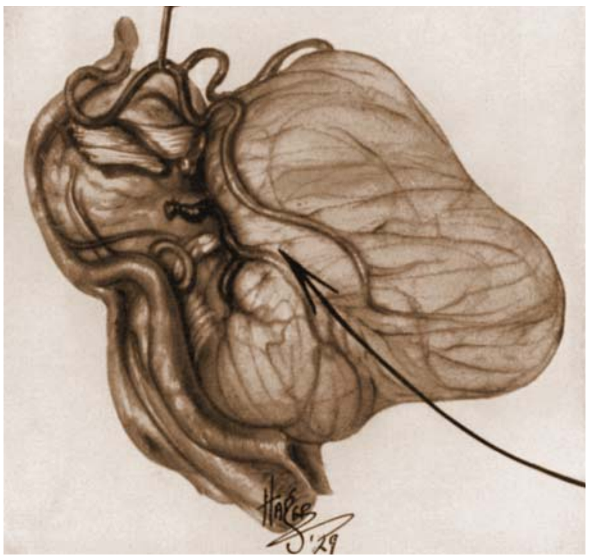


Fig. 4.0.6 *Dandy's unilateral exposure of the fifth nerve. In this case, a caudal loop of the SCA caused severe tic douloureux.*

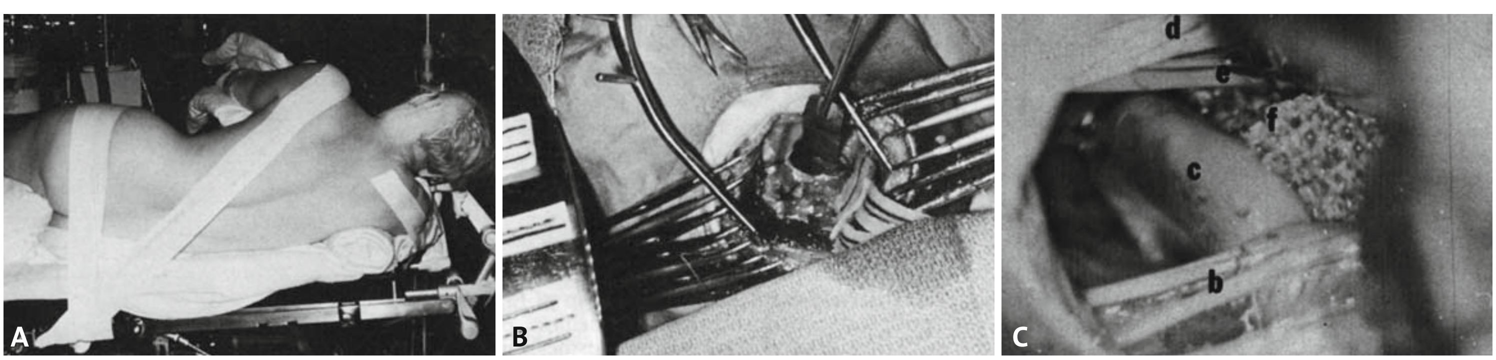


Fig. 4.0.7 *Jannetta's microsurgical decompression of the seventh nerve causing hemifacial spasm. Note the lateral decubitus or so-called park bench position exposing the left retroauricular area (A). After performing a limited retrosigmoidal craniotomy (B), the cerebellopontine angle was approached using microsurgical techniques. Intraoperative microphotograph (C) showing the lower cranial nerves. Note the prosthesis (f) between the facial nerve (e) and vertebral artery (c) achieving effective vascular decompression.*

66 of his 215 patients as having vascular abnormalities in relation to the sensory root and demonstrated the superior cerebellar artery as affecting the nerve in more than 30% of his patients who suffered from trigeminal neuralgia. The vascular compression theory failed to gain acceptance at that time; however, W. James Gardner in 1959 cited Dandy's prior observations and suggested that the mechanical factor could be important in causing severe neuralgia [Gardner 1959]. As a result, he developed the neurovascular decompression operation for tic douloureux. This operation was further refined by Peter J. Jannetta and Robert W. Rand in 1966 (Fig. 4.0.7) [Jannetta & Rand 1967]. In 1962, Gardner described a neurovascular compression mechanism at the brain stem exit zone of the facial nerve as the most frequent cause of hemifacial spasm. In his original operation, Gardner placed a small square of gelfoam between the compressing vessel and the facial nerve, via a retrosigmoidal approach [Gardner 1962]. Etiology and microsurgical treatment of the hemifascial spasm was also described by Jannetta and coworkers [Jannetta 1970, 1977].

The first successful operation on an aneurysm of the vertebral artery or its branches via suboccipital craniotomy was performed by Henry Schwartz in 1946 and reported in 1948 [Schwartz 1948]. The majority of cases were treated by unilateral craniectomy using a sitting or semiprone park bench position as descibed by Charles Drake and Wallace Hamby (Fig. 4.0.8) [Drake 1965, Hamby 1969]. In 1984, Yasargil described a paramedian infracerebellar keyhole approach for aneurysms of the posterior inferior cerebellar artery in the first volume of his pioneering work „Microneurosurgery" (Fig. 4.0.9) [Yasargil 1984].

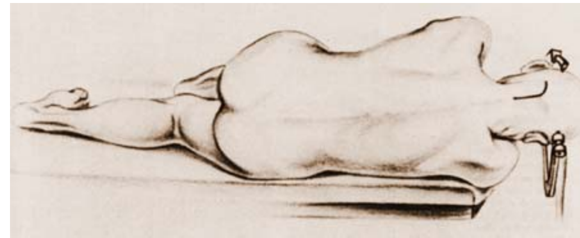


Fig. 4.0.8 *Park bench positioning of a patient treated for an aneurysm of the vertebral artery. Note the so-called hockey stick skin incision, published by Drake in 1979.*

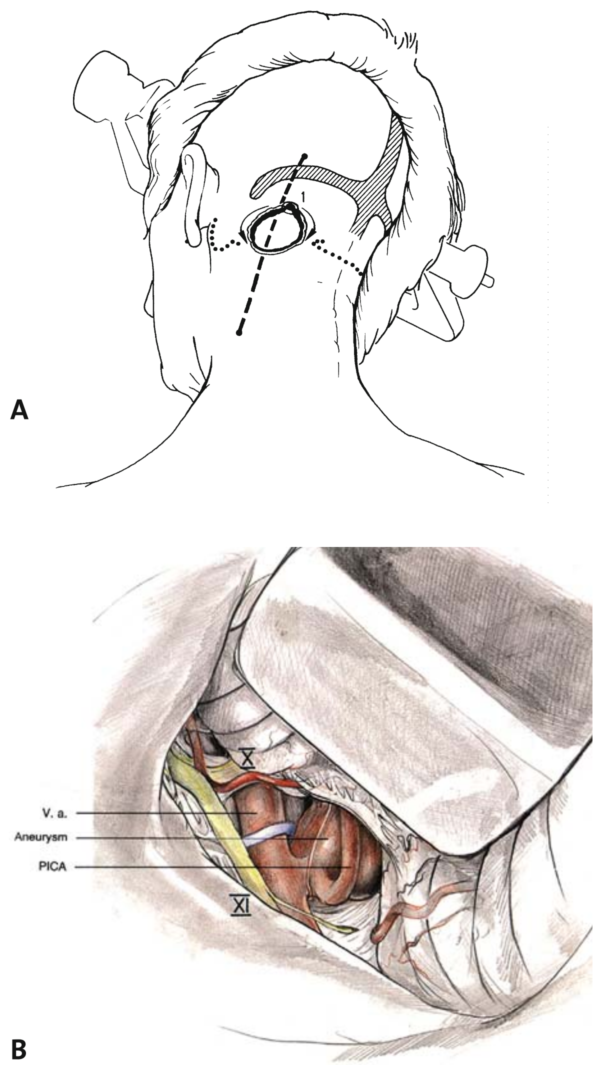


Fig. 4.0.9 *Yasargil's paramedian infracerebellar access for a small aneurysm of the PICA, described in his book "Microneurosurgery" published in 1984. Note the sitting position of the patient (A). Through the retrosigmoidal craniotomy, Yasargil approached the aneurysm in a minimally invasive manner avoiding crude retraction of the cerebellar hemisphere (B).*

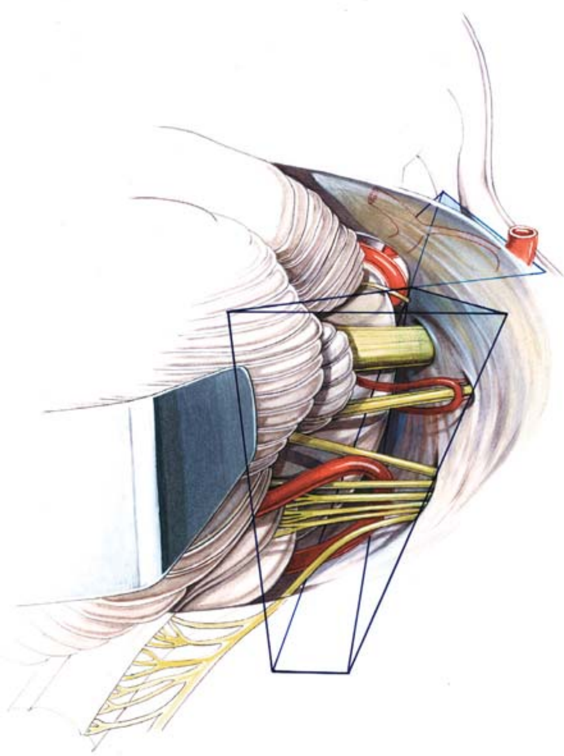


Fig. 4.0.10 *Artist's drawing demonstrating the cerebellopontine angle as a virtual pyramid. This virtual construction also helps to understand how anatomical structures are displaced in the case of space-occupying lesions within the posterior fossa.*

Use of the keyhole concept in the lateral suboccipital, retromastoidal approaches and general anatomical construction of the cerebellopontine angle

As described above, the surgical outcome after lateral suboccipital approaches improved markedly with the use of modern microneurosurgical techniques. However, the first reports already realized the value of retromastoidal exposures using the concept of keyhole surgery. Due to the small surface of the suboccipital area, an extended craniotomy and dural opening could not be used; nevertheless, surgeons were able to overview almost the entire posterior fossa.

In creating these limited lateral suboccipital, retrosigmoidal approaches, some anatomical characteristics should be described in detail.

The cerebellopontine angle is situated between the posterior surface of the petrous temporal and the petrosal surface of the cerebellar hemisphere. The third through the twelfth cranial nerves are located near or within the angular space between the two limbs of the cerebellopontine fissure formed by the petrosal cerebellar surface folding around the pons and middle cerebellar peduncle.

Compared with the suprasellar area, the cerebellopontine angle can also be defined as a pyramid-shaped space, but inclined anteromedially with its apex extending to the posterior clinoid process and the base facing the inner surface of the squamosal part of the temporal and occipital bones. The superior side corresponds to the retrosellar area including the CN III and the inferior surface of the tentorium, with the CN IV running through it. The inferomedial side is close to the foramen magnum, including the vertebral artery and the CN XII. The anterior and posterior sides are represented by the posterior surface of the petrous bone and the petrosal surface of the brain stem and cerebellum, respectively. The majority of vital structures, such as the superior cerebellar, anterior inferior, posterior inferior cerebellar arteries, and the third to twelfth cranial nerves, are confined in the medial third of the pyramid (Fig. 4.0.10).

Approaching the anatomical structures of the cerebellopontine angle, different target regions require different variations in the shape, placement and size of the retrosigmoidal craniotomy (Fig. 4.0.11).

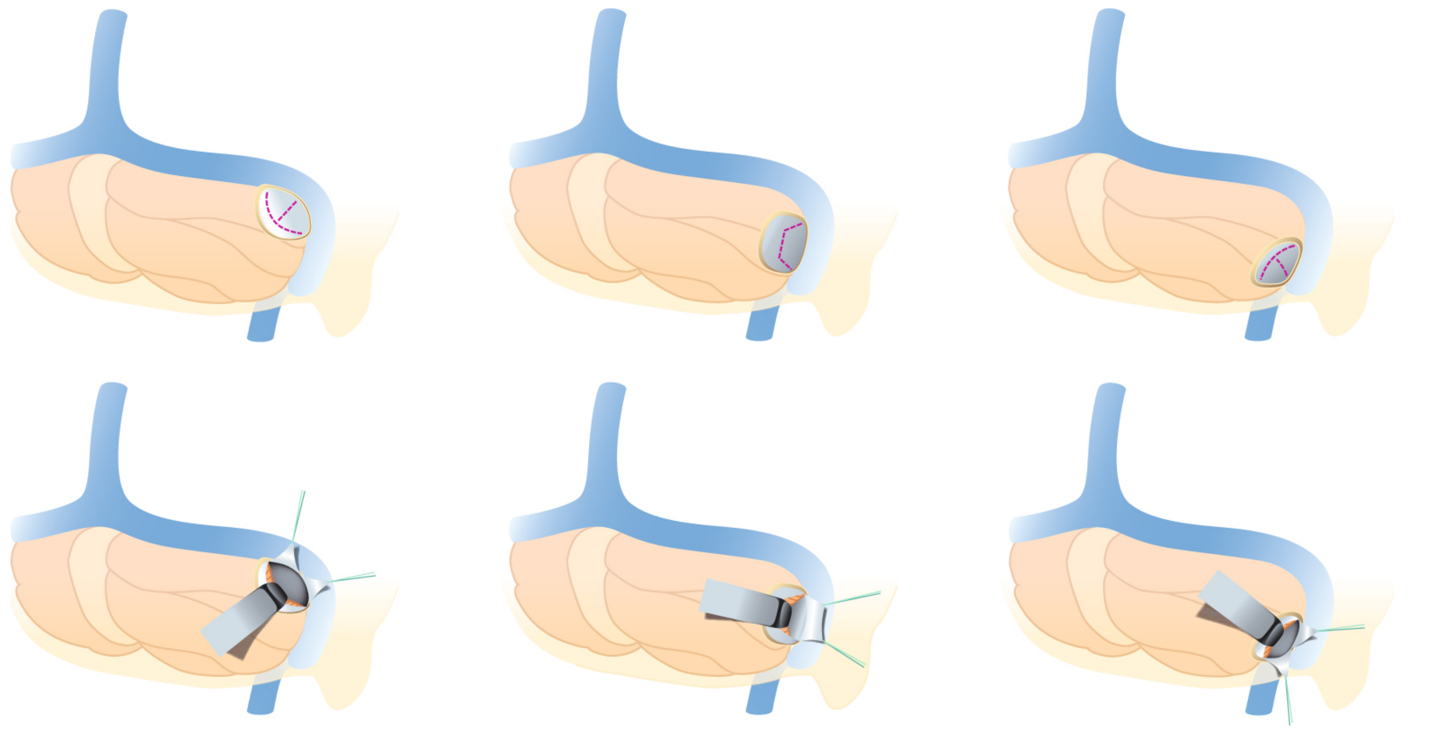


Fig. 4.0.11 *Superior, central and caudal variants of the retrosigmoidal approach. The different variations each require a different performance of the craniotomy, dural opening and a different placement of the cerebellar retractor.*

Superior variation	Central variation	Caudal variation
Transversal sinus Sigmoid sinus Superior petrosal sinus Angle between the posterior surface of the petrous bone and the tentorium Tentorial incisura Upper petrosal and lateral tentorial surface of the cerebellum Posterolateral surface of the mesencephalon CN III, CN IV, CN V, CN VI CN VII, CN VIII Basilar apex, incl. perforators PCA, SCA Petrosal vein of Dandy	Transversal sinus Posterior surface of the petrous bone IAC Petrosal surface of the cerebellum Flocculus Posterolateral surface of the pons CN V, CN VI, CN VII CN VIII, CN IX, CN X, CN XI BA, AICA, PICA, incl. perforators Bochdalek's choroid plexus of the fourth ventricle	Transversal sinus Posterior surface of the petrous bone and craniocervical junction Foramen magnum Jugular foramen Petrosal and suboccipital surface of the cerebellum Posterolateral surface of the medulla oblongata CN VII, CN VIII, CN IX, CN X CN XI, CN XII BA, vertebrobasilar junction, VA PICA, incl. perforators Bochdalek's choroid plexus of the fourth ventricle

Table 4.0.1 *Anatomical structures exposed by different variations of the lateral suboccipital, retrosigmoidal approach.*

For observation of the upper neurovascular complex, the superior variation should be performed. The craniotomy is placed at the transition of the transverse sinus into the sigmoid sinus and the size of the triangular craniotomy should be ca. 10 to 20 mm. The dural opening should allow safe dissection in the angle between tentorium and the posterior surface of the petrous bone. Exposing the trigeminal nerve, the spatula is placed parallel to the superior petrosal sinus.

For exposure of lesions of the midportion of the cerebellopontine angle such as acoustic neurinomas, the craniotomy should be placed below the transverse sinus just medial to the sigmoid sinus. The size of the craniotomy according to this central variation of the retrosigmoidal approach ranges from 15 to 20 mm and the shape should be quadrangular. The dural opening should be done in a curved fashion with its base toward to the sigmoid sinus. The brain spatula is placed parallel to the sigmoid sinus retracting and protecting the lateral surface of the cerebellum.

Exposing the lower neurovascular complex and the foramen magnum, the craniotomy should be performed more caudally along the sigmoid sinus. The size of the caudal variation of the craniotomy should be ca. 20 mm, with a triangular form allowing a nontraumatic placement of the brain retractor.

Surgical technique

1. Patient positioning

Patient positioning for lateral suboccipital, retromastoidal approaches is highly controversial. The sitting, prone, supine or park bench positions for exposure of the lateral posterior fossa offer different advantages and drawbacks; however, positioning of the patient does not particularly affect the surgical options offered by the lateral suboccipital approach.

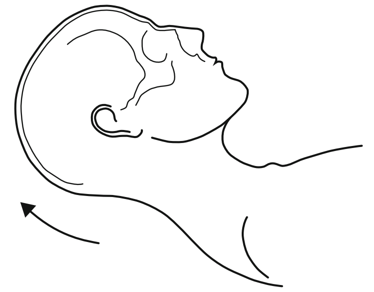


Fig. 4.0.12

According to our experience, we use the simple supine position for the majority of our patients. During surgery, the surgeon remains at the ipsilateral shoulder of the patient, providing an efficient working position. Advantages of this positioning are the simplicity of the technique for both surgeons and nurses, and comfort for the patient. Venous and CSF congestion is minimal compared with the prone or semiprone park bench positions and the position supports the gravity-related self-retraction of the cerebellar hemisphere. After removal of CSF, the cerebellum usually sinks spontaneously and subsequently, significant retraction of the cerebellar hemisphere is not necessary. However, this positioning has also considerable limitations especially in patients with very short necks and prominent shoulders. In such cases, the excessive cervical twisting required with this approach may cause kinking of the main cervical vessels, making a prone position necessary.

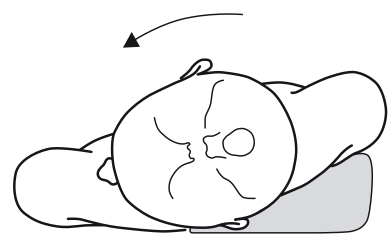


Fig. 4.0.13

Step 1

The head is elevated above the level of the thorax. This maneuvre facilitates additionally the cranial venous drainage and decompresses the larynx, the ventilation tube and the main cervical vessels (Fig. 4.0.12).

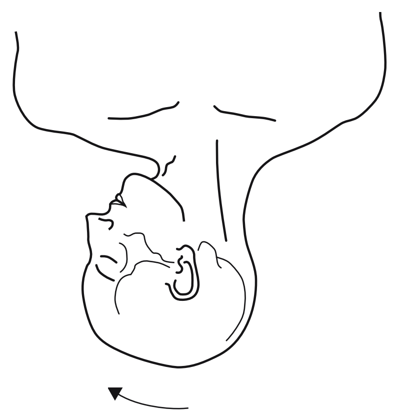


Fig. 4.0.14

Step 2

The head is carefully rotated 75°–100° to the contralateral side and the ipsilateral shoulder is elevated with a cushion (Fig. 4.0.13). The degree of exact rotation depends on the precise location of the lesion. Dissecting toward the brain stem, a rotation of ca. 75° is sufficient. On the other hand, if the surgeon has to overview the lateral aspect of the posterior fossa including the internal auditory canal and Meckel cave, the head requires a rotation of more than 90°. To some degree, the availability of new-generation, electrically motorized operating tables enables readjusting of patient posi-

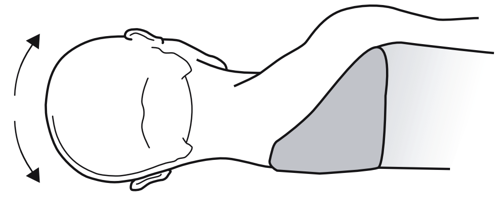


Fig. 4.0.15

tioning during surgery and with an additional tilting of the operating table, an effective rotation of up to 120° can be achieved.

Step 3
In a third step, the head may be anteroflected about 10° in order to achieve an efficient working position for the surgeon without disturbance of the ipsilateral shoulder. However, special care should be taken not to compress the ventilation tube and the larynx (Fig. 4.0.14).

Step 4
The degree of lateroflexion depends on the exact surgical target. When exposing the cerebellopontine angle with structures around the IAC according to the central variation of the retrosigmoidal approach, the head should be positioned in the horizontal plane without lateroflexion. Approaching the foramen magnum region through the caudal variation, the head should be elevated to ca. 10°–15°. When exposing the inferior surface of the tentorium and the upper neurovascular structures of the cerebellopontine angle via the superior variation of the craniotomy, the head should be minimally depressed, allowing optimal visualization during surgery (Fig. 4.0.15).

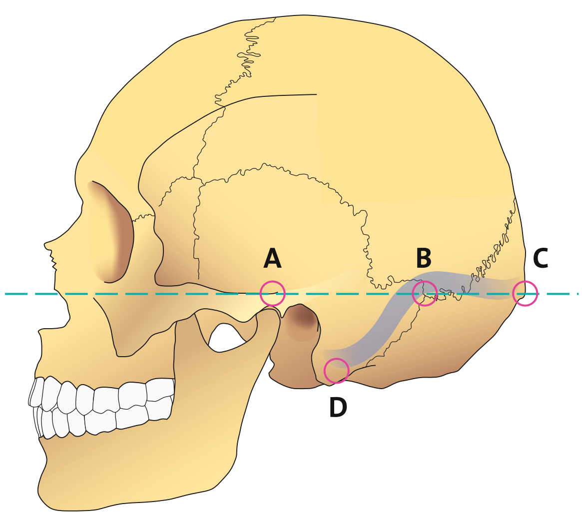
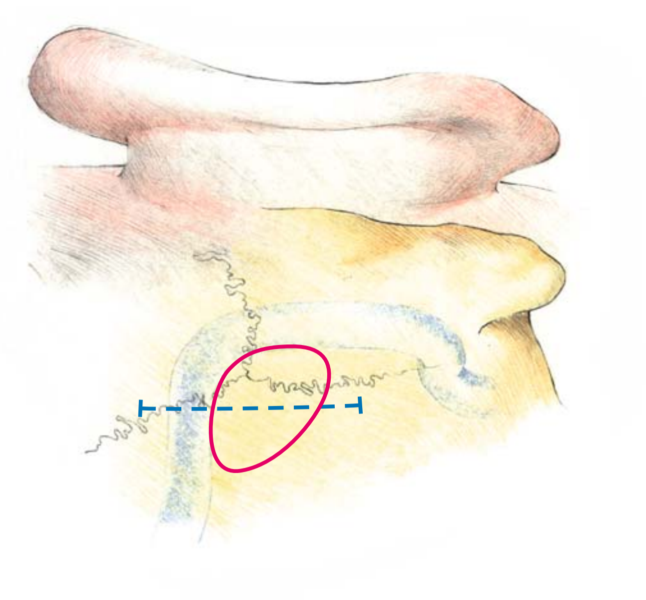


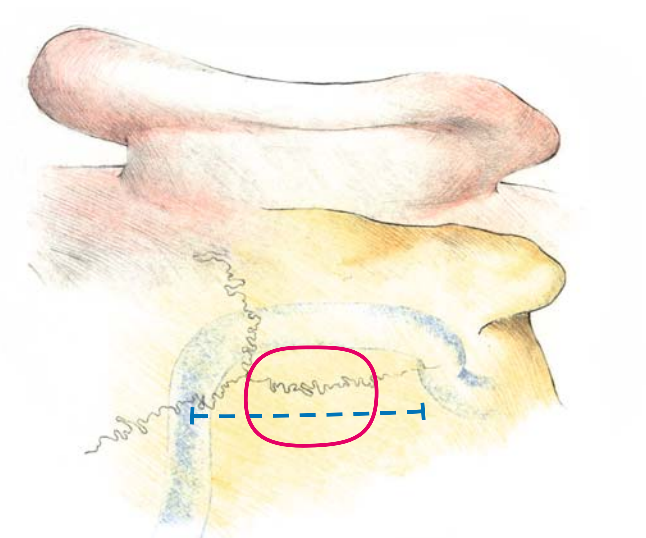
Fig. 4.0.16 *Definition of the transversal and sigmoid sinus, according to the anatomical landmarks of the retroauricular-retromastoidal region. Note the supramastoid crest (A), asterion (B), external occipital protuberance (C) and the mastoid process (D).*

2. Anatomical landmarks and orientation
For preoperative orientation, the important anatomical landmarks of the lateral temporooccipital osseous skull such as the zygomatic arch, external auditory meatus, suprameatal crest, mastoid process and incisura, asterion and the external occipital protuberance are precisely defined. Special attention must be given to the course of the transverse and sigmoid sinus. There are several tricks for accurate localization of the transition of the transversal to the sigmoidal sinus as a key to the exact craniotomy. We emphasize a definition according to the landmarks of the zygomatic arch, supramastoid crest, mastoid process, asterion, and the external occipital protuberance (Fig. 4.0.16). In addition, the appearance of emissary veins and alterations in the level and material of the dura may help to provide accurate sinus definition. However, despite careful orientation, variations of the sinusoid vessels can create surprising difficulties during the first steps of the operation.

After the essential orientation, the borders of the craniotomy are marked with a sterile pen. As described above, taking into consideration the target region, we can distinguish three main variations in the placement of the craniotomy (Fig. 4.0.17). For the central part of the cerebellopontine angle as a target region, the craniotomy should be placed below the transverse sinus just medial to the sigmoid sinus (B). For the upper and lower neurovascular complex as target point, the craniotomy should be placed superiorly (A) or caudally (C) with its anterior border closing the sigmoid sinus, respectively. The diameter of the craniotomy may range from 10 to 20 mm.

After definition of the craniotomy, the hair is shaved retroauricullary according to the line of the skin incision which is ca. 30 to 50 mm in length; the skin is disinfected carefully.


A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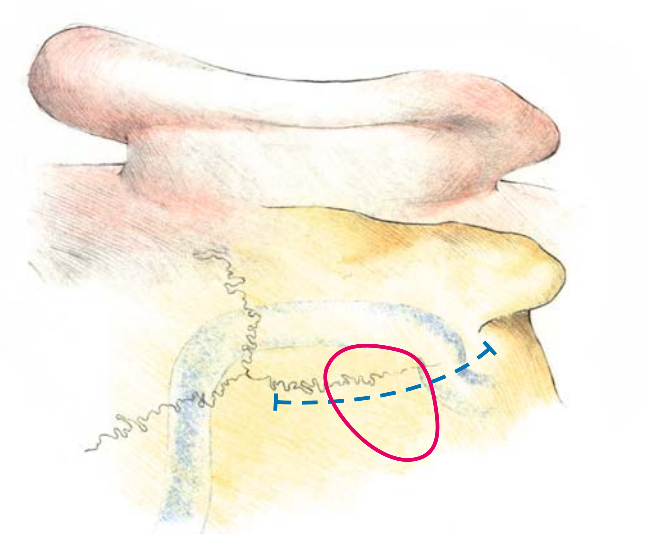

C

Fig. 4.0.17 *Definition of the craniotomy according to the anatomical landmarks of the retroauricular-retromastoidal area and according to the target region.*

A: superiorly placed approach for the upper neurovascular complex including the CN V and SCA.

B: centrally placed craniotomy for the AICA and the facial-vestibulocochlear complex.

C: caudally placed approach for the lower neurovascular structures with the CN IX, CN X, CN XI, CN XII and the PICA.

Note the occipitomastoid, parietomastoid and lambdoid sutures with the asterion and the precise definition of the transversal and sigmoid sinus.

3. Craniotomy and dural opening

Step 1

Right side. A straight or slightly curved skin incision within the retroauricular area is made. The skin incision should be created over the posterior third part of the planned craniotomy, otherwise the retracted muscular layer may hinder intradural visualization. In the further course of the operation, this maneuvre provides easy application of the operating microscope and surgical dissection with microinstruments (Fig. 4.0.18).

Step 2

After bilateral retraction of the skin and the subcutaneous tissue, the sternocleidomastoid fascia is incised in a longitudinal straight fashion. The insertion of the sternocleidomastoid muscle is then freed, exposing the occipitomastoidal area. In cases with thick muscular layers or a caudal extension of the craniotomy, the splenius capitis, longus capitis and superior oblique muscles are separated from their attachments to the bone. Note that the muscular tissue should be freed carefully to the anterior mastoid region, but forcibly in the posterior occipital direction, allowing optimal exposure after craniotomy. Special care is taken to observe the occipital artery when it appears from the arterial sulcus of the occipital bone. Emissary veins are also usually exposed in the mastoid area, indicating the close course of the sigmoid and transverse sinuses. Local hemostasis should be performed rapidly and precisely (Fig. 4.0.19).

Step 3

After bone exposure, a tiny groove is usually visible according to the asterion, which is usually located at the inferior margin of the transverse sinus just posterior from the transition into the sigmoid sinus. Other bony structures such as the occipitomastoid, squa-

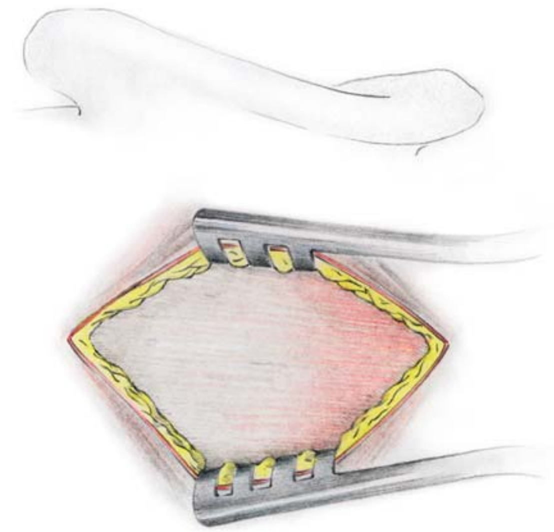


Fig. 4.0.18

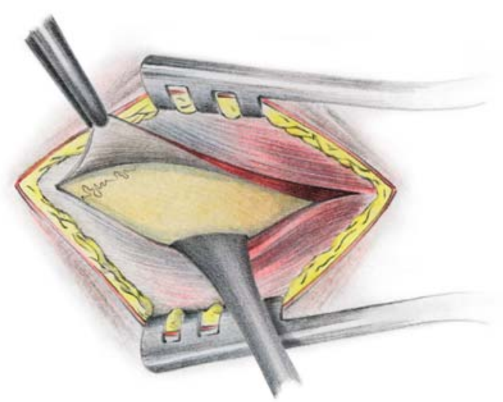


Fig.4.0.19

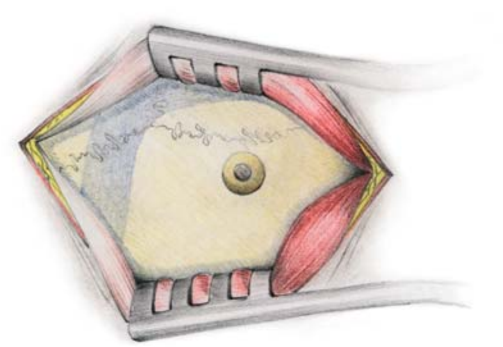


Fig. 4.0.20

Fig. 4.0.21

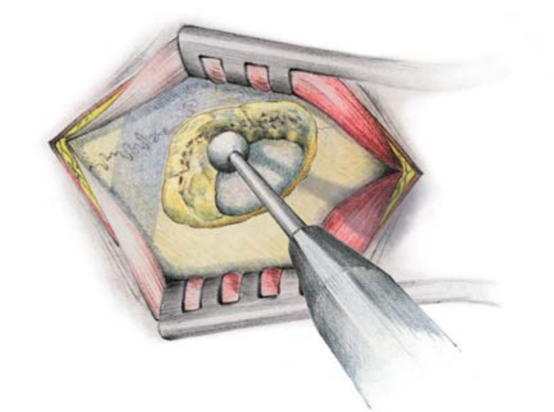


Fig. 4.0.22

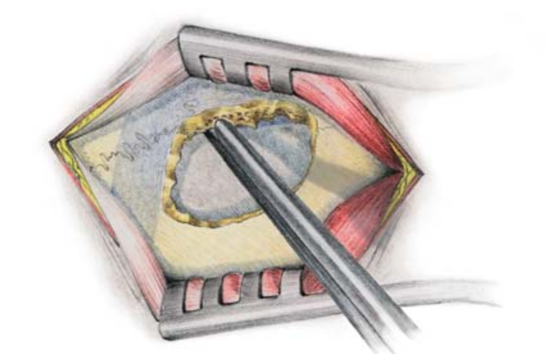
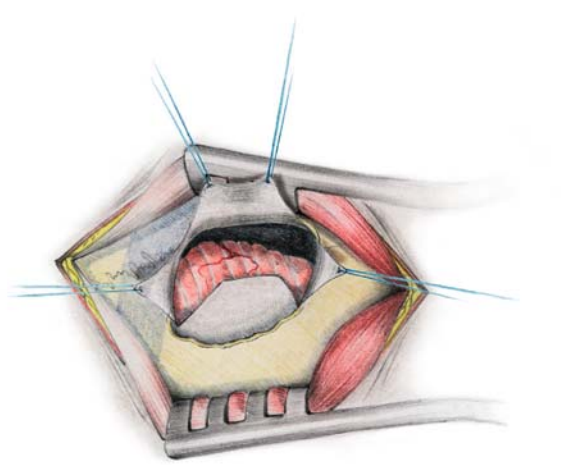


Fig. 4.0.23



mosal and lambdoid sutures and the mastoid incisura may also help to identify the course of the sigmoid sinus. After identification of the important bony landmarks, a burr hole is placed according to the occipitomastoid suture, just caudally from the asterion. We prefer an osteoclastic craniotomy using high-speed drill avoiding a hazardous osteoplastic procedure near to the prominent sinusoid vessels (Fig. 4.0.20).

Step 4

Further bone is removed with the high-speed drill exposing the edge of the sigmoid sinus (Fig. 4.0.21).

Step 5

An important step of the approach is the removal of the inner edge of the craniotomy using fine punches whilst protecting the dura. With careful removal of this inner bone edge, the angle for visualization and manipulation can significantly increase, allowing a direct line of sight down the posterior surface of the petrous bone. For exposure of the cerebello-pontine angle, a square-shaped craniectomy is sufficient according to placement of the brain spatula and to the main direction of surgical dissection (Fig. 4.0.22).

Step 6

The dura should be opened in a curved fashion with its base toward the sigmoid sinus. The free dural flap is fixed laterally with two sutures; other dural elevation sutures are not required. In some cases, according to the individual situation, minimal enlargement of the dural opening may be necessary in a Y-shaped form (Fig. 4.0.23).

4. Intradural dissection

Step 1

Right side. Dissection shown on fresh human cadavers. Arterial vessels are prepared with red, veins with blue colored solution. After opening the dura mater, the cerebellar surface can be observed. Note a prominent superficial vein running from the suboccipital to the tentorial surface of the cerebellum. In this case, the craniotomy was performed close to the junction between the transversal and sigmoid sinus (Fig. 4.0.24).

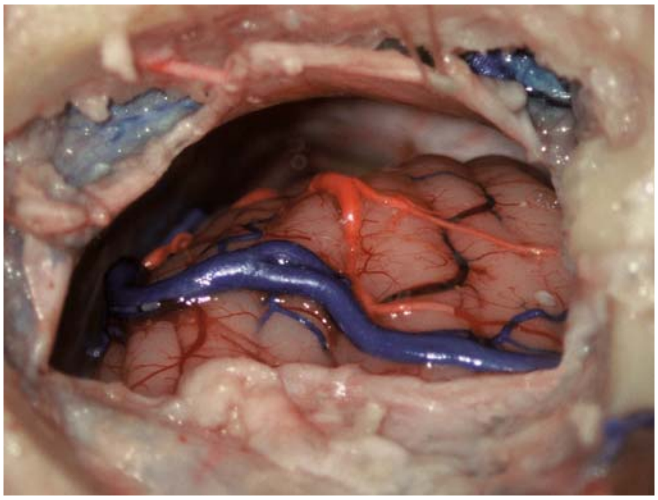


Fig. 4.0.24

Step 2

After gentle mobilization of the cerebellum, the angle between the tentorium and the posterior surface of the petrous bone can be approached according to the course of the superior petrosal sinus. After opening the arachnoid membranes, adequate amounts of CSF should be aspirated supporting gravity-related self-retraction of the cerebellar hemisphere. The spatula is placed parallel to the superior petrosal sinus protecting the upper lateral surface of the cerebellum (Fig. 4.0.25).

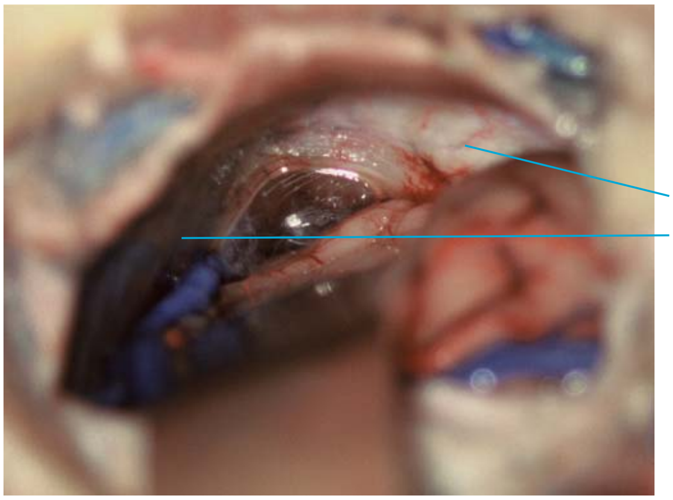


Fig. 4.0.25

Step 3

After aspiration of CSF, the petrous vein of Dandy and the CN V are exposed. The upper neurovascular complex can be optimally exposed with the superior variation of the retrosigmoidal approach (Fig. 4.0.26).

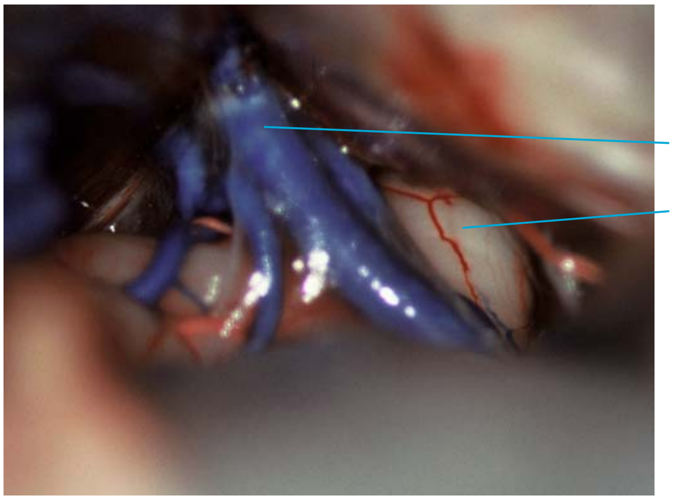


Fig. 4.0.26

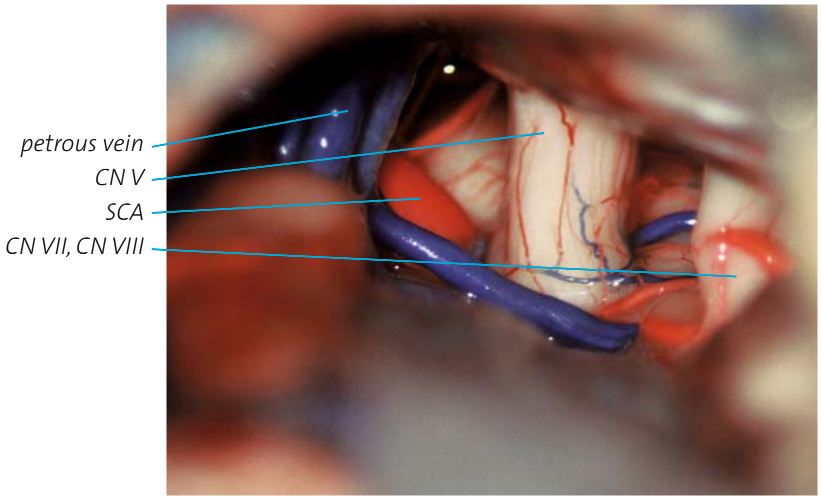


Fig. 4.0.27

Step 4

After further dissection of arachnoidal membranes within the upper cerebellopontine angle, the relationship between the petrous vein, CN V, CN VII and CN VIII becomes evident. Note a prominent SCA close to the CN V (Fig. 4.0.27).

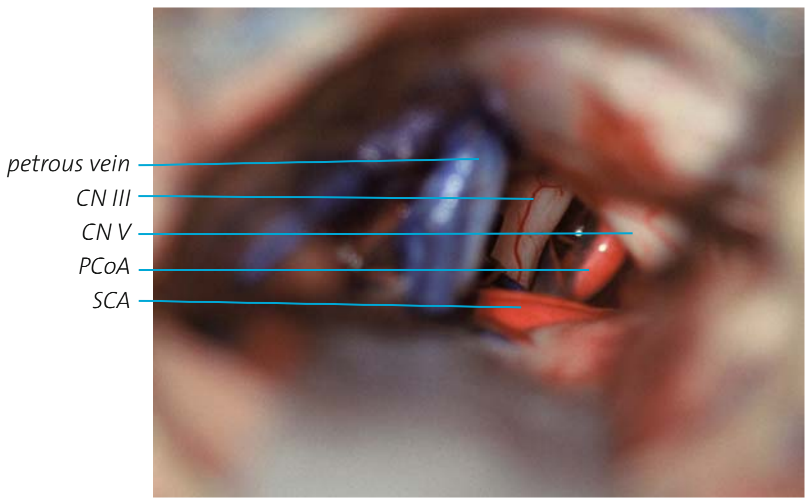


Fig. 4.0.28

Step 5

Between the petrous vein and CN V, a deep-seated area with the CN III is approached. Note the double SCA and the PCoA (Fig. 4.0.28).

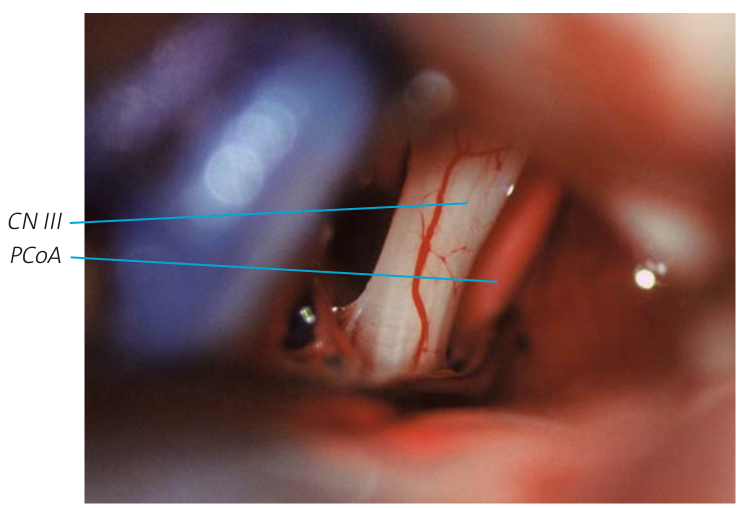


Fig. 4.0.29

Step 6

Higher magnification of the CN III. In the background, the PCoA appears (Fig. 4.0.29).

Step 7
Dissecting in a caudal direction from the CN V, the facial and vestibulocochlear nerves are exposed. Note the flocculus (Fig. 4.0.30).

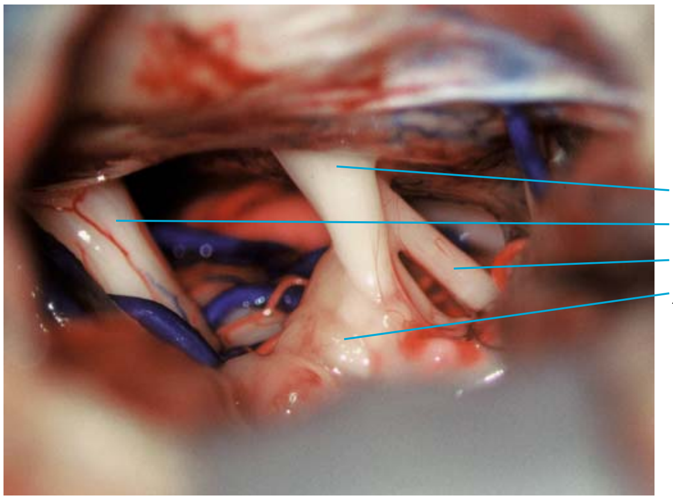


Fig. 4.0.30

Step 8
Focusing into the deep-seated prepontine area, the BA and the CN VI are visualized. Note the venous vessels of the anterolateral surface of the pons (Fig. 4.0.31).

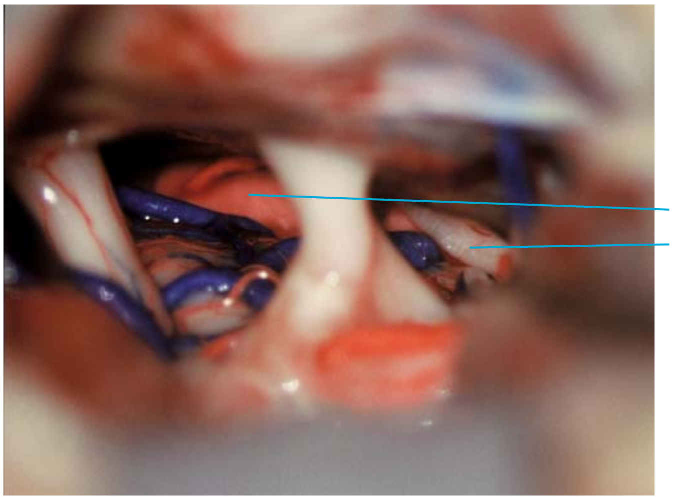


Fig. 4.0.31

Step 9
In a more caudal course of dissection, the region of the jugular foramen is approached. Note the loop of the AICA between the facial and glossopharyngeal nerves. Bochdalek's choroid plexus of the fourth ventricle appears close to the CN X (Fig. 4.0.32)

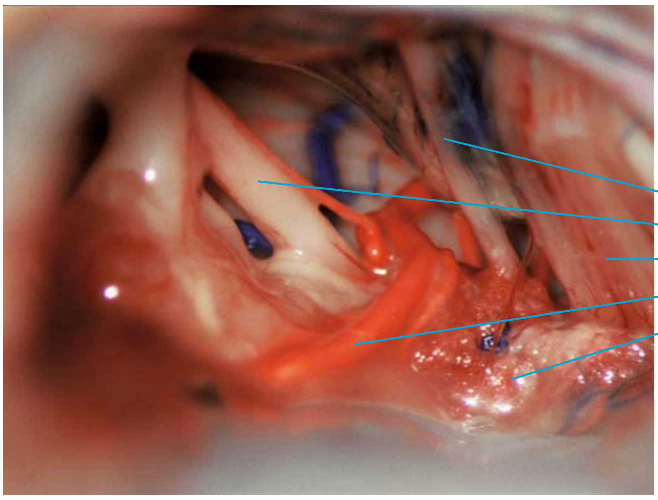


Fig. 4.0.32

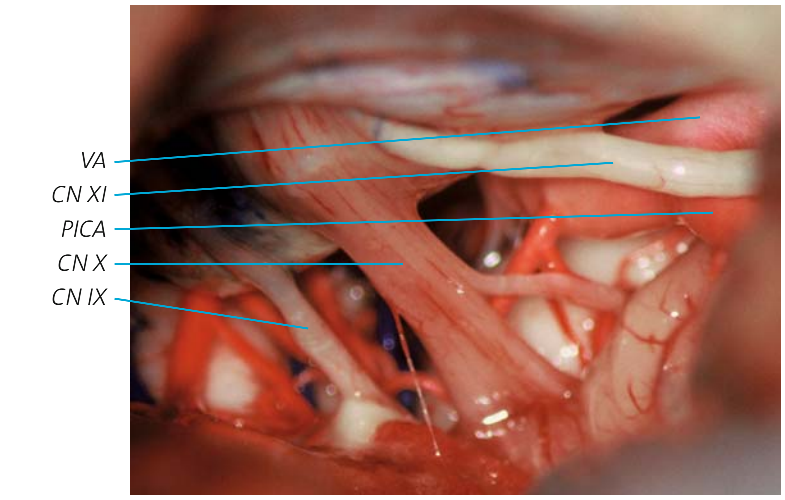


Fig. 4.0.33

Step 10
Exposure of the lower cerebellopontine angle with the CN IX, CN X and CN XI. Note the origin of the PICA from the VA (Fig. 4.0.33)

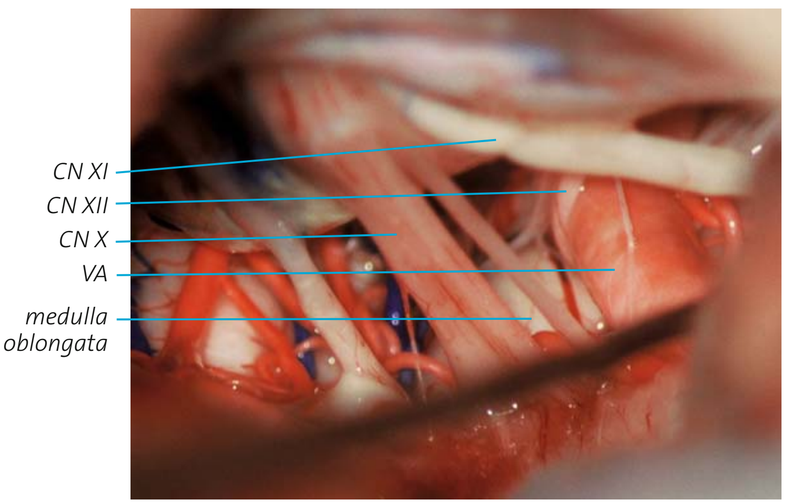


Fig. 4.0.34

Step 11
Center of attention is the surface of the VA with fibers of the hypoglossal nerve. Note the anterolateral surface of the medulla oblongata (Fig. 4.0.34)

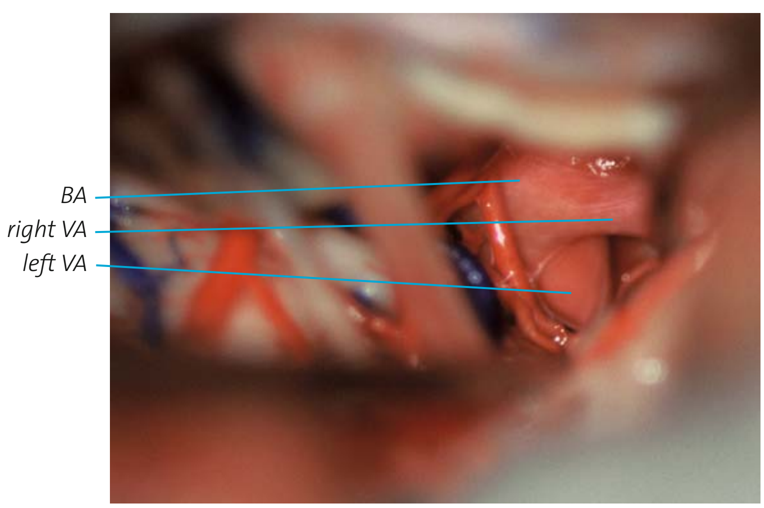


Fig. 4.0.35

Step 12
Dissecting along the anterior foramen magnum, the junction of both vertebral arteries can be well visualized (Fig. 4.0.35)

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with Ringer solution at body temperature. The dural incision is closed with interrupted or continuous sutures. If tension has developed in the dural plane, a small piece of muscle can be used for a watertight closure; in other cases, plastic material may be required. A plate of gelfoam is placed extradurally and the craniectomy is closed with bone cement. After final verification of hemostasis, the muscle and subcutaneous layers are closed with interrupted sutures and the skin with running or interrupted sutures. A suction drain is not necessary.

Potential errors and their consequences

- Inadequate preoperative planning with the consequence of inadequate exposure of the target region and significant deterioration in efficiency of surgical exposure of the target region. As the most important part of procedure, planning is the task of the surgeon!
- Special attention should be paid to patient positioning. Inadequate positioning may cause compression of the main cervical vessels resulting in hypoperfusion or severe venous congestion in the posterior fossa.
- Inadequate placement of the surgical approach causing injury to the transverse or sigmoid sinus with severe venous bleeding. The approach must be determined after accurate surgical orientation according to anatomical knowledge and preoperative planning.
- Inadequate removal of CSF with severe contusion of adjacent portions of the cerebellar hemisphere due to spatula pressure. Increasing pressure within the posterior fossa may cause severe neurological deterioration.
- Injuries to sensitive nerves and vessels in the lateral posterior fossa during microsurgical dissection.
- Inadequate hemostasis within the surgical site with subsequent postoperative rebleeding.
- Inadequate dural closure with postoperative CSF fistula. In most cases, nasoliquorrhea occurs because of frequently opened mastoid cells.
- Inadequate extracranial hemostasis causing postoperative soft tissue hematoma.

Tips and tricks

- Special care should be given to preoperative planning and patient positioning according to the precise localization of the lesion. Note that laterally located lesions need less rotation but medially located lesions require more head rotation.

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and superficial neurovascular structures; 2. placement of craniotomy; 3. skin incision.

- To provide the intradural manipulation allowing a direct line of sight down the posterior surface of the petrous bone, the next three details are important:
  1. The skin incision should be created over the posterior third part of the craniotomy, otherwise the retracted suboccipital muscles may hide the intradural surgical dissection (Fig. 4.0.36).
  2. The attachment of the sternocleidomastoid and splenius capitis muscles should be mobilized forcibly in the posterior and gently in the anterior mastoidal direction, protecting the intradural visualization (Fig. 4.0.37).
  3. Removal of the anterior inner edge of the craniectomy over the sigmoid sinus under protection of the dura using fine punches. The angle for visualization can also significantly increase with careful removal of this inner bone edge (Fig. 4.0.38).

- The dura should be opened in a “C” shaped, semilunar fashion and held toward the sigmoid sinus with two sutures. It is easy to gain better visualization of the foramen magnum or tentorium with a caudal or cranial enlargement of the dural opening (Fig. 4.0.39).

- The first step of the intradural dissection should be the opening of the cerebellomedullar cistern and sufficient drainage of CSF.

Fig. 4.0.36

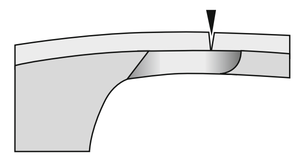


Fig. 4.0.37

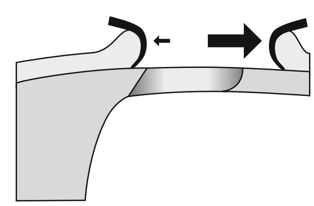


Fig. 4.0.38

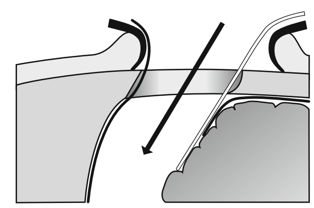


Fig. 4.0.39

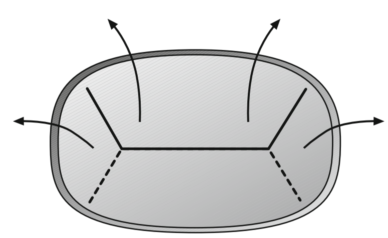
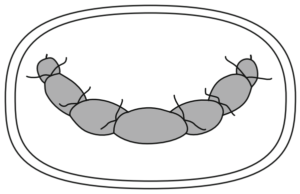
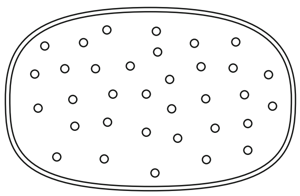


Fig. 4.0.40



- After finishing the intracranial procedure, the dural opening should be closed watertight using interrupted or running sutures. If tension has developed, which is very frequent, a small piece of muscle can be sewn into the dural closure. In other cases, plastic graft material should be used (Fig. 4.0.40).

Fig. 4.0.41



- The bony opening of the craniectomy should be closed with bone cement avoiding muscle ingrowth and attachment to the dura mater with subsequent postoperative cervical pain (Fig. 4.0.41).

- Because of the limited approach, a suction drain is not recommended.

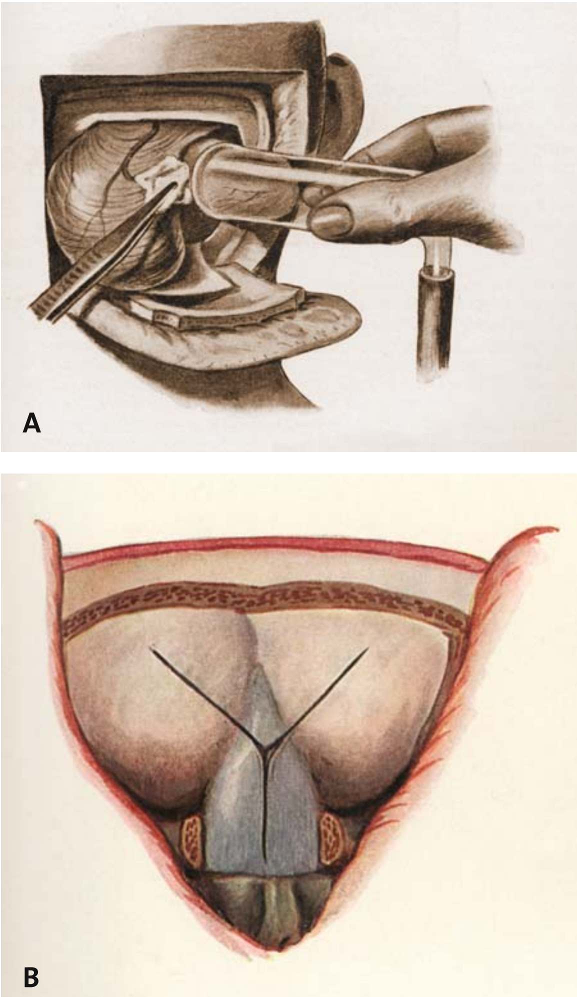


Fig. 5.0.1

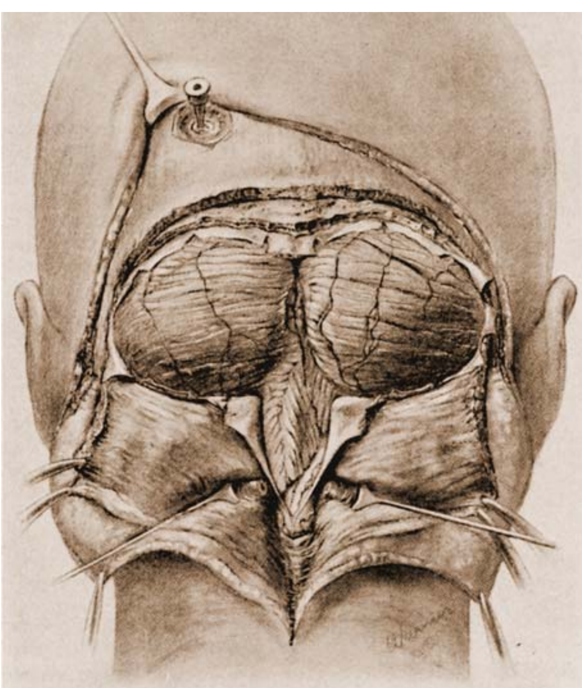


Fig. 5.0.2

5.0 Suboccipital approach

History of the median suboccipital approaches

During the early period of neurosurgery, operative treatment of space-occupying lesions within the posterior fossa was characterized by an extremely high mortality rate. Due to inaccurate preoperative assessment and crude surgical techniques for tumor removal, the treatment failed so frequently that surgeons were reluctant to undertake these operations (Fig. 5.0.1 A). In 1893, Allen Starr published 15 cases of cerebellar tumors with only one patient surviving with neurological recovery [Starr 1893]. On account of these frustrating results, Hermann Oppenheim classified cerebellar lesions as inoperable, reporting a greater than 70% mortality [Oppenheim 1902].

Fedor Krause in 1913 published different approaches to cerebellar tumors describing a broad bilateral exposure of the posterior fossa (Fig. 5.0.1 B). However, only a minority of patients survived this treatment, resulting in a mortality rate ranging from 67% to 88% [Krause 1913].

Wide exposure of the entire suboccipital area was commonly used to approach the posterior fossa. Victor Horsley in 1904 and Harvey Cushing in 1905 reported the *"bilateral exposure of the cerebellar hemispheres through a crossbow incision"* [Horsley 1904, Cushing 1905]. These extended approaches avoided brain stem compression during surgery and allowed posterior fossa decompression after incomplete tumor removal and brain swelling (Fig.5.0.2).

Fig. 5.0.1 *In the early days of neurosurgery, space-occupying lesions were usually removed by blunt finger dissection between the sensitive neurovascular structures. Treatment of cerebellar lesions was often unsuccessful because of the crude surgical techniques. To achieve a nontraumatic dissection, especially within the posterior fossa, Krause in 1909 published a new method using vacuum suction of the tumor mass (A). Note Krause's median suboccipital approach exposing the posterior fossa. He carried out a broad laminectomy of the atlas allowing decompression of the craniocervical region and the dura was opened in a "Y" form (B).*

Fig. 5.0.2 *Cushing's posterior fossa surgery using a bilateral suboccipital approach. Cushing described an "extreme foraminal herniation in a case in which tension was so great as to necessitate removal of the laminae of the atlas and carrying the dural incision to the atlas before respiratory embarrassment was relieved". Note the puncture of the left lateral ventricle.*

On the basis of his experience, Horsley pointed out that a large amount of the cerebellar tissue could be sacrificed and removed with a minor or no demonstrable loss of neurological function. The common approach to lesions of the fourth ventricle was obtained by splitting the vermis on the suboccipital surface, and in some cases, removing the medial part of the cerebellar hemisphere as recommended by Walter E. Dandy and Ludwig G. Kempe [Dandy 1938, Kempe 1970] (Figs. 5.0.3, 5.0.4).

The introduction of microsurgical techniques provided a marked improvement in surgical efficiency. With less invasive approaches as reported by Robert W. Rand and M. Gazi Yasargil, surgical mortality and morbidity could be successfully minimized [Rand 1968, Yasargil 1970]. In particular, the precise dissection within the subarachnoid spaces of the posterior fossa and approaching the fourth ventricle through anatomical pathways offered a significant development in surgical results (Fig. 5.0.5).

In the following the importance of these anatomical considerations is discussed in full.

Fig. 5.0.3 *Exploration of a partial cystic tumor of the posterior fossa through a median suboccipital approach as described by Dandy. The patient suffered from severe headaches caused by a consecutive obstructive hydrocephalus. Note the intraoperative use of monopolar coagulation allowing a safe surgical dissection.*

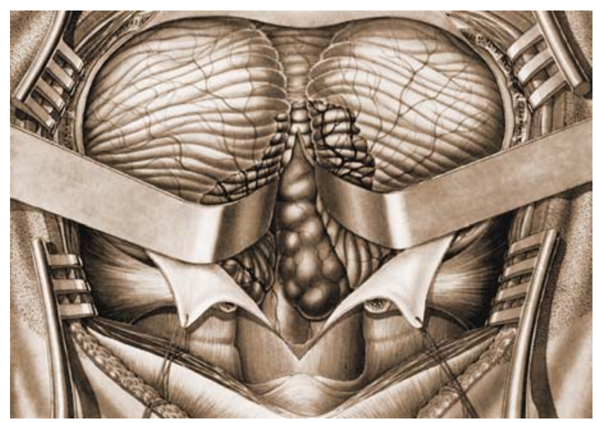


Fig. 5.0.4 *Kempe's macrosurgical posterior fossa exploration published in 1968 in his comprehensive neurosurgical textbook. Note the broad bilateral exploration and sectioning of the inferior vermis for approaching the tumor within the fourth ventricle.*

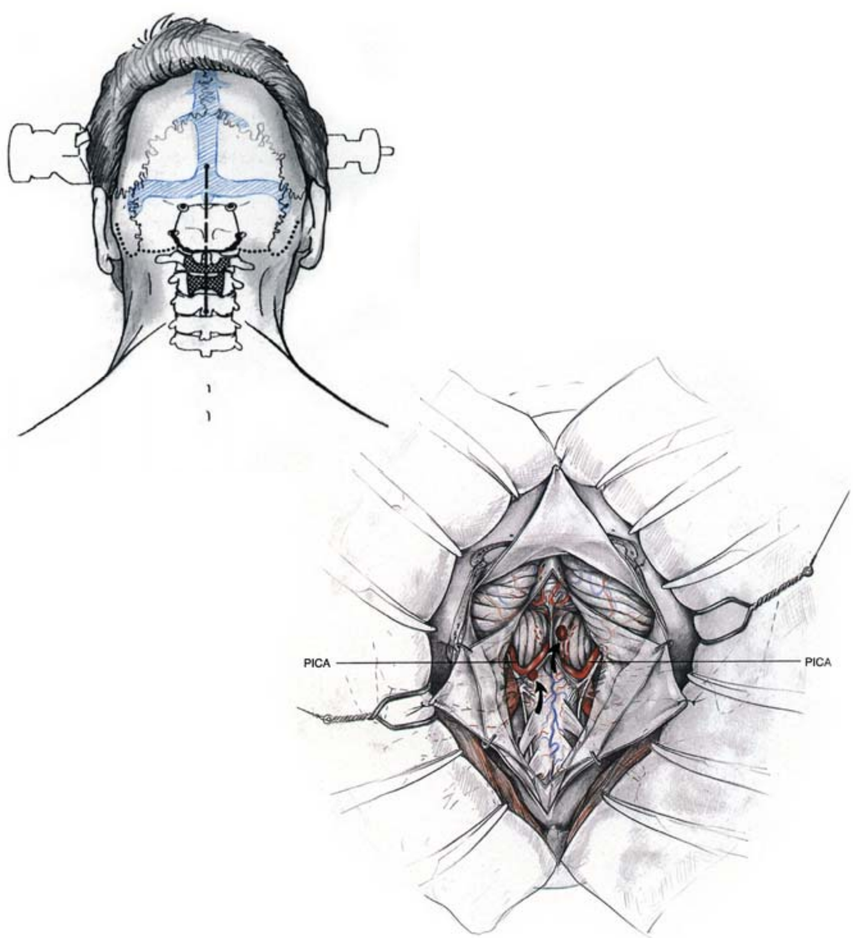


Fig. 5.0.5 *The median suboccipital approach using microsurgical techniques described by Yasargil for distally situated aneurysms of the PICA.*

General anatomical construction of the surgical corridor to the fourth ventricular region

The posterior cranial fossa is the deepest of the three cranial fossae containing the most complex intracranial anatomy with structures of the cerebellum, brain stem, ten pairs of cranial nerves, and complex arterial and venous relationships. The posterior fossa extends from the tentorial incisura to the foramen magnum between the supratentorial and intraspinal spaces. It is surrounded by the occipital, temporal, parietal, and sphenoid bones. In its narrow space, which consists of only approximately one-eighth of the intracranial volume, are the most important vital pathways regulating consciousness, cardiorespiratory and other autonomic functions, motor activities and sensory reception, and centers for controlling balance and gait.

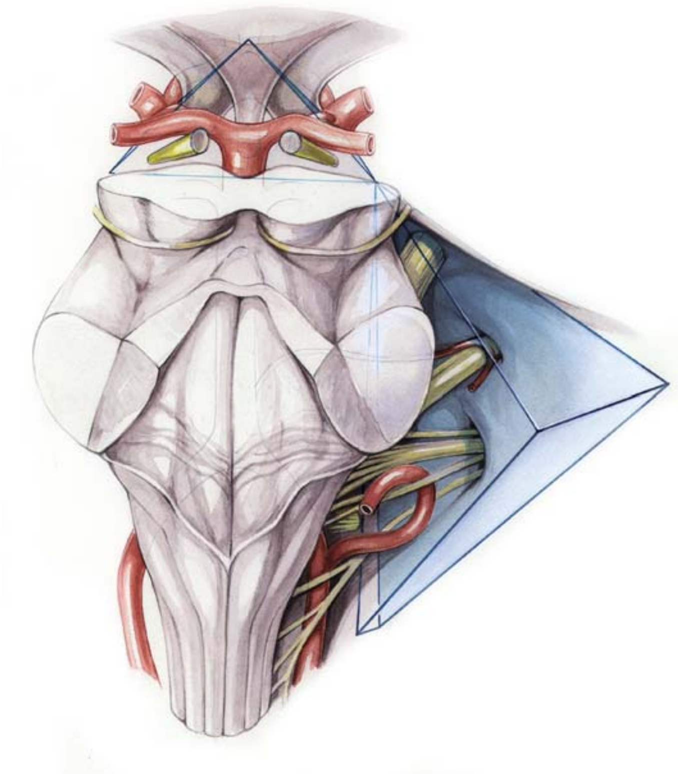


Fig. 5.0.6 *Artistic illustration of the fourth ventricle, rhomboid fossa and the surrounding anatomical structures.*

Operative approaches to the fourth ventricle and most cerebellar tumors are commonly directed around and through the suboccipital area of the posterior fossa. According to the falx cerebelli, the suboccipital surface of the cerebellum is divided by the posterior cerebellar incisura into right- and left-sided hemispheres. The vermis cerebelli is folded into this incisura and forms a type of cortical surface within the incisura. The suboccipital cerebellar surface is divided horizontally by the suboccipital fissure into superior and inferior parts. This suboccipital fissure has a vermian and a hemispheric part. The vermian part separates the tuber and the pyramid and is termed the prepyramidal fissure. In the hemispheric part, the prebiventral fissure separates the biventral and inferior semilunar lobules of the cerebellar hemispheres. The tonsils and the uvula are situated inferomedial from the lobulus biventral and pyramid covering the access to the caudal part of the fourth ventricle.

Via the suboccipital approach, access is gained to the fourth ventricular chamber through a triangle-formed space between the two tonsils, the so-called vallecula, and through the cerebellomedullary fissure, the narrow space between the tonsils and the medulla oblongata. The vallecula communicates through the foramen of Magendie with the chamber of the fourth ventricle (Fig. 5.0.6). Surgical exposure of the ventricle requires dissection of the foramen of Magendie and opening of the caudal part of the ventricular roof. This caudal roof of the fourth ventricle is formed by the inferocaudal part of the vermis with the uvula and nodulus and the inferior medullary velum covering the tonsils of both cerebellar hemispheres. The tela choroidea stretches between the inferior medullary velum and the taenia of the medulla oblongata forming the choroid plexus of the fourth ventricle with branches of the posterior inferior cerebellar artery.

In the past, operative access to the fourth ventricle was obtained by splitting the cerebellar vermis and, in some cases, by removing the medial part of the cerebellar hemisphere. However, careful microsurgical dissection of the vallecula and the cerebellomedullary fissure provides a broad exposure of the caudal entrance into the ventricle. Opening the foramen of Magendie and tela choroidea will provide adequate exposure of the full length of the floor of the ventricle without splitting of the vermis or removing neural tissue (Fig. 5.0.7). This maneuvre can be compared with the transchoroidal enlargement of the foramen of Monro. In addition, by opening the inferior medullary velum, one can approach the entire ventricular chamber including the fastigium, the lateral recesses toward the foramen of Luschka and the aqueduct of Sylvius. It is important to note that there are no reports of deficits following separate opening of the velum and tela compared with possible severe gait disturbances and ataxia after splitting of the vermis.

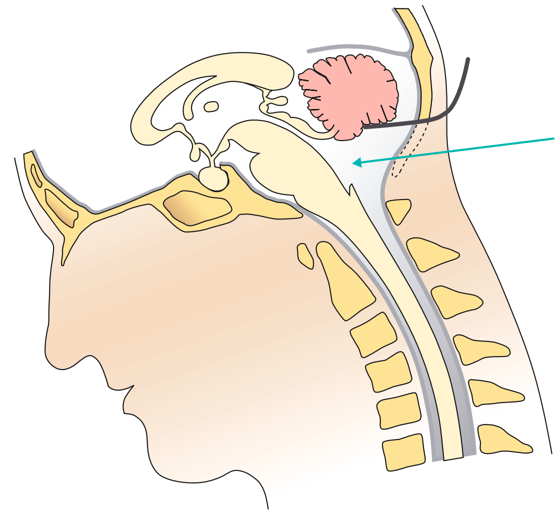


Fig. 5.0.7 *Operative exposure of the fourth ventricle using the median suboccipital approach. Note that careful retraction of the nodulus and uvula after dissection of the cerebellomedullary fissure provides a broad approach to the ventricular chamber without splitting the inferior vermis.*

In the following, the basic surgical technique of the median suboccipital infracerebellar approach is described.

Craniocervical junction	**Fourth ventricle**
Posterior circumference of the foramen magnum	Choroid plexus of the fourth ventricle
Marginal sinus, occipital sinus	Rhomboid fossa
Suboccipital surface of the cerebellar hemispheres	Foramen of Luschka
Cerebellar tonsils, lower vermis, vallecula	Fastigium
Inferior medullary velum	Superior medullary velum
Choroid plexus of the fourth ventricle	Aqueduct
Foramen of Magendie	Posterior third ventricle
Cervicomedullary junction	
Posterior surface of the medulla oblongata	
First denticulate ligaments	
CN XII, CN XI, CN X, CN IX, first cervical root	
VA, PICA, incl. perforators	

Table 5.0.1 *Anatomical structures which can be reached through the median suboccipital approach.*

Surgical technique

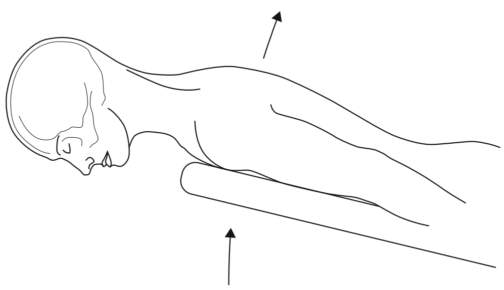


Fig. 5.0.8

Fig. 5.0.9

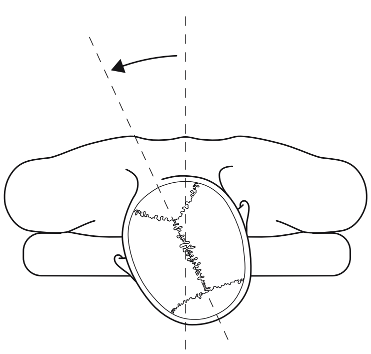


Fig. 5.0.10

1. Patient positioning

Surgery of the posterior fossa including the fourth ventricle can be performed with the patient in the sitting or the prone position. As a main advantage, the sitting position improves the venous drainage of the posterior fossa and allows blood, CSF, and irrigating solutions to drain from the operative field. However, the sitting position carries a very severe anesthesiological risk with danger of cardiopulmonary instability, air embolism, severe pneumocephalus or ventricular collapse caused by an enormous loss of CSF. In addition, exposing the fourth ventricle in the sitting position requires retraction of the cerebellar hemispheres against gravity, resulting in contusion of the cerebellar tissue. In our department, we use the prone position for exposing the posterior fossa via the median suboccipital approach. Advantages of this positioning are the simplicity of the technique and comfort for the patient. With an adequate positioning of the head, the cerebellum falls away from the brain stem surface opening the subvermial surgical corridor. At the same time, the perpendicular direction of surgical dissection provides an efficient working position with optimal visualization of the operating field.

Step 1

As a first step of positioning, the body and the head are elevated ca. 20° to 30° as in an anti-Trendelenburg position. This elevation is necessary to bring the head above the level of the thorax offering optimal venous drainage (Fig. 5.0.8).

Step 2

In a second step, the head may be anteroflected about 45° in order to bring the tentorium in a perpendicular plane. This so-called Concorde position provides an efficient working position for the surgeon dissecting toward the inferior cerebellar surface and within the fourth ventricle. However, special care should be taken not to compress the ventilation tube and the larynx. Excessive anteflection can also cause venous congestion due to compression of the jugular veins (Fig. 5.0.9).

Step 3

For lesions located mainly in the midline, rotation of the head is not necessary. However, mediolaterally situated lesions require a slight rotation of 5°–15° (Fig. 5.0.10).

2. Anatomical landmarks and orientation

For preoperative orientation, the important anatomical landmarks of the posterolateral osseous skull and spine, such as the external auditory meatus, mastoid process, the highest nuchal line, the external occipital protuberance, the foramen magnum and the spinous process of C2 are precisely determined (Fig. 5.0.11). Special attention should be given to the course of the transverse sinus as the border of the posterior fossa, and definition of the midline structures.

After exact orientation, the borders of the craniotomy are marked with a sterile pen. Usually, the craniotomy is placed median or slightly paramedian extending from the foramen magnum to the inferior nuchal line with a diameter of about 3 cm. In some cases, the superior rim of the posterior arch of C1 can additionally be removed, allowing optimal exposure of the cervicomedullary junction.

After defining the craniotomy, the hair is shaved and carefully disinfected according to the midline skin incision of 6 to 8 cm in length (Fig. 5.0.11).

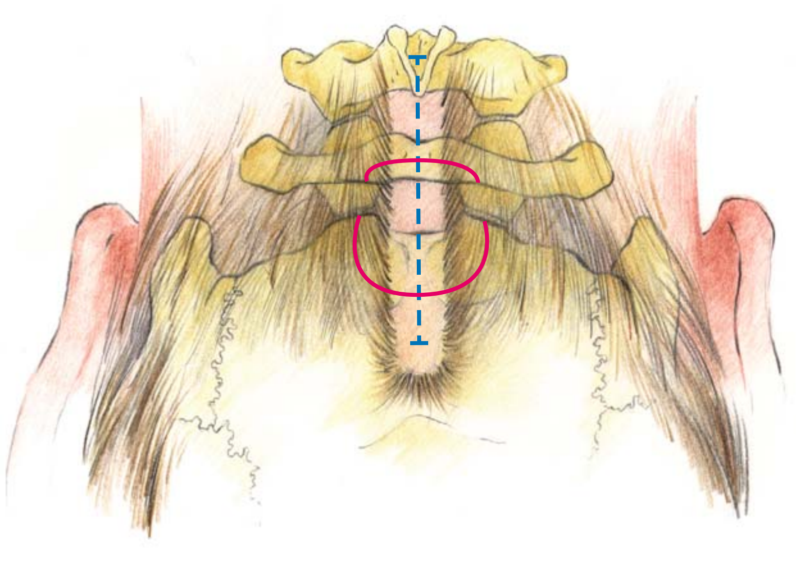


Fig. 5.0.11 *Definition of the craniotomy according to the anatomical landmarks of the posterior craniocervical region. The midline skin incision should reach the easily palpable C2 spinous process.*

3. Craniotomy and dural opening

Step 1

After patient positioning and anatomical orientation, the skin is prepared with alcohol solution. To begin the suboccipital exposure, a straight midline incision is made extending from the inion to the well palpable spinous process of C2 (Fig. 5.0.12).

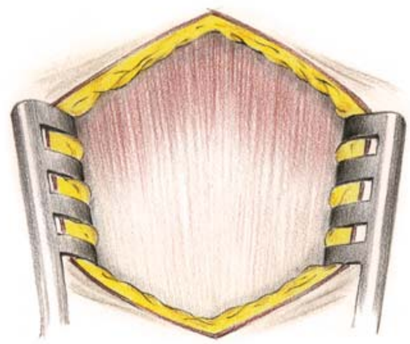


Fig. 5.0.12

Step 2

After retraction of the skin, the ligamentum nuchae is precisely defined and split according to the midline. Soft tissue dissection and separation of the suboccipital muscles should be made strictly in the midline through the ligamentum nuchae, thus avoiding misguiding into the highly vascular paramedian muscles (Fig. 5.0.13).

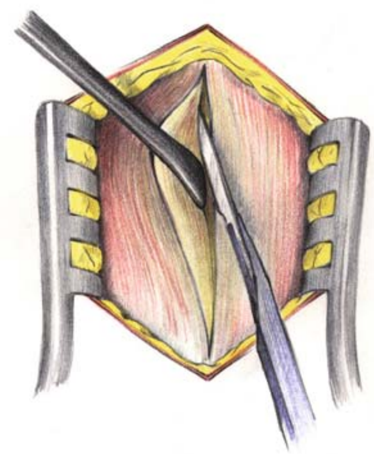


Fig. 5.0.13

Step 3

A low profile, self-retaining retractor is then used to hold back the thick suboccipitial muscle layers, e.g., the trapezius, splenius and semispinalis capitis muscles. The rectus capitis posterior minor is dissected from the tubercle on the posterior arch of the atlas exposing the suboccipital area with the foramen magnum and the posterior arch of C1. Local hemostasis needs to be performed rapidly and precisely. After retraction of the muscles, two paramedian burr hole trephinations are performed exposing the dura mater of both cerebellar hemispheres (Fig. 5.0.14).

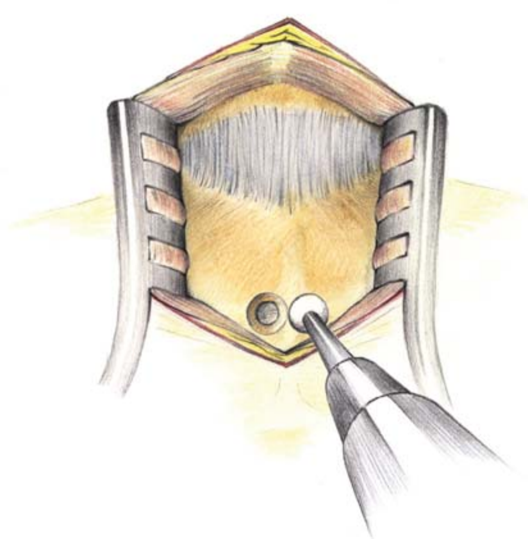
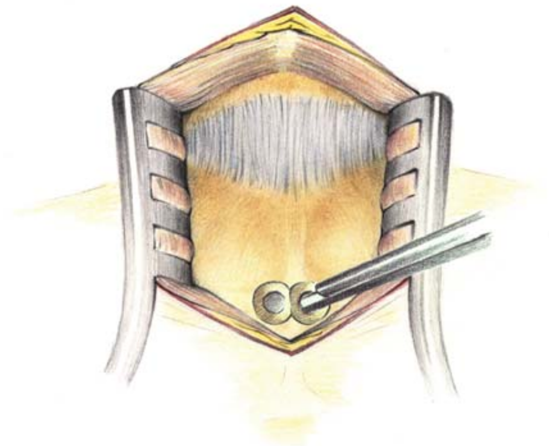


Fig. 5.0.14

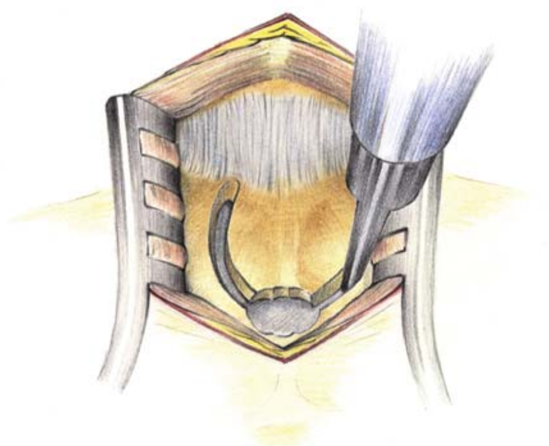
Fig. 5.0.15



Step 4

Next, the paramedian burr holes are connected using fine punches with removal of the internal occipital crest, avoiding damage to the occipital sinus (Fig. 5.0.15).

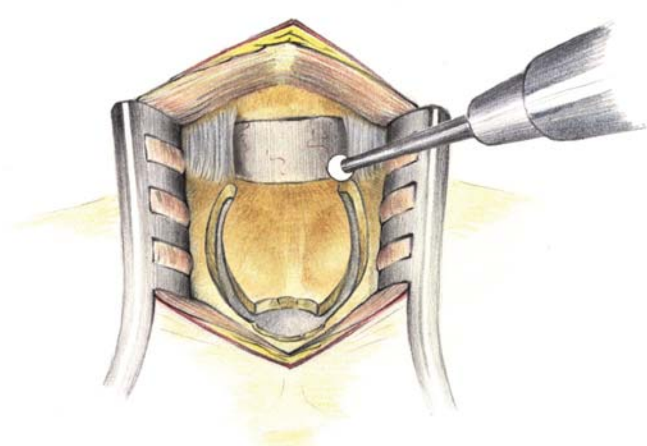
Fig. 5.0.16



Step 5

After careful exposure of the dura mater and the occipital sinus, an osteoplastic craniotomy is performed using a high-speed craniotome. From the burr hole trephinations, curved lines are sawed on both sides to the posterior margin of the foramen magnum (Fig. 5.0.16).

Fig. 5.0.17



Step 6

According to the craniotomy lines, the thick posterior margin of the foramen magnum is then removed using a high-speed drill, avoiding injury to the dura mater of the lateral craniocervical junction. Note avoiding surgical injury to the vertebral artery (Fig. 5.0.17).

Step 7 A

Observing the vallecula and the fourth ventricle, the bone flap should be elevated with a blunt dissector. Using this "open-door" technique, the flap is retracted caudally without detaching from the atlantooccipital ligament and fixed temporarily on the nuchal ligament. Nevertheless, this suboccipital keyhole does not offer adequate exposure of the cervicomedullary junction (Fig. 5.0.18 A).

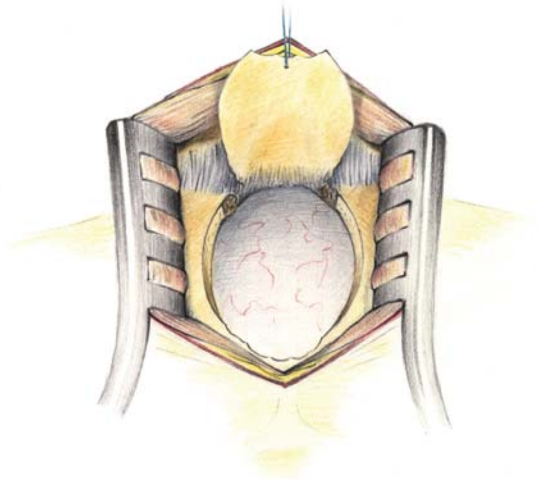


Fig. 5.0.18 A

Step 7 B

If visualization of the upper cervical spine is required, an extended suboccipital craniotomy must be performed. After removal of the bone flap, the superior border of the posterior arch of the atlas should also be additionally removed. This partial removal of the posterior arch without C1 laminectomy allows additional exposure of the craniocervical region, and after dural opening, open visualization of the cervicomedullary junction (Fig. 5.0.18 B).

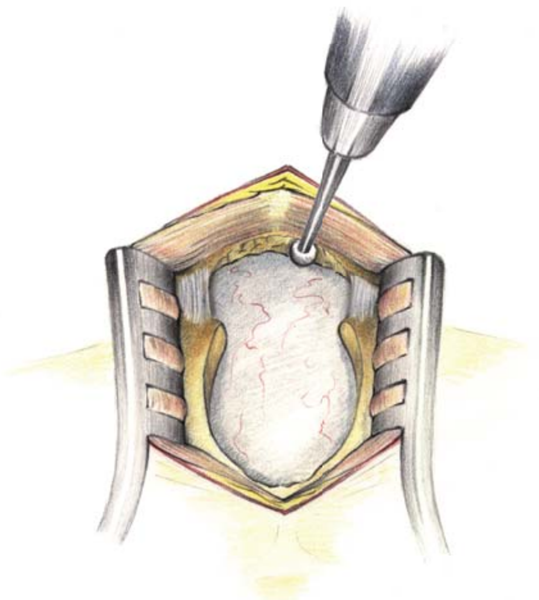


Fig. 5.0.18 B

Step 8

The dura is opened in a reverse Y-shaped fashion extending toward the foramen magnum and the free dural flaps are fixed with holding sutures. In young children, the dura may be full of venous channels and a prominent marginal sinus may be present in the region of the foramen magnum. This may bleed excessively upon dural opening and hemoclips or sutures should be used for hemostasis (Fig. 5.0.19).

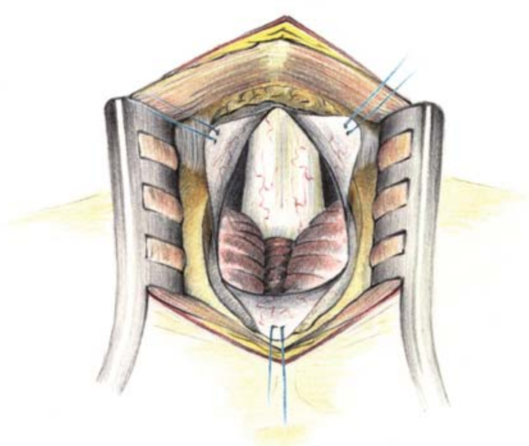


Fig. 5.0.19

4. Intradural dissection

Step 1

Dissection performed on a fresh human cadaver. The vessels are prepared with colored latex solution. After opening the dura mater, the intact arachnoid membranes of the great cerebellomedullary cistern can be seen. The first step is the sufficient drainage of CSF by opening the arachnoid sheet. This helps further relaxation of the brain by releasing CSF and will initiate dissection of the cerebellar tonsils, the vermian peg, and the floor of the fourth ventricle (Fig. 5.0.20).

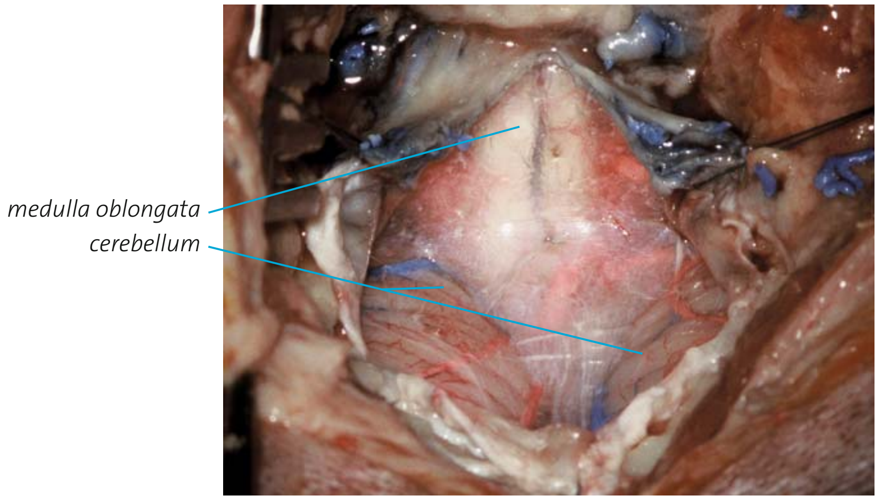


Fig. 5.0.20

Step 2

After opening and retraction of the arachnoid, the cervicomedullary junction is seen and, in part, the suboccipital surface of the cerebellum. Note the lobulus biventer and the cerebellar tonsils hiding the view into the fourth ventricle. The vertebral arteries can be observed on both sides of the medulla; the PICA disappears into the cerebellomedullary fissure (Fig. 5.0.21).

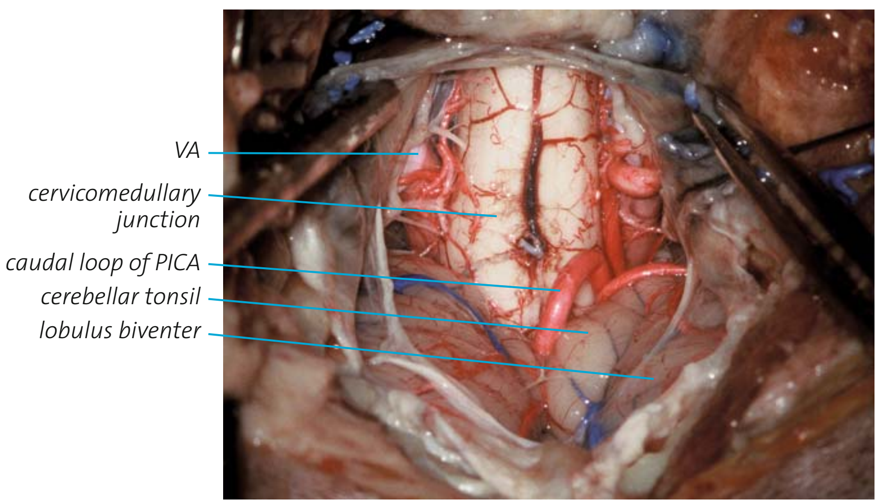


Fig. 5.0.21

Step 3

Dissecting more laterally, the entrance of the right VA into the intracranial space can be observed. Note the cervical root of the CN XI and the first denticulate ligament. Note the arachnoid membrane of the great cerebellomedullary cistern (Fig. 5.0.22).

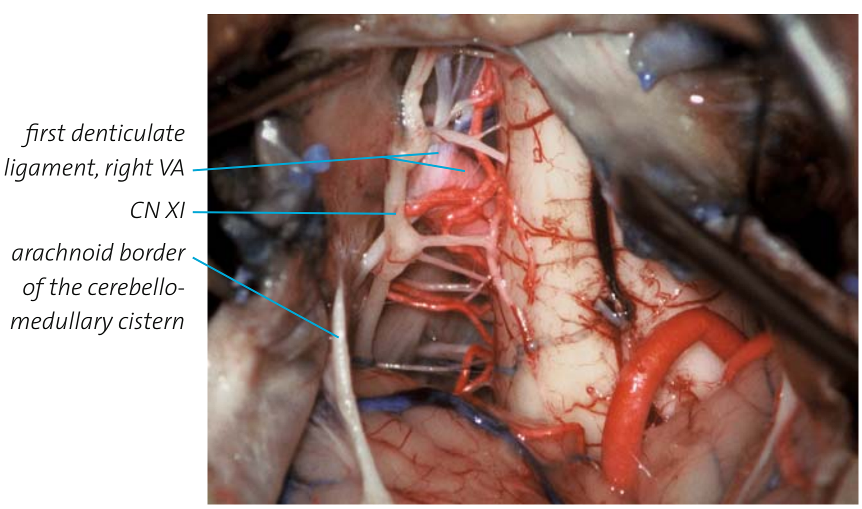


Fig. 5.0.22

Step 4

After careful retraction of the brain stem, the entrance of the CN XII into the hypoglossal canal can be seen. Note the right VA and the CN XI (Fig. 5.0.23).

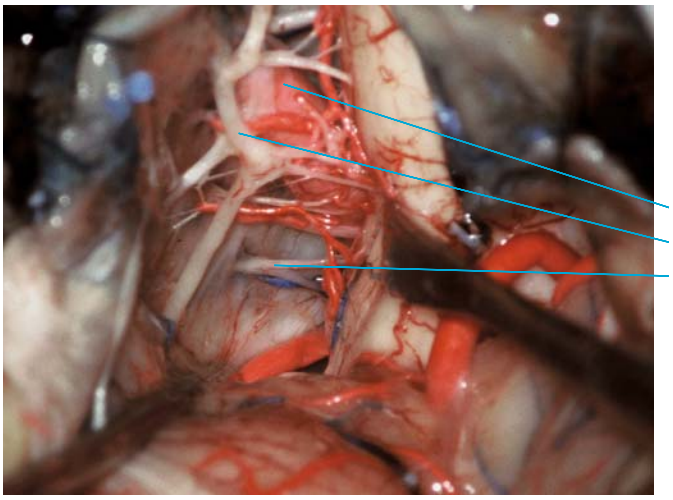


Fig. 5.0.23

Step 5

After mobilization of the cerebellum, the CN X and Bochdalek's choroid plexus of the fourth ventricle can be observed. Note the first loop of the PICA close to the caudal cranial nerves (Fig. 5.0.24).

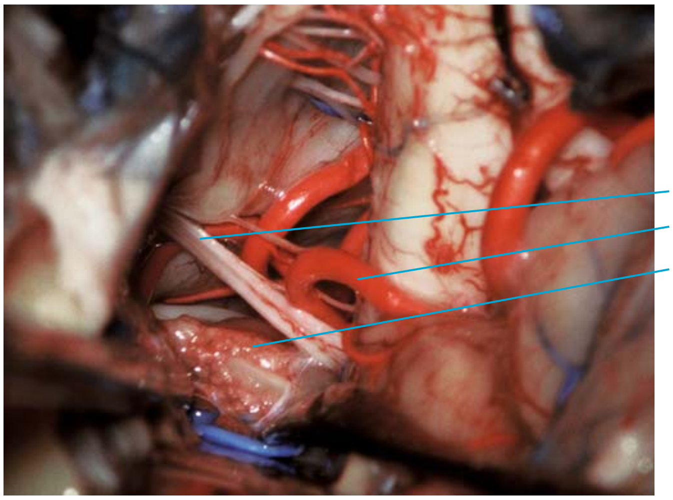


Fig. 5.0.24

Step 6

Focusing more medially, the right tonsil is retracted. Both posterior cerebellar arteries disappear into a triangle-formed chamber between the two tonsils, the so-called vallecula. Note the cerebellomedullary fissure, the narrow space between the tonsils and the medulla oblongata (Fig. 5.0.25).

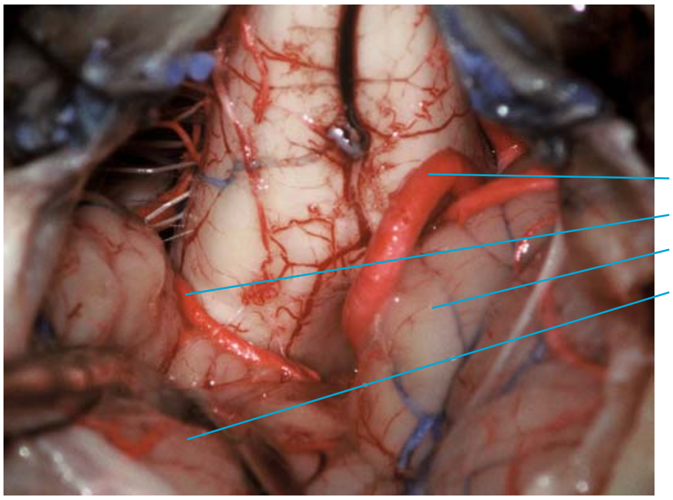


Fig. 5.0.25

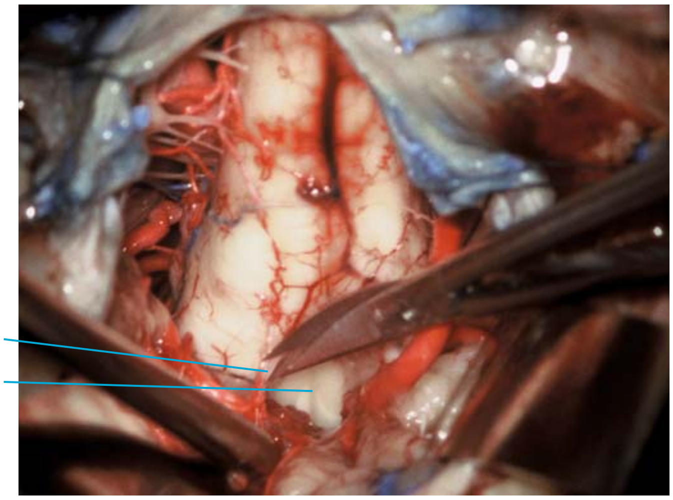


Fig. 5.0.26

Step 7

To expose the chamber of the fourth ventricle, the tonsils should be moved away from the medulla, taking care not to damage the posterior inferior cerebellar arteries. The tela choroidea is carefully dissected from the taenia of the medulla oblongata, enlarging the foramen of Magendie. Note the caudal part of the fourth ventricle (Fig. 5.0.26).

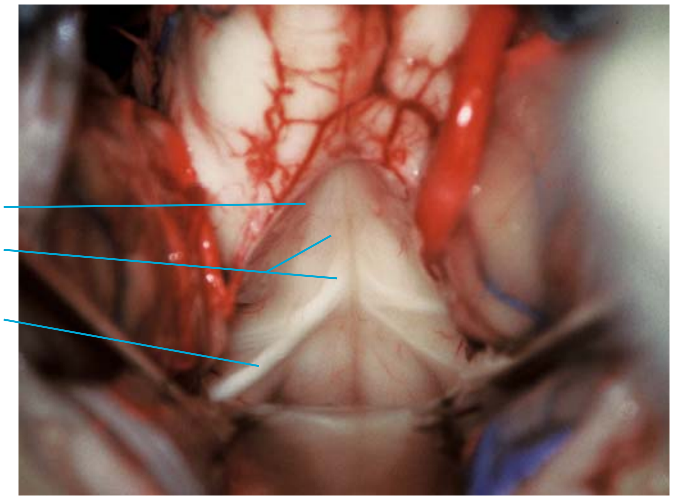


Fig. 5.0.27

Step 8

After opening the foramen of Magendie and dissection of the tela choroidea away from the taenia of the medulla oblongata, the inferior medullary velum and the vermis are gently retracted, providing a broad view of the fourth ventricle. The caudal part of the rhomboid fossa appears with the trigone of the hypoglossal and vagus nerve. The area postrema, a triangular field caudal to the trigone of the vagus nerve with strongly vascularized reddish glia-rich tissue, can also be well observed. Note the white tissue of the medullary striae (Fig. 5.0.27).

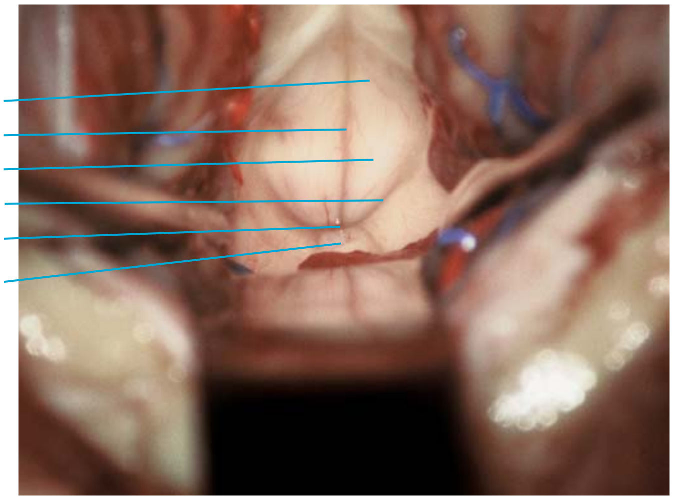


Fig. 5.0.28

Step 9

Using adequate head positioning and careful surgical dissection, exposure of the cranial part of the fourth ventricle is possible without incision and splitting of the vermis, thus avoiding severe postoperative ataxia. The facial colliculus appears cranial from the medullary striae according to the genu of the facial nerve. Note the median eminence between the median and limiting sulcus. Note the cerebral aqueduct and the superior medullary velum (Fig. 5.0.28)

Step 10
Dissecting more laterally within the ventricular chamber, the vestibular area and the lateral recess of the fourth ventricle can be observed. Note the medullary striae, facial colliculus and the limiting sulcus of the rhomboid fossa (Fig. 5.0.29)

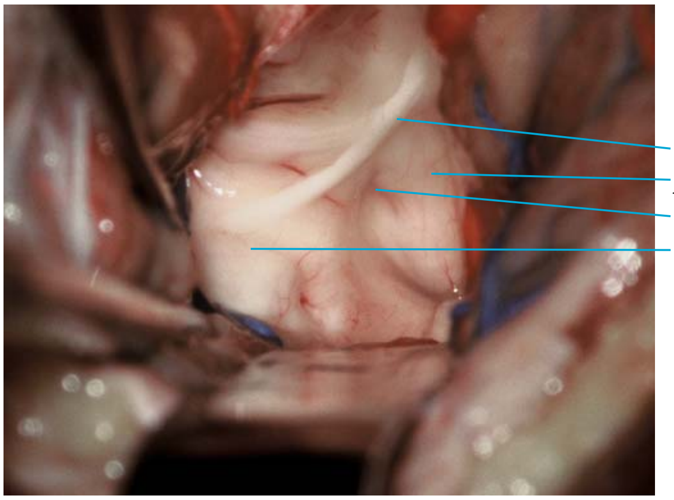


Fig. 5.0.29

Step 11
Observing again the craniocervical junction, the dural entrance of the left vertebral artery can be seen. Note the first denticulate ligament. The spinal root of the CN XI crosses the intracranial VA and the CN XII disappears into the hypoglossal canal (Fig. 5.0.30)

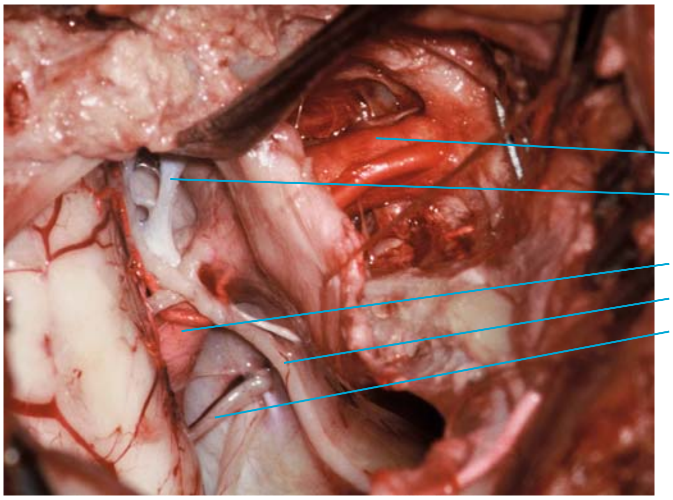


Fig. 5.0.30

Step 12
Dissection shows the intra- and extradural course of the VA, the blunt dissector points to the first cervical root after removal of the posterolateral dura of the craniocervical junction. Note the spinal part of the CN XI (Fig. 5.0.31)

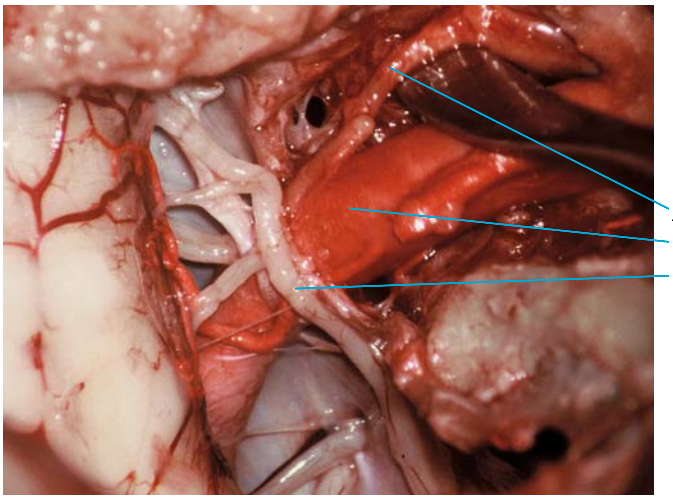


Fig. 5.0.31

5. Dura, bone and wound closure

Closure of midline posterior fossa exposures must be performed meticulously. After completion of the intracranial procedure, the intradural space is filled with Ringer solution at body temperature. The dural incision is closed with interrupted sutures. If shrinkage has developed in the dural plane, which is a frequent problem, a small piece of muscle can be sewn into the dural closure. In other cases, an artificial dural graft can be used. After watertight dural closure, a plate of gelfoam is placed extradurally. The bone should be reattached using titanium plates. After final verification of hemostasis, the muscles should be closed in anatomical layers. The subcutaneous layer is closed with interrupted sutures and the skin with running or interrupted sutures. Suction drainage is not required.

Potential errors and their consequences

- Poor preoperative planning with poor exposure of the target region and significant deterioration in efficiency of surgically excising the lesion. Planning is the most important part of surgery and the task of the surgeon!
- Inadequate positioning of the patient with insufficient exposure of the target.
- Loss of the midline, dissecting the deep suboccipital muscles. This can cause unwarranted bleeding, inadequate exposure of the bony surface and postoperative discomfort.
- Injury to the occipital sinus after burr hole trephination or injury to the marginal sinus after craniotomy with excessive venous bleeding.
- Inadequate removal of CSF at the first stage of the intracranial dissection with subsequent injury to the cerebellar surface.
- Need to split the inferior vermis after inadequate preoperative planning, poor patient positioning or inadequate craniotomy.
- Injury to sensitive neurovascular structures of the cervicomedullar region and cerebellomedullary fissure with postoperative neurological sequelae.
- Injury to the rhomboid fossa during tumor removal with subsequent severe cranial nerve disorders.
- Postoperative hydrocephalus due to incomplete tumor removal or intraventricular blood clot. In such cases, endoscopic third ventriculostomy should be performed with temporary implantation of a ventricular drain.

Fig. 5.0.32

Fig. 5.0.33

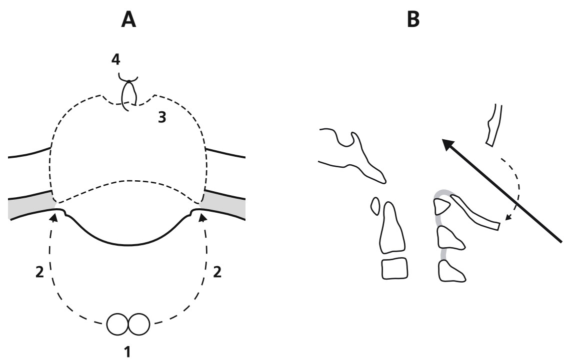


Fig. 5.0.34

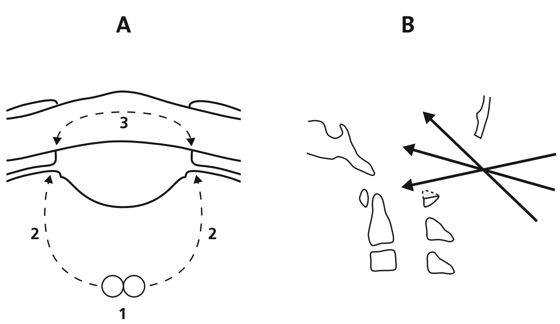
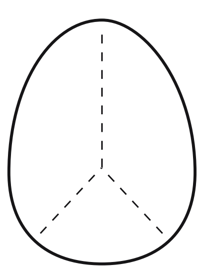


Fig. 5.0.35



- Inadequate dural closure with postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap.
- Inadequate hemostasis causing postoperative soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning of patients. The result is an excellent overview of the target area and an efficient working position during surgery.

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures and superficial neurovascular structures; 2. placement of craniotomy; 3. skin incision.

- Using a Concorde prone position, cerebellar retraction and splitting of the inferior vermis can be effectively avoided (Fig. 5.0.32).

- Stages of the suboccipital "open-door" keyhole craniotomy (Fig. 5.0.33 A, B): 1. two paramedian burr holes and removal of the internal occipital crest; 2. craniotomy using a high-speed craniotome; 3. elevation of the bone flap and 4. temporary fixation on the nuchal ligament

- Stages of craniotomy (Fig. 5.0.34 A, B): 1. two paramedian burr hole trephinations; 2.median suboccipital craniotomy; 3. due to partial removal of the posterior arch of the atlas without laminectomy the exploration of the cervico-medullary junction can be extended.

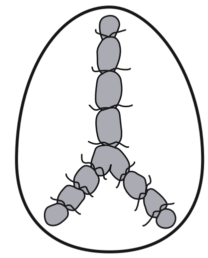
- The dura should be opened in a reverse "Y"-shaped fashion avoiding injury to the occipital sinus. In young patients and children, extensive sinusoid vessels around the foramen magnum may be present which should be occluded with hemoclips or sutures (Fig. 5.0.35).

- The first step of the intradural dissection should be the opening of the cerebellomedullar cistern and sufficient CSF drainage.

- After finishing the intracranial procedure, the dural opening should be closed watertight using interrupted or running sutures.

If tension has developed, which is not uncommon, a small piece of muscle can be sewn into the dural closure. In other cases an artificial dural graft should be used (Fig. 5.0.36).

Fig. 5.0.36



- After dural closure, the bone flap should be tightly fixed with a titanium plate.
- The deep suboccipital muscles should be meticulously closed in anatomical layers. This also helps to avoid postoperative CSF leakage.
- Suction drain should not be used to avoid postoperative CSF leak.

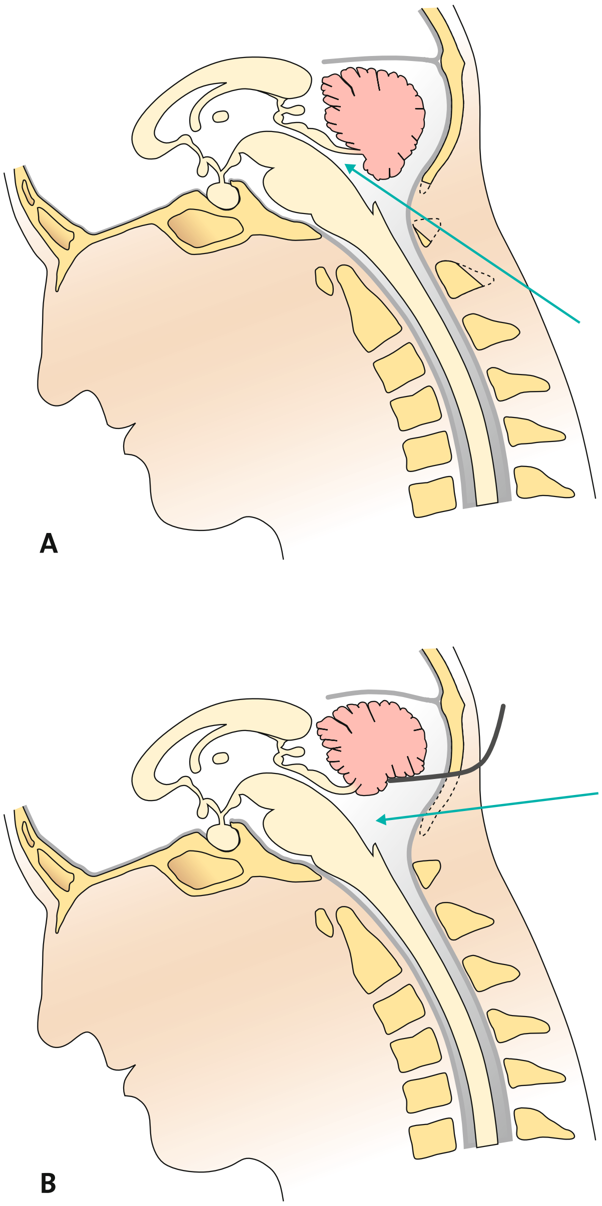


Fig. 5.1.1 *Caudal variation of the median suboccipital approach after partial removal of the posterior arch of C1 and the spinous process of C2 (A). Compared with the basic suboccipital exposure (B) the caudal variant avoids retraction of the cerebellum exposing the Sylvian aqueduct.*

5.1 Caudal variation of the median suboccipital approach

The median suboccipital infracerebellar approach allows visualization of the main part of the fourth ventricle. In some cases, however, the cranial part of the ventricular chamber can be approached only after excessive retraction or even partial sectioning of the inferior vermis, resulting in postoperative coordination disturbances and ataxia. To avoid destruction of sensitive neural tissue, exposure of the cranial fourth ventricle and the Sylvian aqueduct should follow the plane of the rhomboid fossa, placing the dural opening as caudally as possible.

The essence of the caudal variation of the median suboccipital approach is exposure of the upper part of the fourth ventricle through the foramen magnum from a caudal direction. After a craniocervical midline skin incision and soft tissue dissection, the posterior arch of the atlas and the spinous process of the axis are partially removed, revealing the posterior craniocervical region and foramen magnum. After a limited dural opening, the rhomboid fossa of the fourth ventricle including the Sylvian aqueduct can be observed (Fig.5.1.1).

Craniocervical junction	Fourth ventricle	Third ventricle
Posterior and posterolateral circumference of the foramen magnum Posterior arch of the atlas Spinous process of the axis Marginal sinus Cervicomedullary junction Posterior surface of the medulla oblongata Cerebellar tonsils Lower vermis Vallecula Inferior medullary velum Choroid plexus of the fourth ventricle Foramen of Magendie PICA	Choroid plexus of the fourth ventricle Rhomboid fossa Fastigium Superior medullary velum Cerebral aqueduct	Posterior chamber of the third ventricle

Table 5.1.1 *Anatomical structures reached by the caudal variation of the median suboccipital approach.*

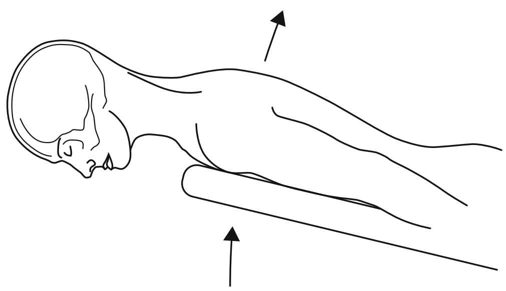


Fig. 5.1.2

Fig. 5.1.3

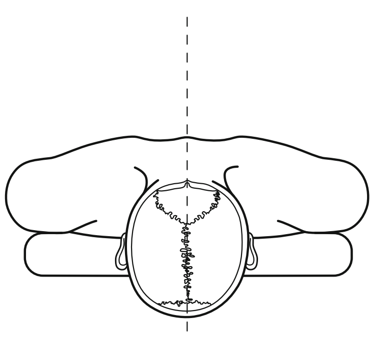


Fig. 5.1.4

Surgical technique

1. Patient positioning

Similar to the median suboccipital approach, the patient is brought into the prone position. Goal of the positioning is the maximal inclination of the head, allowing surgical dissection parallel to the plane of the rhomboid fossa.

Step 1

After fixing in the three-pin head holder, the body and the head are elevated ca. 20° to 30° on the operating table. This elevation is necessary to bring the head above the level of the thorax allowing optimal venous drainage (Fig. 5.1.2).

Step 2

In a second step, the head may be maximally anteroflected. This extreme Concorde position allows an efficient working direction according to the plane of the rhomboid fossa. Special attention should be given to avoid severe compression of the larynx with the ventilation tube and the main cervical vessels (Fig. 5.1.3).

Step 3

As the target of the approach is the mid-located fourth ventricle and aqueduct, rotation or lateroflexion of the head is not necessary (Fig. 5.1.4).

2. Anatomical landmarks and orientation

For preoperative orientation, the important anatomical landmarks of the posterolateral osseous skull and spine, e.g., the external occipital protuberance, foramen magnum, mastoid process, and the spinous processes of C2 to C4 are precisely determined (Fig. 5.1.5).

After exact orientation, the hair of the suboccipital area should be combed or shaved according to the suboccipital midline skin incision (Fig. 5.1.5). The skin is disinfected meticulously.

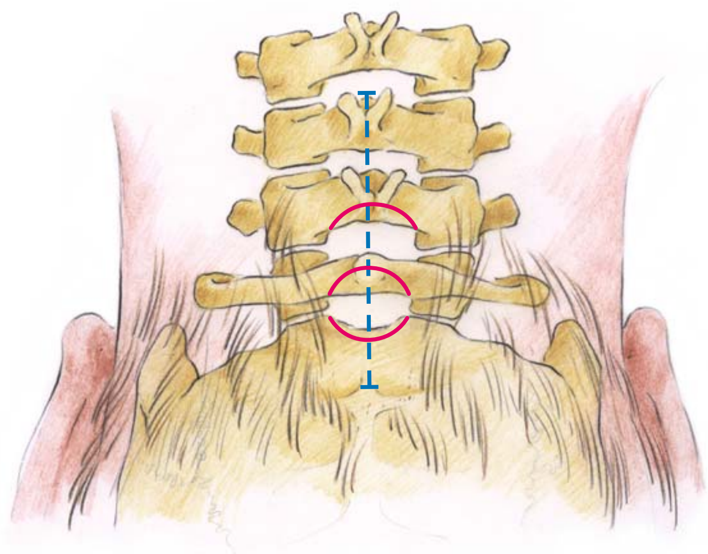


Fig. 5.1.5 *Definition of the surgical approach according to the anatomical landmarks of the posterior craniocervical region. The midline skin incision should extend from the easily palpable C3 spinous process up to the foramen magnum.*

3. Craniotomy and dural opening

Step 1

After patient positioning and anatomical orientation, the skin is prepared with alcohol solution. A straight midline incision is then made extending from the foramen magnum to the spinous process of C3. After retraction of the skin, the ligamentum nuchae is precisely defined according to the midline. Similar to the median suboccipital approach, soft tissue dissection and separation of the suboccipital muscles should be done strictly in the midline avoiding cutting into highly vascular muscular tissue (Fig. 5.1.6).

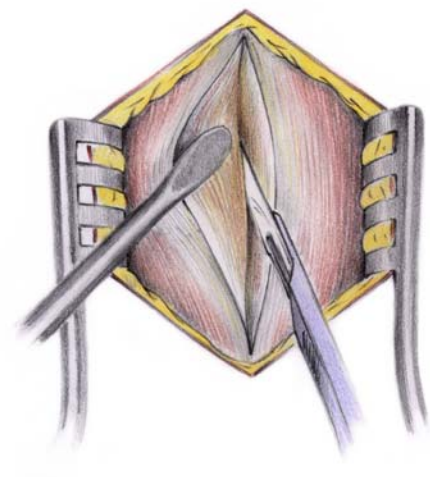


Fig. 5.1.6

Step 2

A self-retaining retractor is used to hold back the thick muscular layer, e.g., the trapezius, splenius and semispinalis capitis muscles, exposing the posterior craniocervical junction. The rectus capitis posterior major arises with a pointed tendon from the spinous process of the axis, the rectus capitis posterior minor on the posterior tubercle of the atlas. Both muscles are dissected from their insertion and retracted laterally, observing the foramen magnum, posterior arch of C1 and the spinous process of C2. Avoiding a complete laminectomy, the top of the spinous process of the axis is removed using a high-speed drill (Fig. 5.1.7).

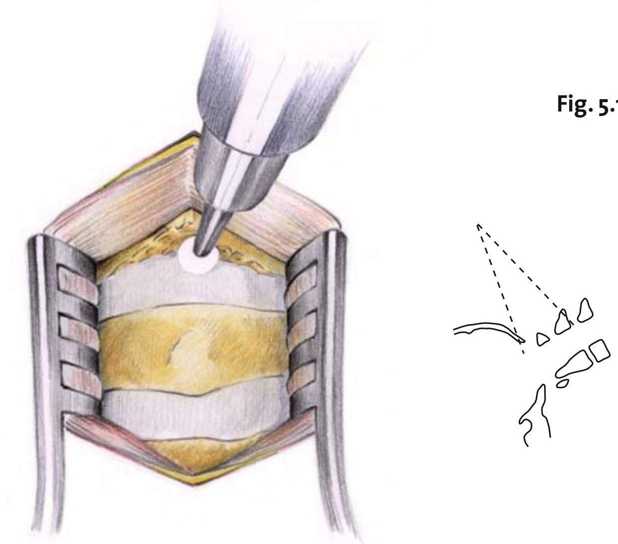


Fig. 5.1.7

Step 3

Thereafter, the superior part of the posterior arch of the atlas is removed enlarging the foramen magnum (Fig. 5.1.8).

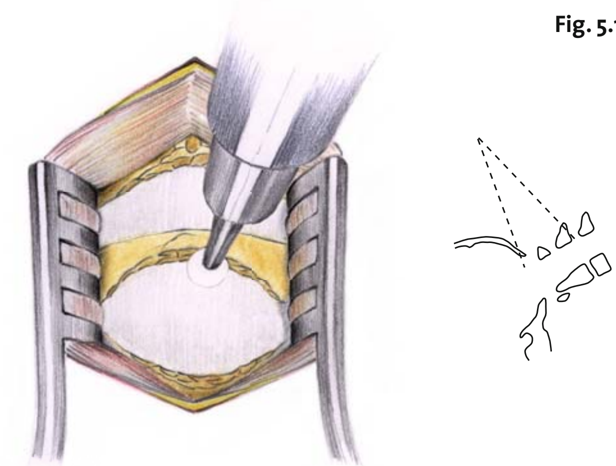


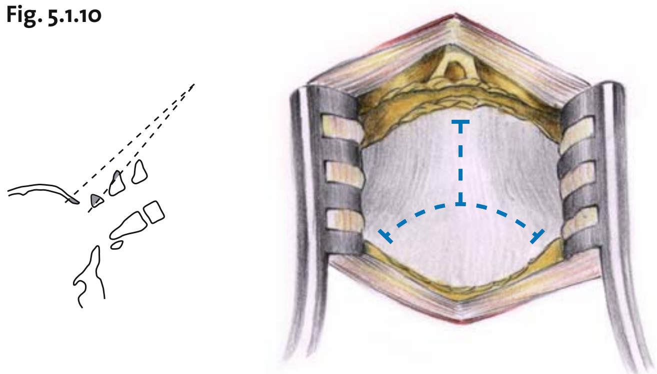
Fig. 5.1.8

Fig. 5.1.9

Step 4

Thereafter, the posterior margin of the foramen magnum is removed exposing the posterior atlanto-occipital membrane. Rapid and precise local hemostasis is necessary (Fig. 5.1.9).

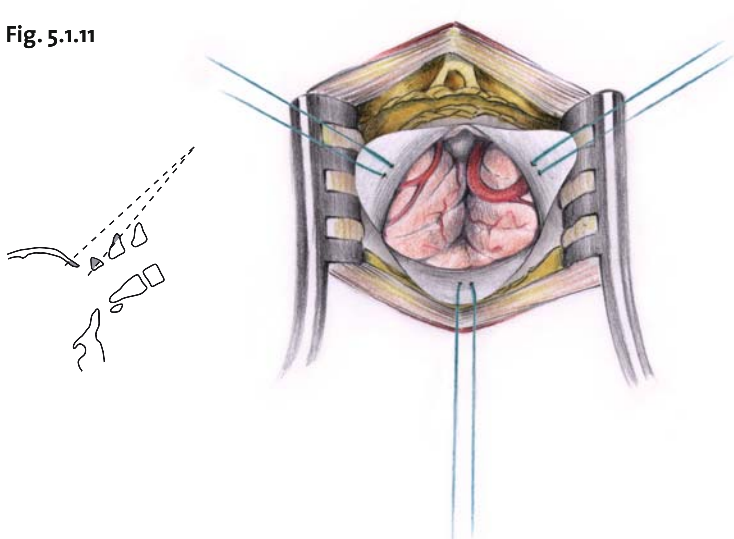
Fig. 5.1.10



Step 5

After bone removal, the direction of view is changed (note schematic picture on the left), observing the posterior margin of the foramen magnum from a caudal aspect. The posterior atlanto-occipital membrane is partially removed or incised according to the dural opening (Fig. 5.1.10).

Fig. 5.1.11



Step 6

The dura is opened in a straight or reverse Y-shaped fashion and the free dural flaps are retracted with holding sutures. When prominent sinusoid vessels are present, particularly in young children, hemoclips or sutures should be used for sufficient hemostasis (Fig. 5.1.11).

4. Intradural dissection

Step 1

Dissection performed on a fresh human cadaver. Note the red arterial and blue venous vessels. After opening the dura mater, the intact arachnoid membranes of the great cerebellomedullary cistern can be seen. Sufficient drainage of CSF by opening the arachnoid membranes offers immediate decompression of the posterior fossa. Note the cerebellar tonsils and the caudal loop of the PICA appearing through the arachnoidal layers (Fig. 5.1.12).

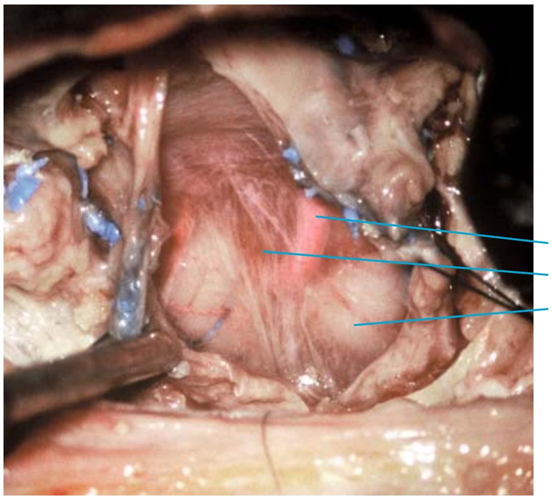


Fig. 5.1.12

Step 2

After opening the arachnoid of the cerebellomedullary cistern, the region of the vallecula is observed. Note the medial aspect of both tonsils according to the limited dural opening. The PICA disappears into the vallecula (Fig. 5.1.13).

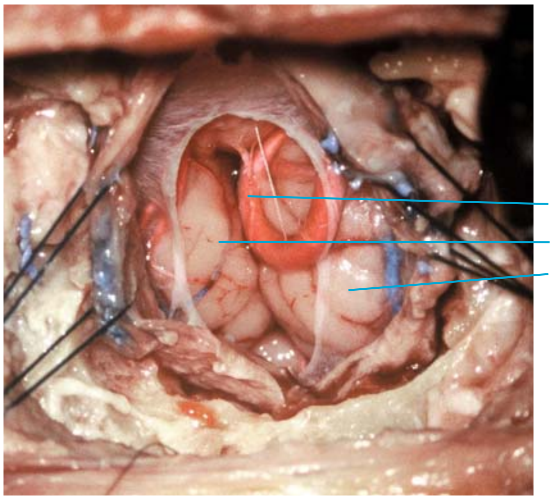


Fig. 5.1.13

Step 3

After opening the foramen of Magendie, the tonsils and the inferior vermis with the choroid plexus are gently retracted exposing the chamber of the fourth ventricle. The special surgical view allows visualization of the superior medullary velum. Note the rhomboid fossa and the cerebral aqueduct (Fig. 5.1.14).

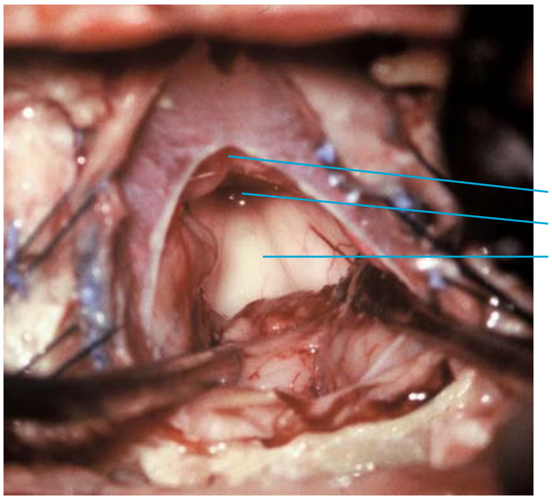


Fig. 5.1.14

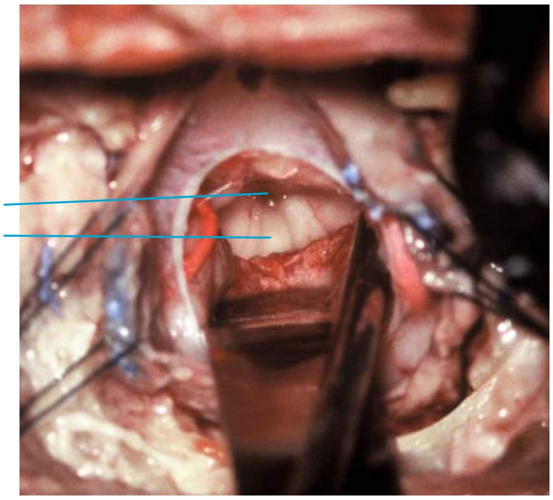


Fig. 5.1.15

Step 4

When observing the cranial part of the fourth ventricle, note the superior medullary velum and the caudal part of the cerebral aqueduct (Fig. 5.1.15).

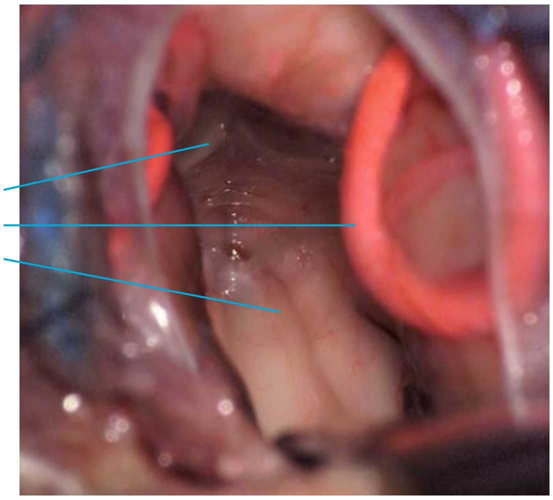


Fig. 5.1.16

Step 5

The entrance of the cerebral aqueduct visualized from the fourth ventricle. Note the rhomboid fossa with the medullary striae and the superior medullary velum (Fig. 5.1.16).

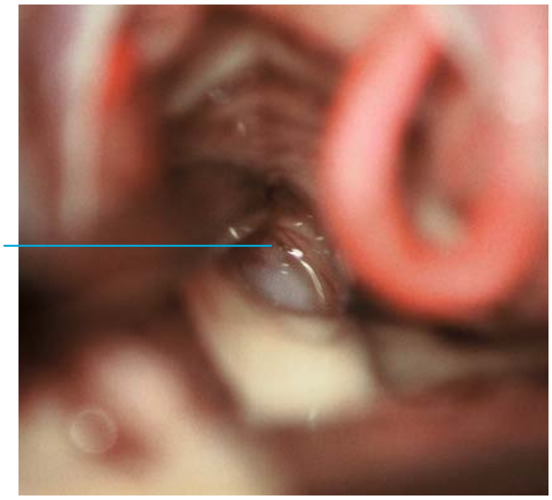


Fig. 5.1.17

Step 6

With a gentle dissection, the aqueduct is enlarged allowing a limited view into the posterior third ventricle (Fig. 5.1.17).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with Ringer solution at body temperature. The dural incision is closed meticulously with interrupted sutures. If tension has developed in the dural plane, a small piece of muscle can be sewn into the dural closure; in other cases, an artificial dural graft should be used. After watertight dural closure, a plate of gelfoam is placed extradurally and the suboccipital muscles are closed in anatomical layers. The subcutaneous layer is closed with interrupted sutures and the skin with running or interrupted sutures. Suction drainage is not required.

Potential errors and their consequences

- Inadequate preoperative planning with consequent inadequate exposure of the target region and significant deterioration in surgical exposure. Planning of the procedure must be performed by the surgeon!
- Dissection of the deep suboccipital muscles should be performed in the midline according to the nuchal ligament. Misguiding may cause extensive bleeding from the highly vascular tissue, inadequate exposure of the bony surface and postoperative neck pain with headache.
- Poor positioning of the patient may cause inadequate exposure of the fourth ventricle requiring retraction or even splitting of the inferior vermis. The surgeon should perform patient positioning himself.
- Injury to the dura during craniotomy. Dural reconstruction with dural material may be necessary.
- Inadequate removal of CSF from the cerebellomedullary cistern with subsequent injury to the cerebellar surface due to spatula pressure.
- Injury to sensitive neurovascular structures of the cervicomedullar region, cerebellomedullary fissure and fourth ventricle with postoperative neurological sequelae.
- Postoperative occlusive hydrocephalus due to closure of the cerebral aqueduct by tumor tissue or intraventricular blood clot. In this emergency situation, endoscopic third ventriculostomy should be performed immediately with temporary implantation of a ventricular drainage.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate hemostasis causing postoperative intracranial or extracranial soft tissue hematoma.

Tips and tricks

- Take time for preoperative planning and positioning of patients. The result is an excellent overview of the target area and an efficient working position during surgery.
- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures; 2. definition of the approach; 3. skin incision.
- Using a Concorde prone position, cerebellar retraction and splitting of the inferior vermis can be effectively avoided (Fig. 5.1.18 A). Note the extreme inclination of the head (Fig. 5.1.18 B).
- For optimal exposure of the fourth ventricle, the spinous process of C2 and posterior arch of C1 should be partially removed; thereafter the foramen magnum is enlarged approaching the dura mater of the posterior craniocervical junction (Fig. 5.1.19).
- The dura should be opened in a straight or reverse "Y"-shaped fashion avoiding injury to the occipital sinus. In young patients and children, extensive sinusoid vessels around the foramen magnum may be present which should be occluded with hemoclips or sutures (Fig. 5.1.20).
- The first step of the intradural dissection should be the opening of the cerebellomedullar cistern and sufficient CSF drainage.
- After finishing the intracranial procedure, the dural opening should be closed watertight using interrupted or running sutures. If tension has developed, which is not uncommon, a small piece of muscle can be sewn into the dural closure. In other cases, an artificial dural graft should be used (Fig. 5.1.21).
- The deep suboccipital muscles should be meticulously closed in anatomical layers without using a suction drain. This also helps to avoid postoperative CSF leakage.

Fig. 5.1.18 A

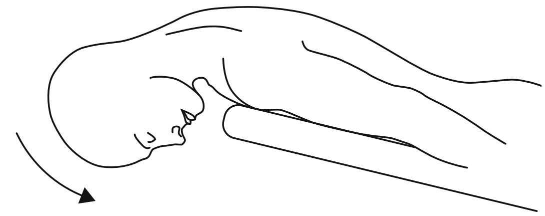


Fig. 5.1.18 B

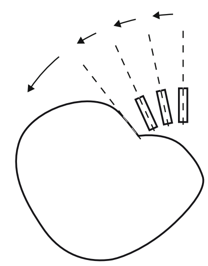


Fig. 5.1.19

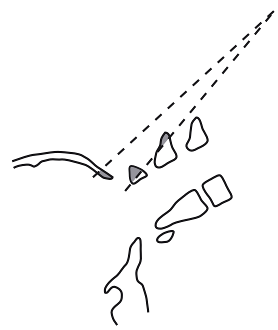


Fig. 5.1.20

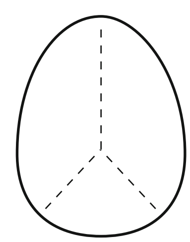
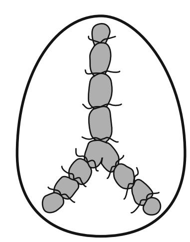


Fig. 5.1.21



6.0 Pineal approach

History of surgical approaches to the pineal region

Anatomically, the location of pineal tumors in the center of the intracranial space above the brain stem have presented a surgical challenge to safe exposure and removal.

The first attempts were palliative interventions in hopeless cases. In 1905, Harvey Cushing reported on a young patient with clinical evidence of a pineal tumor and performed bitemporal decompression [Cushing 1905]. The patient died some weeks later and suffered from a quadrigeminal glioma. The difficulty of these cases is emphasized by Cushing's contemporary statement *"personally I have never succeeded in exposing a pineal tumor sufficiently well to justify an attempt to remove it"*. Other operations were carried out by Arthur Pappenheim and Perceival Baily using occipital decompression with poor patient survival. Arne Torkildsen published a palliative operation in cases with inoperable occlusion of the Sylvian aqueduct [Pappenheim 1906, Baily 1911, 1933, Torkildsen 1933].

Direct exposure of space-occupying lesions of the pineal region was first reported by Ludovicus Pussep in 1910 approaching a pineal cyst via suboccipital transtentorial exposure (Fig. 6.0.1). After partial removal, the 10-year-old boy died on the third postoperative day [Pussep 1910].

In 1911 Fedor Krause, in his pioneering work "Surgery of the Brain and Spine", recommended to approach the pineal region via the supracerebellar infratentorial route [Krause 1911]. Two years later, Krause removed a large tumor in the region of the quadrigeminal plate from a young boy by this infratentorial route which he reported together with Hermann Oppenheim, who diagnosed the patient (Fig. 6.0.2). This was the publication of the first successful extirpation of a tumor from the pineal region and the patient was reported to have been well at least until the first World War. In 1926, Krause added two more patients who were operated on by the same approach; however, he could not remove the tumors [Krause 1913, 1926]. Julius Tandler and Egon Ranzi also described a similar infratentorial supracerebellar route, although without clinical experience (Fig. 6.0.3). On account of the narrow operative field, this approach was rarely used by other surgeons, publishing sporadic

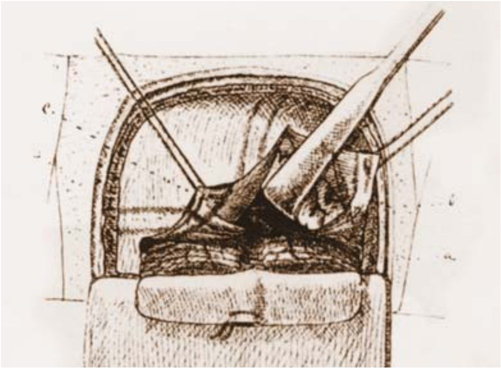


Fig. 6.0.1 *Median suboccipital craniectomy for a cystic tumor of the pineal region, published by Pussep in 1910. After division of the occipital and right transversal sinus, the tumor was approached via a transtentorial route. Pussep was able to achieve a partial tumor resection; however, the 10-year-old patient died on the 3rd postoperative day.*

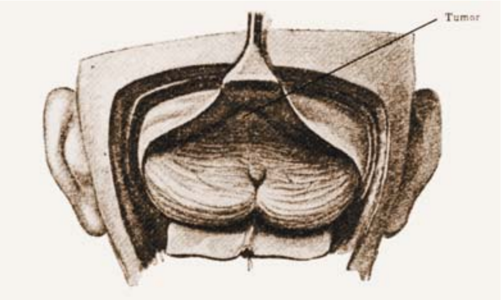


Fig. 6.0.2 *The first successful infratentorial supracerebellar approach for a pineal lesion, described by Krause in 1913. Krause removed a 4 cm tumor with the patient in a sitting position who survived without neurological deterioration.*

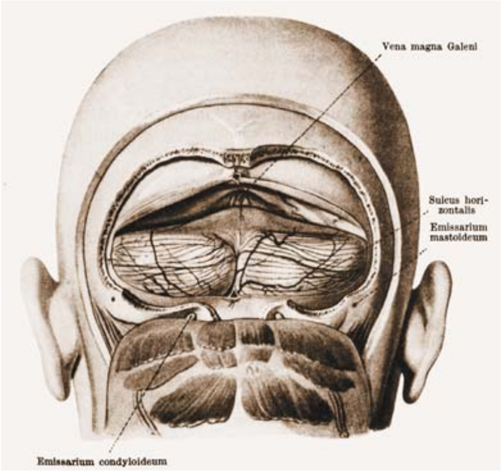


Fig. 6.0.3 *Tandler and Ranzi's suggestion using anatomical considerations to expose the pineal region. Note the infratentorial supracerebellar pathway to the great vein of Galen.*

case reports [Tandler & Ranzi 1920, Baggenstoss & Love 1939]. Bohuslav Zapletal in 1956 described his infratentorial supracerebellar approach which he developed in 1954. He reported on four cases: a malignant astrocytoma, a medulloblastoma of the upper vermis, an epidermoid, and a pineal tumor, the last being successfully removed [Zapletal 1956].

The first interhemispheric transcallosal approach to the pineal region was originally described by Walter E. Dandy in 1915 using a posterior exposure in an animal model (Fig. 7.0.1). In 1921 he published the first clinical experiences [Dandy 1915, 1921]. Otfrid Foerster published his experience with the posterior interhemispheric exposure of the quadrigeminal region in three patients (Fig. 6.0.5). He was the second surgeon to successfully remove a pineal tumor [Foerster 1928]. When Dandy reported ten pineal lesions approached via a right parietal interhemispheric transcallosal exposure, this became the most favoured route for a long period (Figs. 6.0.6, 7.0.2) [Dandy 1921].

Fig. 6.0.4 *Zapletal's infratentorial supracerebellar approach to the pineal region, published in 1956 (A). Schematic drawing in the sagittal section demonstrates the spontaneous opening of the supracerebellar route achieved by a gravity-related sinking of the cerebellum (B).*

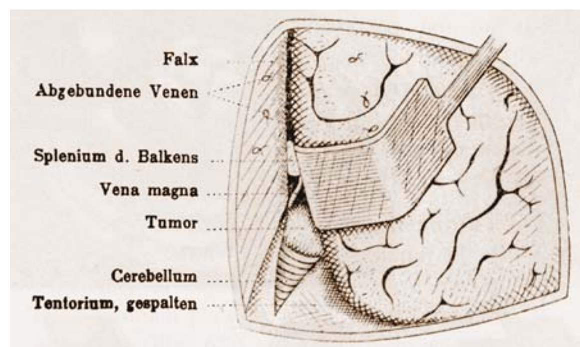


Fig. 6.0.5 *Foerster's interhemispheric approach to the pineal region demonstrated in a schematic picture from 1928. Note the scarified bridging veins of the occipital lobe and transtentorial exposure of the tumor.*

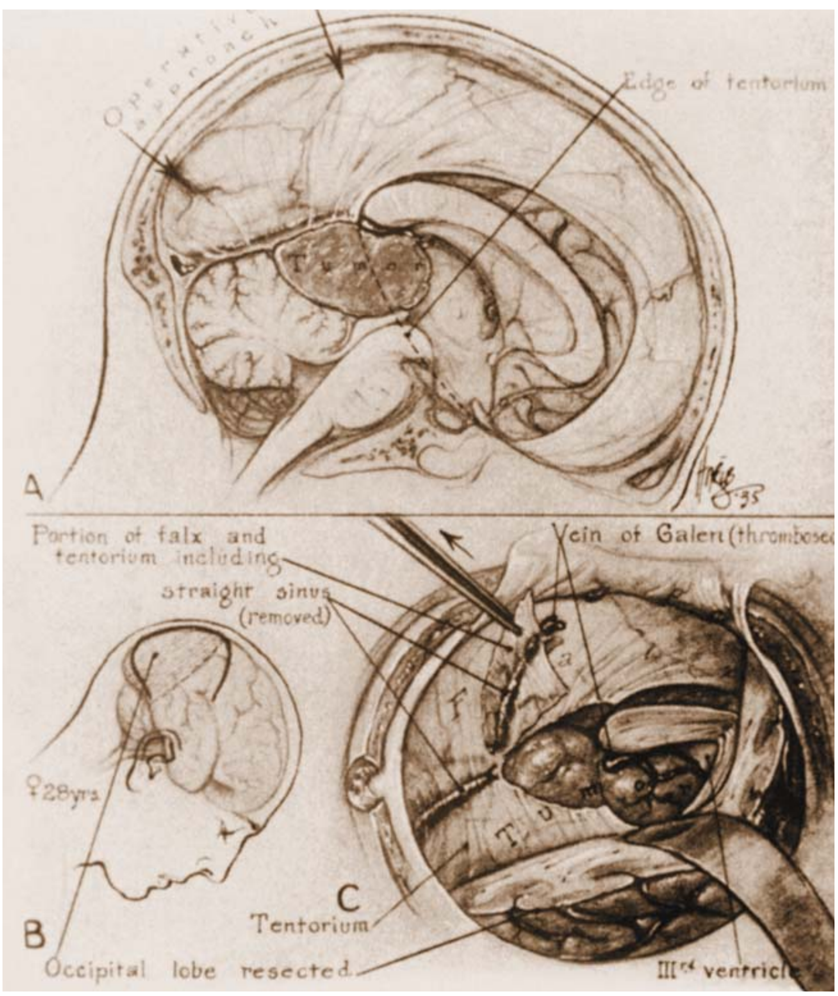


Fig. 6.0.6 *Drawings illustrating the method of producing more adequate exposure of an extended tumor of the pineal region by resecting the occipital lobe published by Dandy in 1936. When necessary, Dandy resected the lower part of the falx, the tentorium, the vein of Galen and the straight sinus (C). Note the relationship of the trajectory of the operative approach (A) to the skin incision (B).*

Fig. 6.0.7 *The transcortical-transventricular approach to pineal tumors described by* van Wagenen *in 1931. This exposure was used only in the case of hydrocephalic dilatation of the lateral ventricles.*

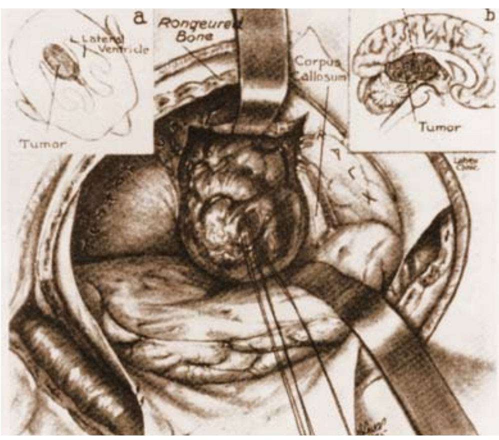


Fig. 6.0.8 *Exposure of an extended pineal tumor by* Horrax *in 1937, using resection of the occipital lobe. The tumor could be successfully removed after transsection of the falx, tentorium and splenium of the corpus callosum.*

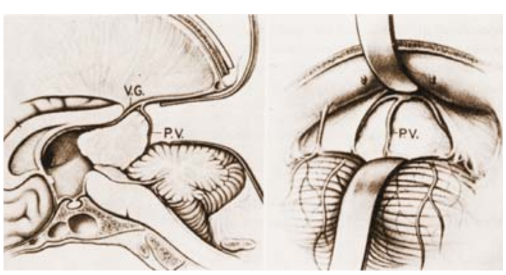


Fig. 6.0.9 *Microsurgical exploration of a large tumor through the infratentorial supracerebellar route published by* Stein *in 1971.*

A more invasive approach was developed by William van Wagenen in 1931 who exposed the pineal region via a transcortical transventricular route (Fig. 6.0.7). Furthermore, in order to optimize visualization of large pineal tumors, Gilbert Horrax used resection of the entire occipital lobe (Fig. 6.0.8) [van Wagenen 1931, Horrax 1937].

These large, traumatic exposures were necessary to bring enough light into the deep-seated pineal area. Accordingly, the crude operative techniques led to disappointing postoperative results. In 1953, Robert W. Rand reported a mortality rate of 70% in their series using macrosurgcial techniques. Hans Ringertz published a 58.8% mortality rate among 51 patients of the Olivecrona clinic [Rand & Lemmen 1953, Ringertz 1954].

In the early 1970s, with introduction of microscopic techniques in neurosurgery, special attention was given again to this vulnerable region. As Benett Stein in 1971 described Fedor Krause's infratentorial supracerebellar approach using microsurgical techniques, a new era started for operative exposure of the pineal region (Figs. 6.0.9, 6.0.10) [Stein 1971, Pendl 1985]. However, in his pioneering description, Krause already realized the essence of the infratentorial supracerebellar exposure: the anatomical structures of the pineal region are free for surgical dissection and the corridor between the tentorium and the cerebellum does not violate any sensitive intracranial structures.

In the following, the importance of this anatomical fact is discussed in detail.

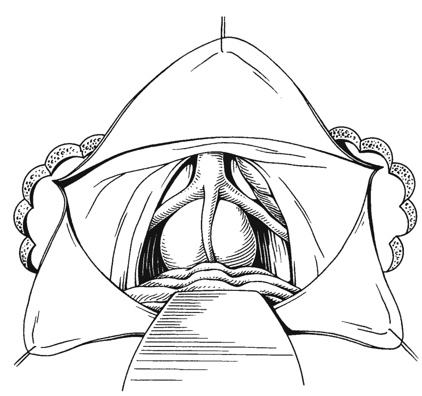


Fig. 6.0.10 Pendl*'s microsurgical access to pineal tumors demonstrated in his comprehensive textbook "Pineal and Midbrain Lesions" published in 1985.*

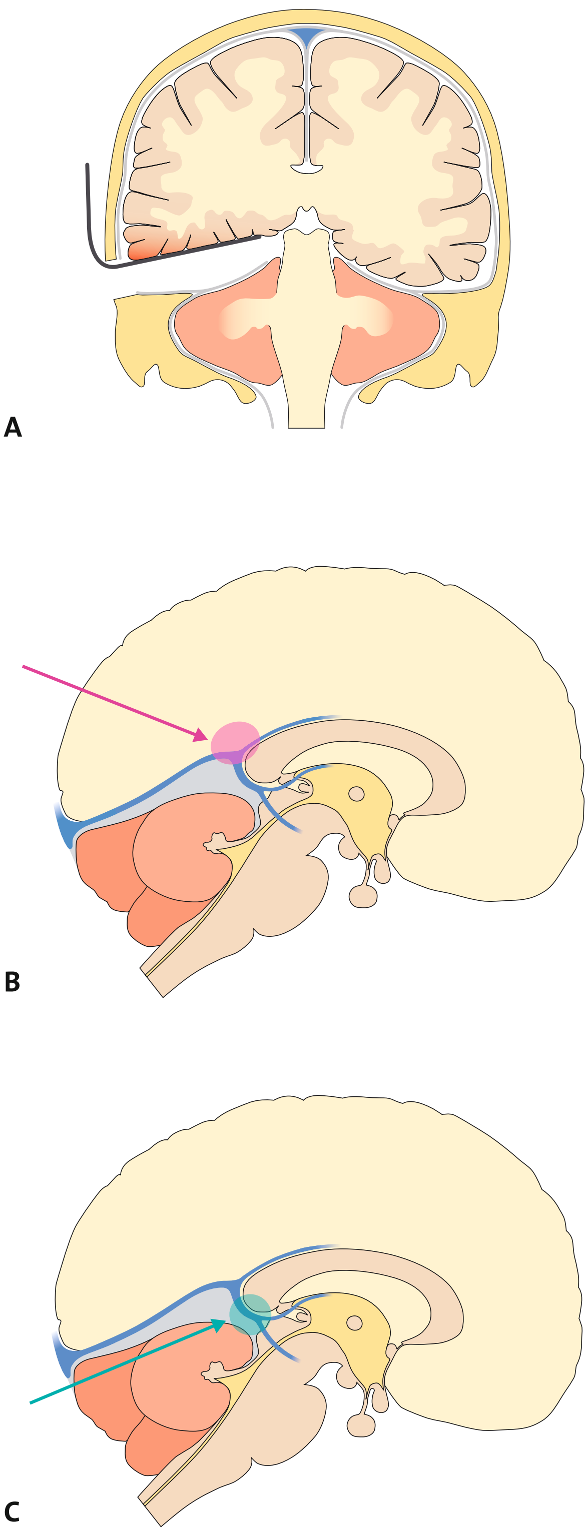
General anatomical construction of the supracerebellar corridor and the pineal region

Lesions within the pineal region can be best exposed via the posterior subtemporal, posterior interhemispheric supratentorial or supracerebellar infratentorial approaches. The posterior subtemporal (chapter 3.1) and posterior interhemispheric approaches (chapter 7.2) should be preferred for lesions centered at the tentorial edge, especially if they are situated above the great cerebral vein of Galen and have a lateral extension (Fig. 6.0.11 A,B). However, most tumors are located primarily beneath the deep venous system. In these cases, the infratentorial exposure reduces the risk of venous injury. In this way, the infratentorial supracerebellar approach is best suited to lesions near to the midline situated at the level or caudally from the vein of Galen (Fig. 6.0.11 C).

The supracerebellar corridor is located below the dural tent of the tentorium offering a free surgical route to the pineal region from the posterior direction. At the level of the tentorial hiatus, this corridor is closed by a milky, triangular arachnoid plate. The pineal region can be entered only after dissecting this tough membrane in a lateral to medial direction, preserving the superior cerebellar vein. The triangular view into the pineal region is partially occupied by the great vein of Galen and the splenium of the corpus callosum; however, with gentle mobilization of the upper vermis, the subarachnoid space of the quadrigeminal cistern can be visualized. The floor of the quadrigeminal cistern is formed by the upper surface of the mesencephalon and the virtual roof corresponds to the lower surface of the splenium corporis callosi, crura of the fornices, hippocampal commissure and the vein of Galen. The basal vein of Rosenthal and the CN IV disappear laterally into the ambient cistern. In an anterior direction, the pineal body, habenular and posterior commissures and the entrance into the velum interpositum can be approached.

The optimal placement of the craniotomy depends on the precise location of the lesion. Apically situated lesions near to the splenium of the corpus callosum should be approached via a basally placed craniotomy. On the contrary, lesions of the quadrigeminal plate and cerebellomesencephalic fissure are best approached from a more apical direction (Fig. 6.0.12).

Although the infratentorial approach is optimal for median situated target points, lesions located more laterally can be also exposed.

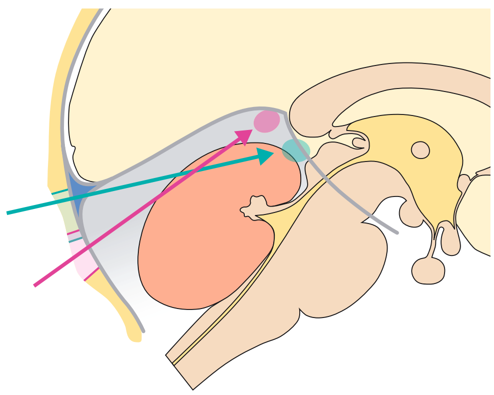


A

B

C

Fig. 6.0.11 *The posterior subtemporal approach offers adequate exposure of the posterior tentorial hiatus (A). Pineal lesions situated above the great cerebral vein of Galen are best reached through the posterior interhemispheric approach (B). The infratentorial supracerebellar approach can be recommended for lesions beneath the deep venous system located near to the midline (C).*



In cases of paramedian located lesions, we prefer a paramedially placed craniotomy and contralateral exposure of the target area according to the concept of keyhole approaches (Fig. 6.0.13).

Fig. 6.0.12 *The optimal placement of the craniotomy depends on the exact location of the lesion. Apically situated lesions near to the splenium of the corpus callosum should be approached via a basally placed craniotomy (red arrow). On the contrary, lesions of the quadrigeminal plate and cerebellomesencephalic fissure are best approached from a more apical direction, creating the craniotomy near to the confluence of sinuses (green arrow).*

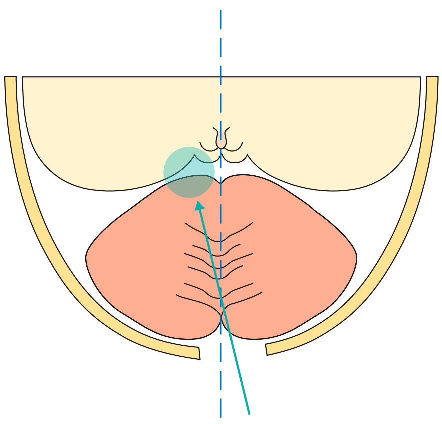


Fig. 6.0.13 *Although the infratentorial approach is optimal for median situated target points, lesions located more laterally can also be exposed. In cases of paramedian located lesions, we recommend a paramedially placed craniotomy and contralateral exposure of the target area.*

Supracerebellar corridor	**Pineal region and third ventricle**
Confluence of sinuses Inferior surface of the tentorium Straight sinus Upper vermis Tentorial cerebellar surface Central cerebellar vein Great cerebral vein of Galen	Splenium of the corpus callosum Pineal gland Quadrigeminal plate Posterior commissure Pulvinar thalami Crus fornicis Hippocampal commissure, velum interpositum Chamber of the third ventricle Anterior commissure Collumna fornices, triangular recess N IV Distal vessels of the PCA and SCA Great cerebral vein of Galen, central cerebellar vein Basal vein of Rosenthal, internal cerebral vein

Table 6.0.1 *Anatomical structures exposed through the supracerebellar intratentorial approach.*

Surgical technique

1. Patient positioning

Optimal patient positioning for infratentorial supracerebellar approaches is controversial. In the majority of neurosurgical departments, the sitting position is preferred for infratentorial exposure of the pineal region. The main advantage is that the sitting position allows gravity to work in the surgeons favor by reducing pooling of blood in the operating field and by allowing minimal cerebellar retraction during surgery. Advantages of the prone position are the simplicity of the technique both for surgical as for anesthesiological personnel and comfort for the patient. Compared with the difficult sitting position, there is no danger of air embolism, cardiopulmonary instability, severe pneumocephalus or ventricular collapse. The perpendicular direction of surgical dissection allows an efficient working position and excellent overview of the operating field.

Step 1

At first, the body and the head are elevated ca. 20° to 30° by moving the operating table. This elevation is necessary to bring the head above the level of the thorax for optimal venous drainage, facilitating the often difficult dissection of the tumor from the deep venous system (Fig. 6.0.14).

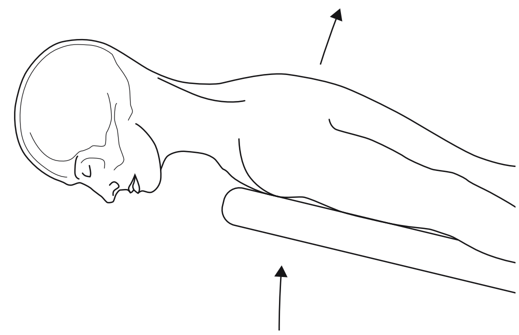


Fig. 6.0.14

Step 2

In a second step the head may be anteroflected about 45° in order to bring the tentorium in a perpendicular plane. This maximal flexion of the neck with concomitant reverse Trendelenburg positioning of the body, the so-called Concorde position, provides an efficient working position for the surgeon dissecting toward the inferior tentorial surface. However, special attention should be given not to compress the ventilation tube and the larynx. Excessive anteroflection may also cause venous congestion due to compression of the jugular veins making surgical dissection more difficult within the pineal region (Fig. 6.0.15).

Fig. 6.0.15

Step 3

For lesions located in the midline, rotation of the head is not necessary. However, mediolaterally situated lesions require a slight rotation of 5°– 15°, according to the accurate pathoanatomical situation. In this case we prefer a paramedian craniotomy and contralateral exposure of the target area as discussed above (Fig. 6.0.16).

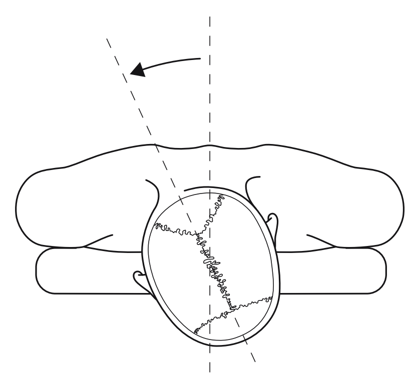


Fig. 6.0.16

2. Anatomical landmarks and orientation

For preoperative orientation, the important anatomical landmarks of the posterolateral osseous skull such as the foramen magnum, mastoid process, lambdoid suture, highest nuchal line and the external occipital protuberance are precisely determined. Special attention should be given to the course of the transverse sinus as definition of the posterior fossa level and to the accurate determination of the torcular region as keys to the exact craniotomy (Fig. 6.0.17). However, despite careful orientation, variations in the sinusoid anatomy of the posterior fossa can result in surprising difficulties during the first steps of the operation. Therefore, preoperative evaluation with high-resolution CT and MR imaging and definition of the individual anatomical situation are essential before surgery.

After orientation, the borders of the craniotomy are marked with a sterile pen. Usually, the craniotomy is placed median or slightly paramedian with a diameter of 2 to 3 cm (Fig.6.0.17).

After defining the craniotomy, the hair is shaved according to a midline skin incision of about 5 cm in length and disinfected carefully.

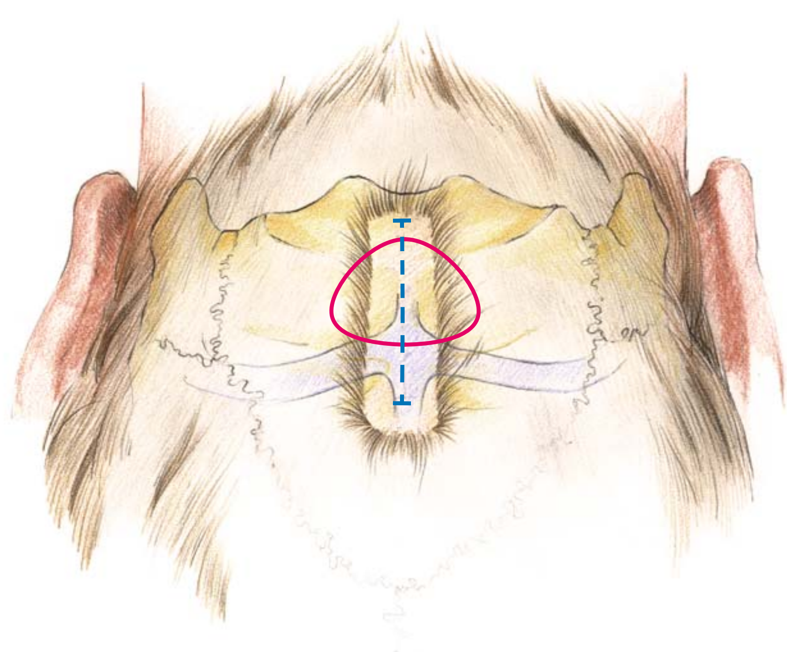
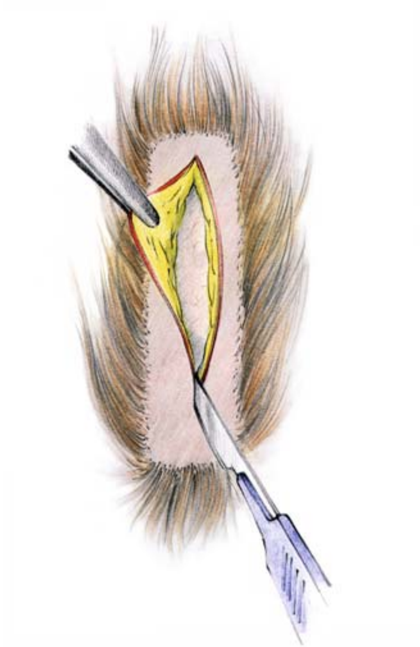


Fig. 6.0.17 *Definition of the craniotomy according to the anatomical landmarks of the occipital region. The skin incision should be performed according to the midline after minimal or even without shaving the hair. Special attention must be given to the course of the transverse sinus and location of the confluens sinuum.*

Fig. 6.0.18

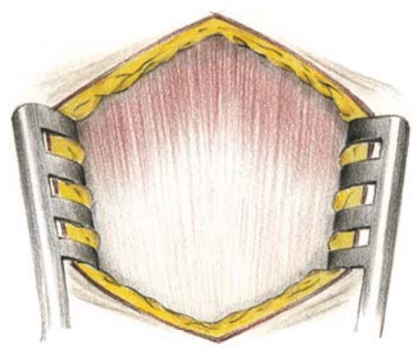


3. Craniotomy

Step 1

After patient positioning, anatomical orientation and minimal or even absent shaving of the hair, the skin is prepared with alcohol solution. To begin the suboccipital exposure, a straight midline incision is made over the torcular region (Fig. 6.0.18).

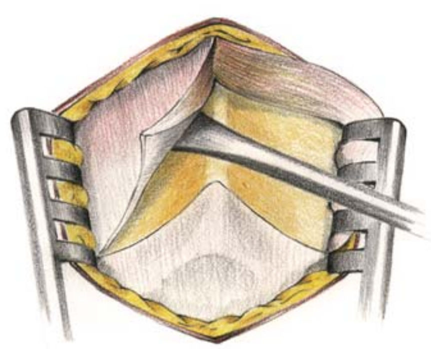
Fig. 6.0.19



Step 2

The skinflaps are retracted strongly. The level of the foramen magnum itself does not need to be exposed (Fig. 6.0.19).

Fig. 6.0.20

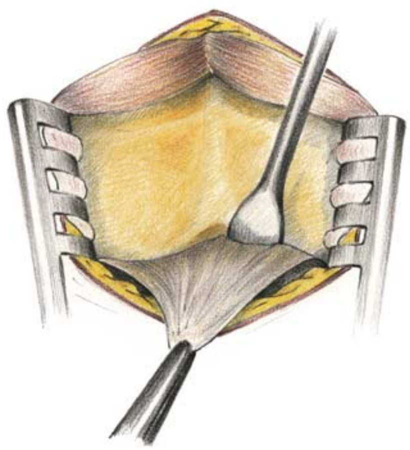


Step 3

After retraction of the subcutaneous layer, the nuchal ligament is defined and divided related strictly to the midline, separating the suboccipital muscles. The fascia of the semispinalis capitis muscles and the periosteal sheet at the external occipital protuberance are incised in a reverse Y-shaped fashion. The insertion of the semispinalis muscle is then stripped from the periosteal covering of the external protuberance (Fig. 6.0.20).

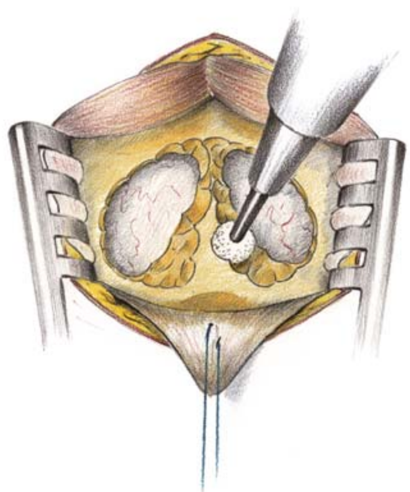
Step 4
The leaflet covering the external protuberance is mobilized with an elevator and reflected with strong sutures. The semispinalis muscles are retracted bilaterally with a wound retractor (Fig. 6.0.21).

Fig. 6.0.21



Step 5
After bony exposure, the occipital bone is partially removed according to the external protuberance with a high-speed drill. We prefer an osteoclastic craniotomy and use bone cement to repair the bony defect after dural closure. In our opinion, a hazardous osteoplastic procedure near to the prominent sinusoid vessels provides no advantage compared to a careful craniectomy (Fig. 6.0.22).

Fig. 6.0.22



Step 6
The internal occipital protuberance is then removed with fine punches, observing the edge of the torcular herophili. The internal occipital crest is also removed according to midline, exposing the occipital sinus. Special care should be taken to avoid injury to the occipital and transversal sinuses (Fig. 6.0.23).

Fig. 6.0.23

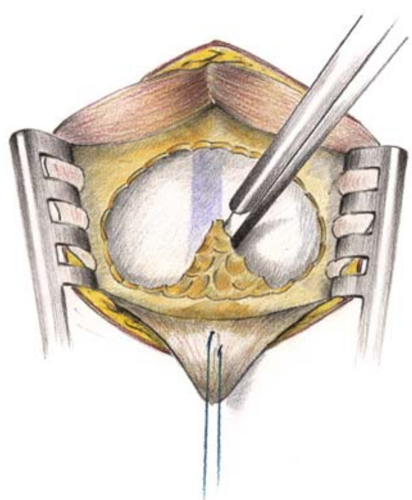
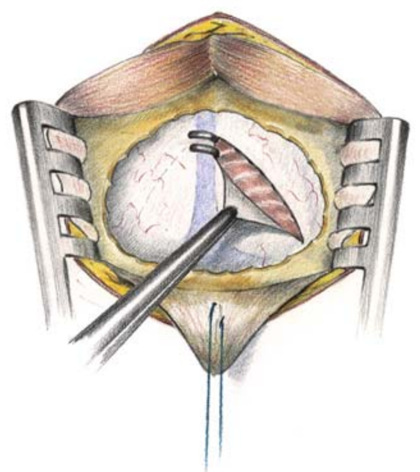


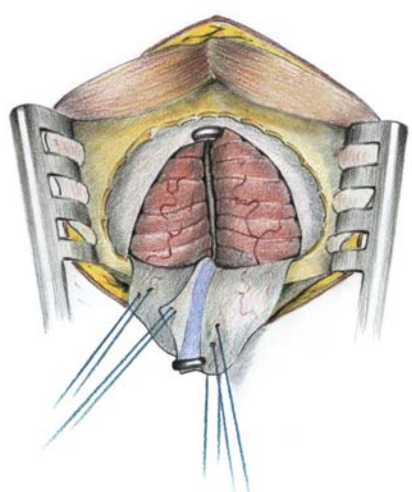
Fig. 6.0.24



Step 7

The dura should be opened in a semilunar fashion with its base toward the confluens sinuum, closing the occipital sinus with hemoclips (Fig. 6.0.24).

Fig. 6.0.25



Step 8

The cerebellar falx is divided and the dural flap elevated with holding sutures. Although major elevation of the dura is necessary to open the corridor below the tentorium, excessive retraction can block the sinus and lead to increased venous pressure which should be avoided (Fig. 6.0.25).

4. Intradural dissection

Step 1

Fresh human cadaver. The arteries are prepared with red colored solution, and the veins with blue latex. After opening the dura mater, both cerebellar hemispheres can be observed. Note the hemoclips closing the occipital sinus and division of the cerebellar falx. The first step of the intracranial procedure is, as usual, the sufficient drainage of CSF. After removal of CSF, the infratentorial supracerebellar route can be opened without significant retractor pressure (Fig. 6.0.26).

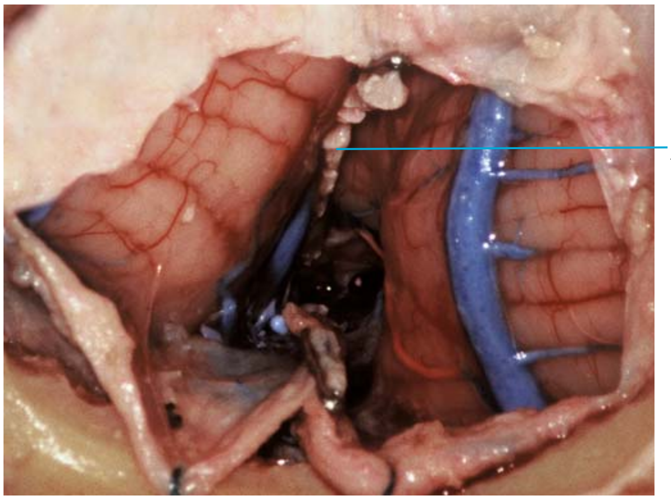


Fig. 6.0.26

Step 2

The upper vermis of the cerebellum is gently retracted exposing the supracerebellar infratentorial route. Once the retractor is in place, the thickened milky arachnoid membrane can be seen obscuring the view into the pineal region. Note the edge of the tentorial incisura and the dura according to the straight sinus (Fig. 6.0.27).

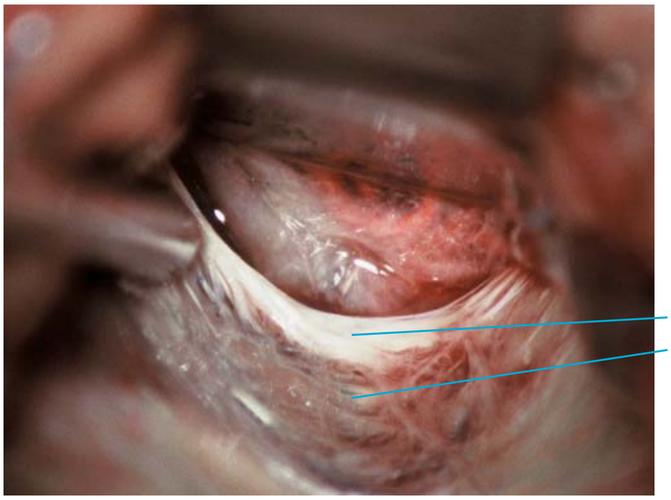


Fig. 6.0.27

Step 3

The membranous plate is opened in a lateral to medial direction with fine microscissors. The great cerebral vein of Galen appears in the background leading into the straight sinus (Fig. 6.0.28).

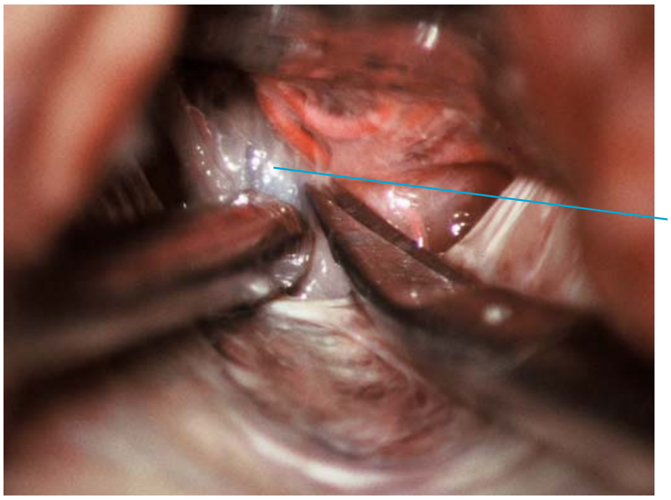


Fig. 6.0.28

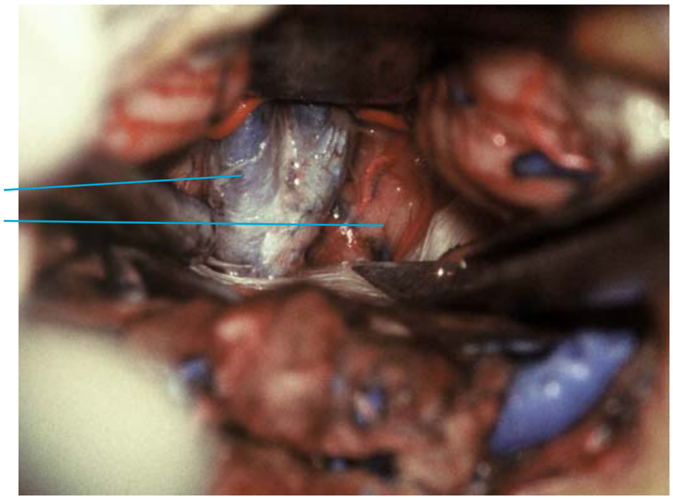


Fig. 6.0.29

Step 4

After complete opening of the arachnoid membrane, the great cerebral vein of Galen can be fully exposed. In this case, the occipital lobe is herniated through the tentorial incisura into the posterior fossa obscuring the exposure into the pineal region (Fig. 6.0.29).

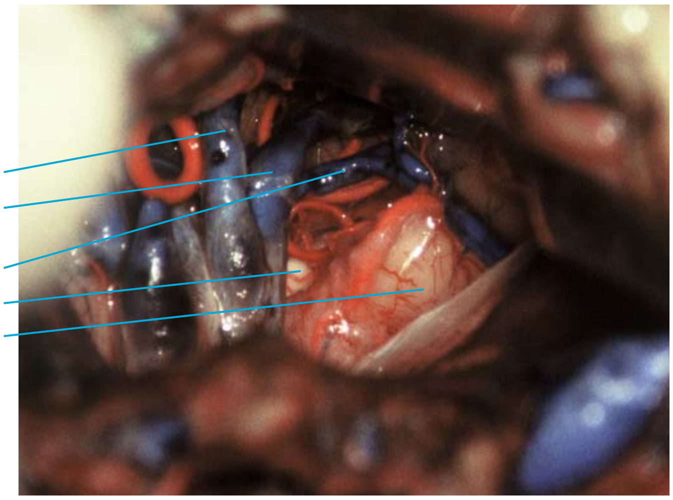


Fig. 6.0.30

Step 5

After further mobilization of the upper vermis, the lateral part of the quadrigeminal cistern is exposed. Note the central cerebellar vein, left internal cerebral vein, and the left basal vein of Rosenthal. The occipital lobe is gently retracted with a dissector approaching the splenium of the corpus callosum (Fig. 6.0.30).

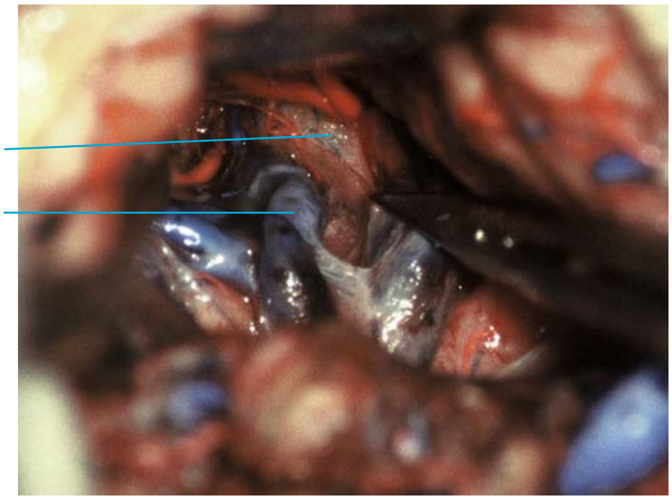


Fig.6.0.31

Step 6

The central cerebellar vein is gently retracted to the left, exposing the right internal cerebral vein. Note the pineal gland appearing in the angle between the central cerebellar and internal cerebral veins (Fig. 6.0.31).

Step 7

The internal cerebral vein is followed anteriorly disappearing into the velum interpositum. Note the small perforating vessels supplying the quadrigeminal plate of the mesencephalon (Fig. 6.0.32).

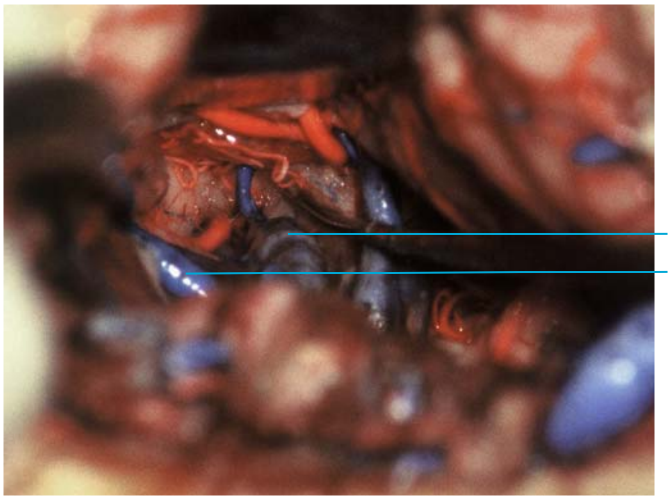


Fig. 6.0.32

Step 8

Exposure of the entrance into the velum interpositum between the splenium of the corpus callosum and the lateralized pineal gland (Fig. 6.0.33).

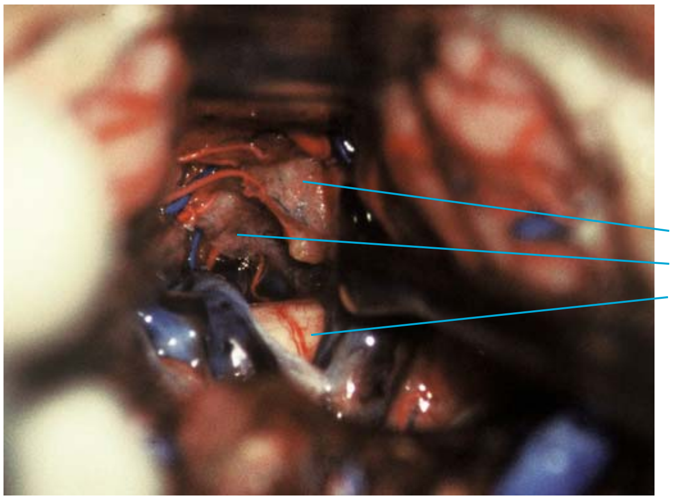


Fig. 6.0.33

Step 9

After opening the arachnoid membranes of the velum interpositum, the habenular commissure can be seen. Note CSF appearing from the posterior third ventricle (Fig. 6.0.34).

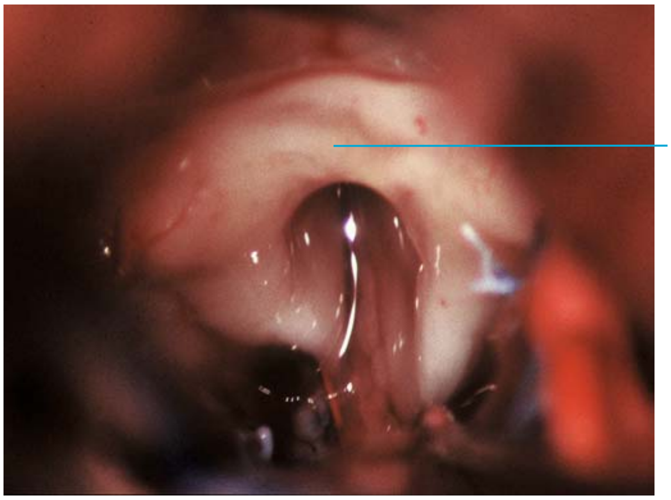
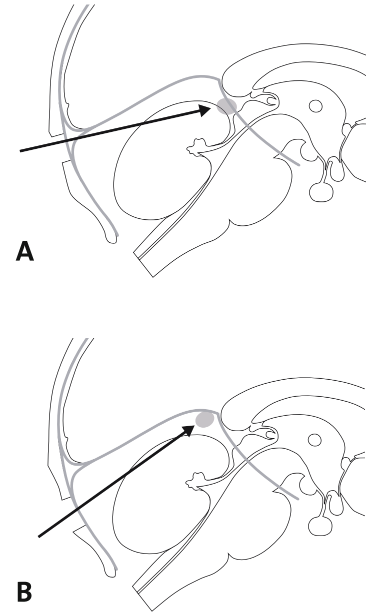


Fig. 6.0.34

5. Dura, bone and wound closure

After completion of the intracranial procedure, the subarachnoid space is filled with Ringer solution at body temperature. The dural incision is closed with interrupted sutures. If shrinkage has developed in the dural plane, the triangular-shaped fascial and periosteal layer can be used as a dural graft to achieve watertight closure. A plate of gelfoam is placed extradurally and the bony defect is closed with bone cement, avoiding fluid collection and postoperative discomfort. After final verification of hemostasis, the muscular and subcutaneous layers are closed with interrupted sutures and the skin with running or interrupted sutures. Suction drainage is not required.

Fig. 6.0.35



Potential errors and their consequences

- Inadequate preoperative planning and positioning of the patient with subsequent inadequate exposure of the target region and significant deterioration in efficiency of surgically excising the lesion. Planning and positioning is the task of the surgeon!
- Injury to the torcular herophili or other sinusoid vessels such as the occipital and transverse sinuses during craniotomy with excessive bleeding. If necessary, the galea-periost flap can be used for repair.
- Extensive retraction of the upper vermis with postoperative cerebellar symptoms. Adequate positioning and early removal of CSF may cause relaxation of the cerebellar surface.
- Injury to vascular structures of the pineal region during microsurgical manipulation with postoperative neurological deficits.
- Injury to the splenium corporis callosi causing left hemialexia, the inability to read in the left visual hemifield, and a broad array of behavioral abnormalities.
- Injury of the quadrigeminal plate may give rise to subsequent Parinoud sign.
- Inadequate intra- or extracranial hemostasis with postoperative rebleeding.
- Inadequate dural closure may lead to postoperative CSF fistula.
- Inadequate closure of the bony dehiscence with subsequent postoperative discomfort.

Fig. 6.0.36

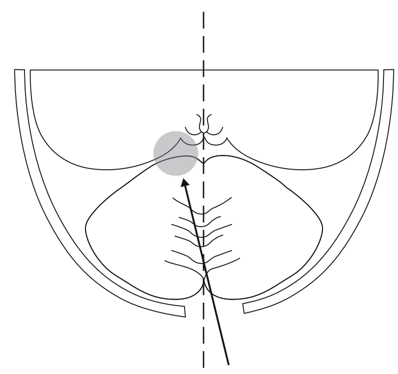


Fig. 6.0.37

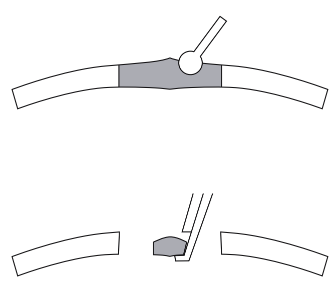


Fig. 6.0.38

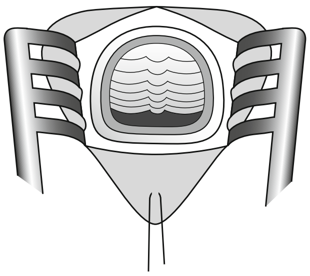


Fig. 6.0.39

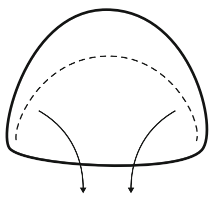


Fig. 6.0.40

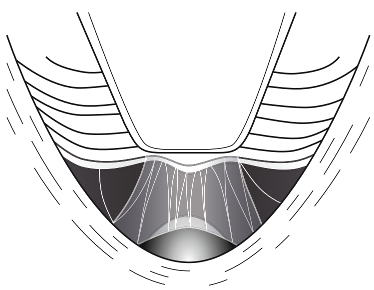


Fig. 6.0.41

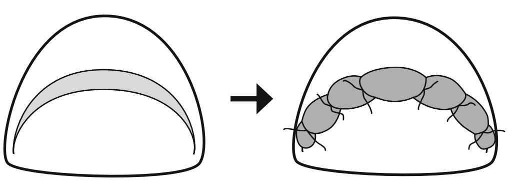
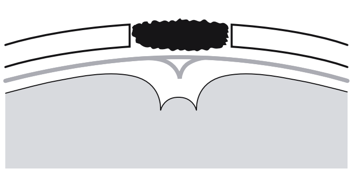


Fig. 6.0.42



Tips and tricks

- Take time for preoperative planning and positioning of patients. The reward is an excellent overview of the target area and an efficient working position.

- Apically situated lesions near to the splenium of corpus callosum should be approached via a caudally placed craniotomy (Fig. 6.0.35 A). On the contrary, lesions of the quadrigeminal plate and cerebellomesencephalic fissure are best approached from a more apical direction (Fig. 6.0.35 B), performing a craniotomy near to the torcular region.

- In cases of laterally located pineal lesions, the craniotomy should be placed paramedian, allowing contralateral exposure of the target area according to the concept of keyhole approaches (Fig. 6.0.36).

- Steps of the osteoclastic craniotomy (Fig. 6.0.37): 1. removal of the external occipital protuberance with a high-speed drill; 2. removal of the internal occipital protuberance and internal occipital crest with fine punches, observing the torcular herophili and the occipital sinus.

- The semispinalis muscles should be retracted bilaterally with a strong wound retractor. The periosteal leaflet covering the external protuberance is reflected with sutures (Fig. 6.0.38).

- The dura should be opened in a "C" shaped form after division of the occipital sinus. Use microclips, dividing the occipital sinus (Fig. 6.0.39).

- The milky arachnoid membrane closing the access into the pineal region is laterally thin and easier to open than in the midline (Fig. 6.0.40).

- If tension has developed during dural closure or a fragment of the dura has been resected, the periosteal sheet of the external protuberance can be used for watertight closure (Fig. 6.0.41).

- After dural closure, the bony defect should be repaired with bone cement avoiding fluid buildup and postoperative discomfort. Suction drain is not required (Fig. 6.0.42).

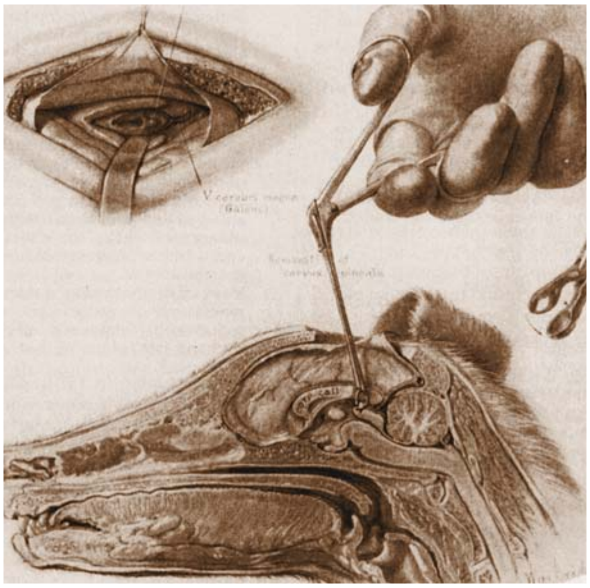


Fig. 7.0.1 *Dandy's interhemispheric approach published in 1915, using a dog model. In his paper entitled "Extirpation of the Pineal Body", he concluded that "the pineal is apparently not essential to life and seems to have no influence upon the animal's well being."*

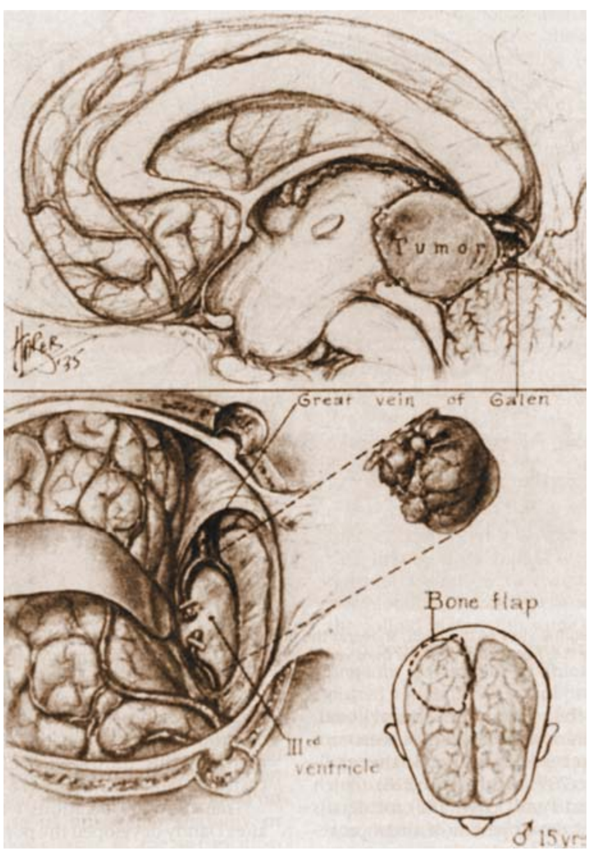


Fig. 7.0.2 *Surgical removal of a tumor from the pineal region reported by Dandy. Note the placement of the bone flap and the posterior interhemispheric approach exposing the pineal process.*

7.0 Interhemispheric approach

History of the interhemispheric approaches

The first interhemispheric transcallosal approach to the pineal region was originally described by Walter E. Dandy in 1915 using a posterior exposure in an animal model (Fig. 7.0.1). His experience led him to suggest the feasibility of such an approach in humans, and six years later, he published his initial experience using this method in three cases of pineal region tumors [Dandy 1915, 1921]. Dandy returned to this subject in 1933 and 1936 (Fig. 7.0.2) as he was able to report on successfull removal of ten pineal lesions via a right parietal interhemispheric transcallosal approach [Dandy 1929, 1936]. This approach was the most favored for many years. Ernest Sachs exposed a large cystic tumor in the pineal region and Max Peet removed a pineal lesion through a right parieto-occipital transcallosal approach [Sachs 1926, Peet 1927]. One year later, Otfrid Foerster published his experience with the posterior interhemispheric exposure of the quadrigeminal plate (Fig. 6.0.5) His interhemispheric suboccipital transtentorial approach, performed successfully in three patients, was suggested by Julius Tandler and Egon Ranzi in their surgical anatomical textbook (Fig. 7.0.3) [Tandler & Ranzi 1920, Foerster 1928].

Dandy also used the posterior interhemispheric transcallosal approach for exposure of space-occupying lesions of the posterior third ventricle. In his monograph entitled "Benign Tumors in the Third Ventricle of the Brain: Diagnosis and Treatment", he described his surgical experience with intraventricular tumors and cystic lesions [Dandy 1931, 1933]. For anterior third ventricular tumors, Dandy preferred the frontal transcortical route (Fig. 8.0.2) and for posteriorly situated lesions the posterior transcallosal interhemispheric approach (Figs. 7.0.2, 8.0.1). The mid-sagittal interhemispheric transcallosal exposure, published initially in 1931, was used only for cystic lesions of the septum pellucidum and cavum vergae (Fig. 7.0.4). It is interesting to note that Dandy reported no neurological deficits occurring as a result of splitting the posterior part of the corpus callosum. However, there have been other suggestions showing that although sectioning the more anterior part of the corpus callosum is not associated with severe distinct symptoms, posterior and complete callosal section has in particular been shown to produce a broad array of behavioral abnormalities.

Accordingly, van Wagenen reported his experience of surgical exposure of the hypothalamic region via the anterior interhemispheric route [van Wagenen 1939]. A similar, strictly midline exposure was also published by Busch describing the anterior interhemispheric transcallosal interforniceal approach for removal of third ventricular tumors [Busch 1944]. Using microsurgical techniques, the surgical literature has contained an increasing number of reports emphasizing the efficacy of the anterior transcallosal approach (Fig. 7.0.5). Special attention should be given to Michael L. J. Apuzzo, who had a unique interest and enormous experience in the surgical treatment of third ventricular tumors [Milhorat 1966, Kempe 1976, Shucart 1978, Delandsheer 1978, Stein 1980, Apuzzo 1982]. Karl Ungersböck and Axel Perneczky, Michael Lawton and Robert Spetzler described the advantages of the contralateral exposure for approaching the lateral and third ventricles [Ungersböck & Perneczky 1986, Lawton & Spetzler 1996].

The first interhemispheric transcallosal approach for the treatment of a ruptured aneurysm of the ACoA was published by Wilhelm Tönnis [Tönnis 1936]. His technique required splitting of the anterior corpus callosum (Fig. 7.0.6). Wallace Hamby and Herbert Olivecrona used a very similar anterior transcallosal exposure [Hamby 1952, Olivecrona 1953]. In 1959, Lawrence Pool described a different, more frontobasally placed bifrontal approach to aneurysms of the ACoA. The region was exposed through an anteroinferior interhemispheric route and the suprasellar region could be effectively approached without splitting of the corpus callosum [Pool 1959]. For distal aneurysms of the ACA, a similar approach was described by Hugo Krayenbühl and Jiro Suzuki [Krayenbühl 1952, Suzuki 1977]. In 1991, Takanori Fukushima and co-workers reported on the unilateral interhemispheric keyhole approach for anterior cerebral artery aneurysms [Fukushima 1991].

This anteroinferior subcallosal interhemispheric approach was also used for tumorous lesions of the third ventricle and anterior midline skull base as described by Dean Lewis in a patient with a large craniopharyngioma [Lewis 1910]. Walter E. Dandy removed prechiasmal intracranial tumors using a bifrontal interhemispheric exposure. Harvey Cushing described the anterior interhemispheric and subfrontal approach for the treatment of olfactory groove meningeomas with the aid of electrosurgery [Dandy 1922, Cushing 1927]. Since these first reports, the anterior interhemispheric approach has been used for many different pathologies of the anterior fossa. Using

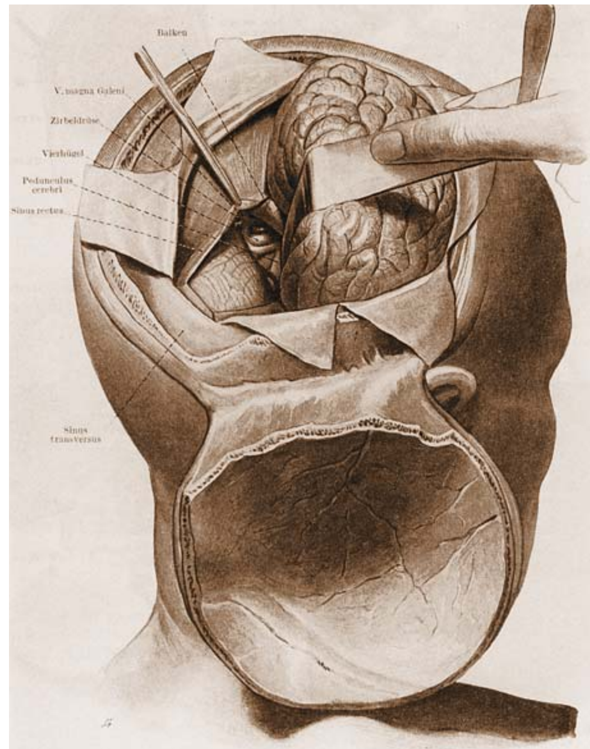


Fig. 7.0.3 *Exposure of the pineal region via the occipital interhemispheric approach, described by Tandler and Ranzi in their textbook published in 1920. Note the traumatic retraction of the occipital lobe, necessary to visualize the deep-seated area.*

Fig. 7.0.4 *Dandy's mid-sagittal interhemispheric approach "establishing communication between the cystic V. ventricle and lateral ventricle", reported in 1931. Note that for exposure of a space-occupying cavum septi pellucidi, Dandy used brain retraction against gravity.*

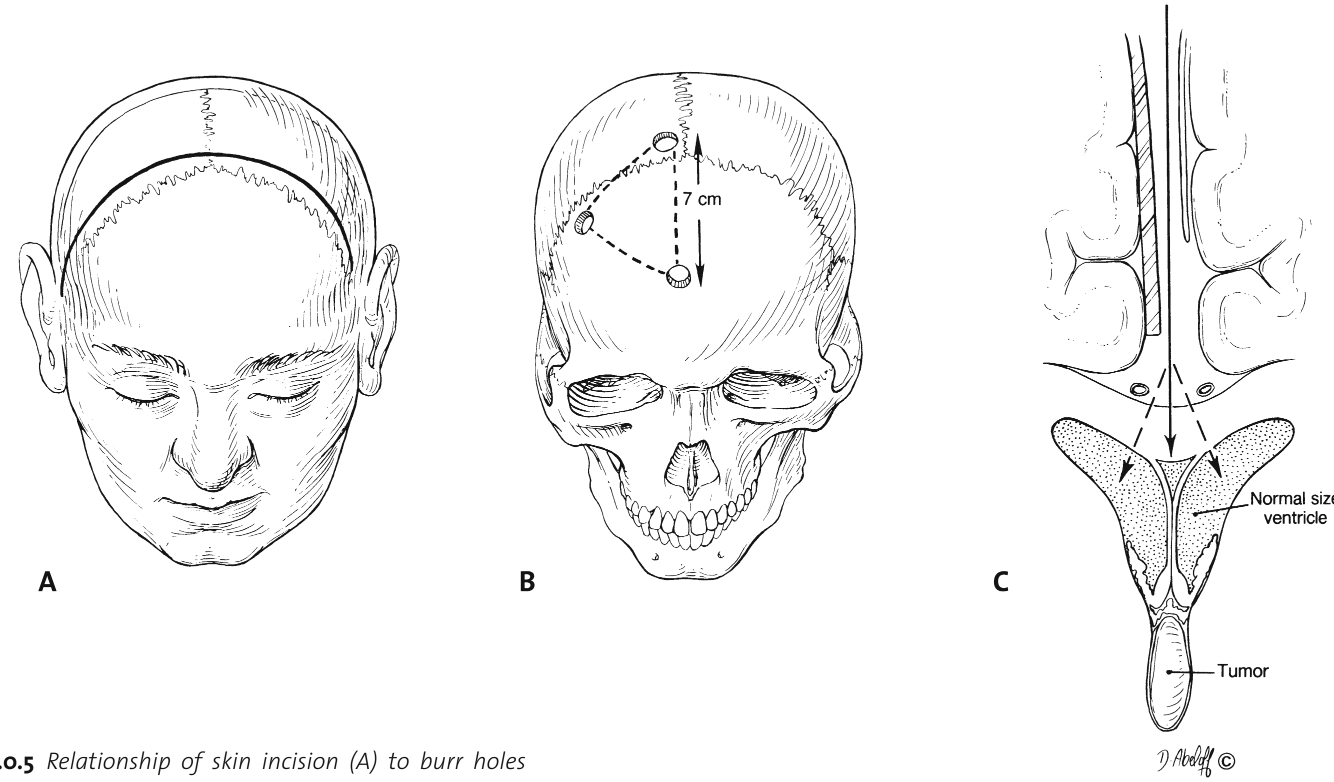


Fig. 7.0.5 *Relationship of skin incision (A) to burr holes and craniotomy (B) using the interhemispheric transcallosal approach reported by William Shucart in Michael L. J. Apuzzo's comprehensive textbook "Surgery of the Third Ventricle", published in 1987 and 1998. This approach was used to visualize entire normal-size anterior ventricular system (C).*

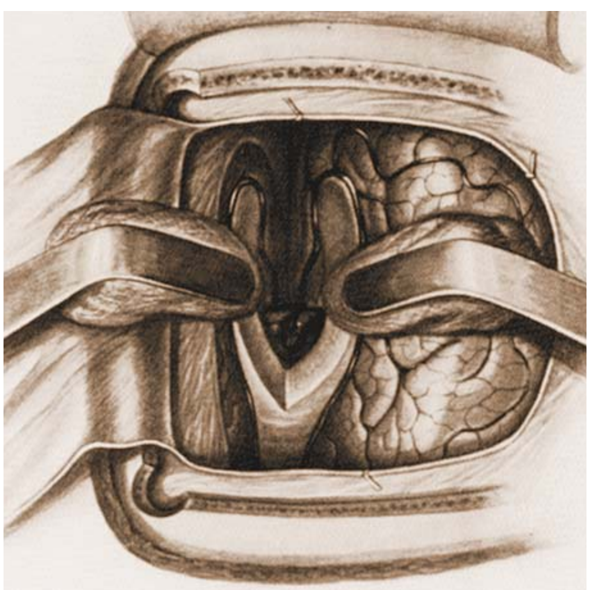


Fig. 7.0.6 *Tönnis' frontal interhemispheric approach for an aneurysm of the anterior communicating artery causing subarachnoid hemorrhage, reported in 1936. The anterior part of the corpus callosum was divided to gain exposure using a unilateral frontal craniotomy.*

microsurgical techniques, M. Gazi Yasargil, Gallingham Sekhar, Ossama Al-Mefty, Madjid Samii and Jiro Suzuki approached skull base meningeomas, craniopharyngiomas, third ventricle tumors and aneurysms from this anterior direction [Yasargil 1980, Sekhar & Al-Mefty 1985, Samii 1981, Suzuki 1981].

It can be seen that during the last decades many different interhemispheric approaches to the midline region have been described. However, in his first experiences, Walter Dandy already realized the importance of the route of the midline corridor: the use of the keyhole concept in interhemispheric approaches.

In the following, the essence of the keyhole concept in neurosurgery is discussed in detail using the anterior and posterior interhemispheric approaches.

Use of the keyhole concept in the interhemispheric approaches and general anatomical construction of the middle corridor

In 1944, DANDY reported on a successful surgical exposure of a ruptured aneurysm of the ACoA, causing severe intraventricular bleeding [DANDY 1944]. He approached the anterior third ventricle via a posterior interhemispheric exposure and diagnosed the ruptured aneurysm without using an operating microscope. It was possible because the interhemispheric fissure allowed an overview of the entire corpus callosum and third ventricle; a surgical dissection using the idea of the keyhole concept (Fig. 7.0.7).

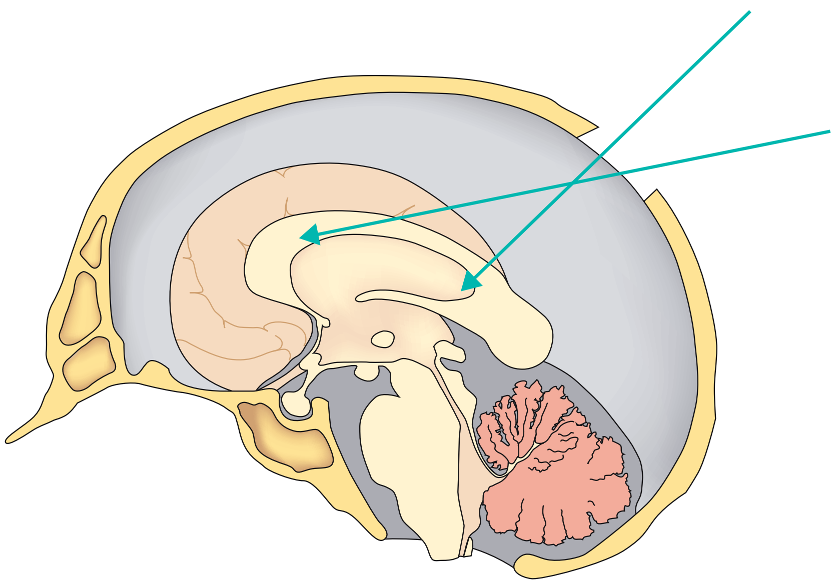


Fig. 7.0.7 *Use of the keyhole concept in interhemispheric approaches. Generally, lesions of the corpus callosum, the lateral and third ventricles, the pineal region and the midline skull base are deep-seated. The schematic drawing of the midline structures demonstrates that a limited exposure can be sufficient to visualize the deep-seated areas using the anatomical corridor of the interhemispheric fissure.*

In interhemispheric approaches, the major topographic elements of the midline corridor require identification and consideration, including the superior and inferior sagittal sinus, parasagittal veins, corpus callosum, pericallosal arteries, fornix, septum pellucidum, cisterna veli interpositii with the internal cerebral veins, lateral and third ventricles, and the anterosuperior part of the suprasellar area.

There is agreement among surgeons that preservation of the sagittal sinus and their venous tributaries is an important goal, creating an interhemispheric exposure. In particular, the combination of brain retraction and venous occlusion may result in extended

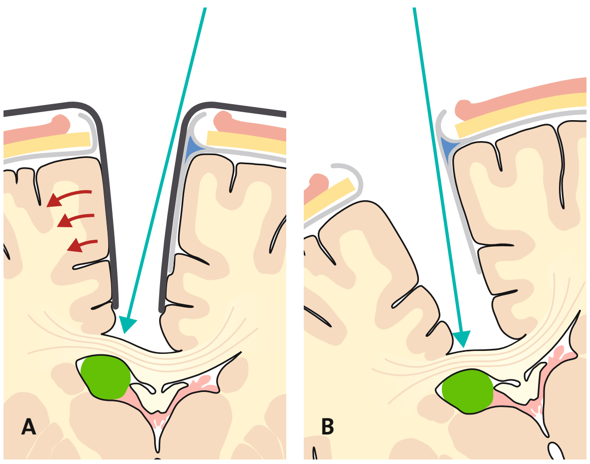


Fig. 7.0.8 *Ipsilateral investigation of the lateral ventricle for medially located lesions (A). With the help of elegant rotation of the head during positioning of the patient, the gravity-related self-retraction of the brain opens the interhemispheric fissure allowing atraumatic surgical dissection without using a brain spatula (B).*

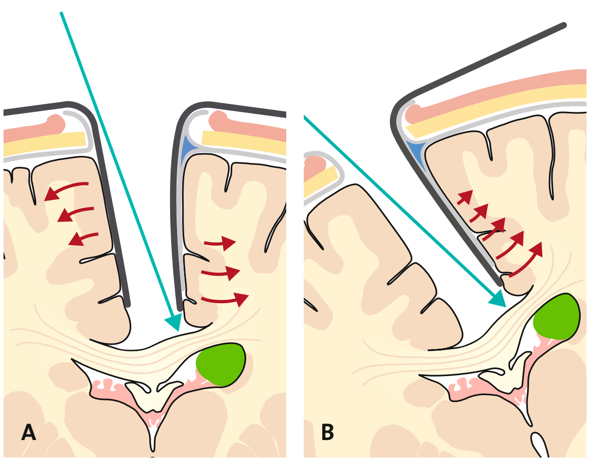


Fig. 7.0.9 *Schematic drawing of the contralateral interhemispheric approach for laterally situated intraventricular lesions (A). Using the contralateral technique, intraoperative traumatization of the side of the lesion can be effectively minimized in order not to jeopardize the frontal or parietal lobe. This is important especially for dominant sided lesions. Note the position of the falx covering and protecting the hemisphere from direct spatula pressure. Using adequate positioning, rough brain retraction can be avoided on both sides: the ipsilateral hemisphere deflates without using a retractor according to the gravity-related self-retraction; the contralateral hemisphere is retracted forcefully; however, protected by the falx cerebri (B).*

venous infarction with postoperative neurological deterioration. If a bridging vein is injured and must be sacrified, the following principle should be considered: cerebral veins are basically anastomotic vessels without valves, therefore to preserve the anastomotic points, the veins can be occluded. However, after occlusion of the bridging vein, the use of a retractor can cause severe compression of this venous anastomosis with subsequent infarction of the surrounding area. For this reason, cerebral retraction must be restricted to the necessary minimum, according to a limited and well-planned craniotomy. Note that only an appropriate placement of a limited bone flap according to preoperative visualization of the venous anatomy, combined with careful dissection and limited brain retraction can effectively minimize surgical damage.

After careful brain retraction and dissection of the pericallosal arteries, which may sometimes be hidden in the sulcus of the corpus callosum or may cross the midline, various modes of entry into the ventricular system are possible. However, it is important to note the possible severe neuro-physiological consequences of an operative commissural section as described in numerous publications [Apuzzo 1986]. An acute syndrome following sectioning of the anterior portion of the corpus callosum can be characterized by a decrease in the spontaneity of speech ranging from a mild slowness in initiating speech to frank mutism. Division of the posterior corpus callosum and splenium may cause a broad range of behavioral abnormalities. For this reason, commissural section should be restricted to the necessary minimum.

Lesions of the lateral ventricle located medially within the ventricular chamber can be optimally exposed through an ipsilateral interhemispheric approach. Using the ipsilateral dissection, the hemisphere can be gently mobilized and retracted away from the falx. Optimal positioning of the head enables nontraumatic exposure of the lateral ventricle after limited callosotomy. Note that retraction of the brain tissue can be effectively minimized: with adequate positioning of the patient the gravity-related self-retraction of the brain opens the interhemispheric route without rough retraction of the cerebral tissue (Fig. 7.0.8). Lesions located laterally in or adjacent to the lateral ventricle, especially within the dominant hemispheric side, should be exposed via a contralateral transcallosal approach. Retracting the falx and the opposite cingulate gyrus, the contralaterally situated lesion can be effectively approached (Fig.7.0.9).

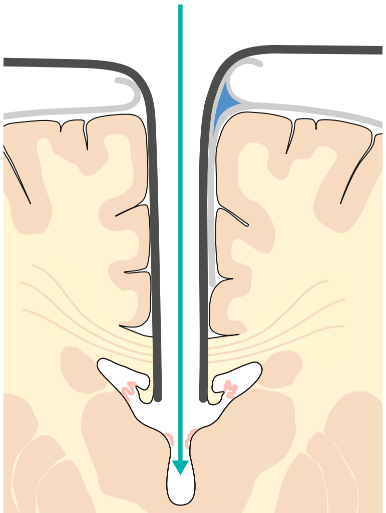


Fig. 7.0.10 *Interfornical investigation of the third ventricle using the interhemispheric approach. After dividing the fornical commissure, the third ventricle is entered through the velum interpositum and its choroidal roof. This approach allows wide exposure of the third ventricular chamber; however, contusions of both fornices may result in severe postoperative memory loss.*

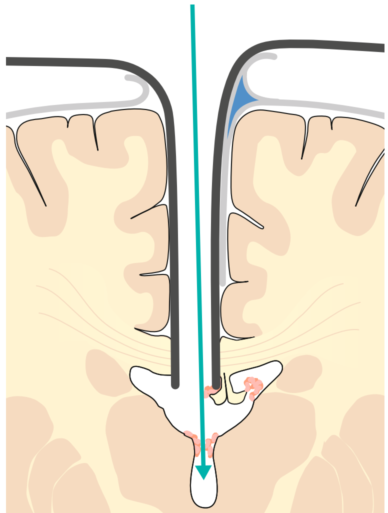


Fig. 7.0.11 *Using the subchoroidal or transchoroidal exposure, the fornix may be gently mobilized under protection of the covering choroidal tissue. The third ventricle can also be widely exposed without transfornical dissection.*

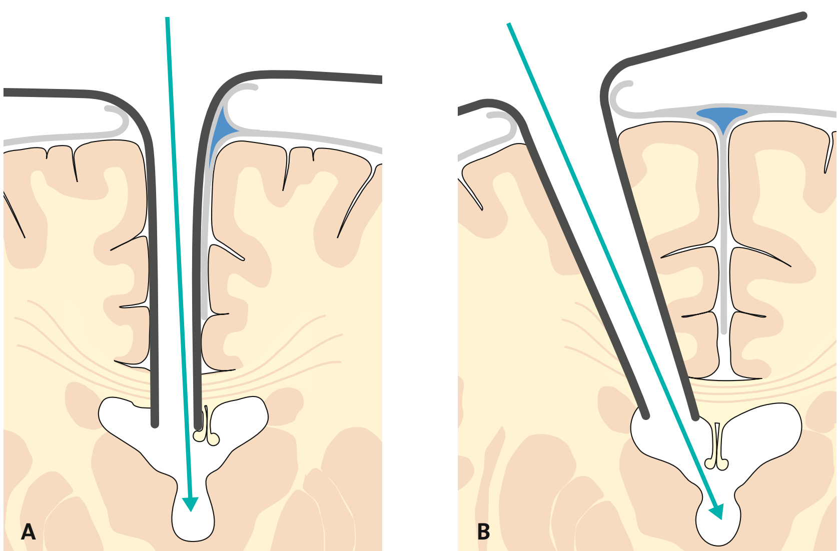


Fig. 7.0.12 *Using the transcallosal transforaminal exposure of the third ventricular chamber, the surgeon gains an overview into the third ventricle through the foramen of Monro; however, only after gentle retraction of the fornix (A). In comparison, using the transcortical route, one is able to investigate the third ventricular chamber without touching the fornical structures. The transcortical route should be used especially in the case of hydrocephalic configuration of the ventricles (B).*

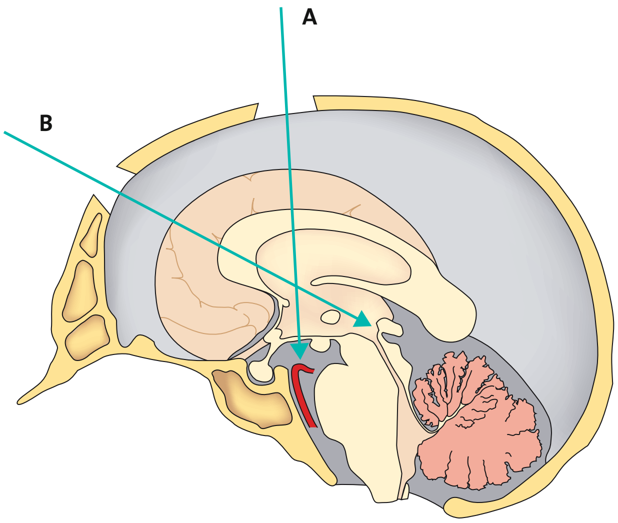


Fig. 7.0.13 *Using a transforaminal approach, optimum placement of the craniotomy is essential to avoid fornical contusion. With good preoperative planning, the individual anatomy of the foramen of Monro and the size and site of the interthalamic adhesion should be determined compared to the target point. Lesions of the anterior third ventricle and the basilar tip should be approached through a posteriorly placed craniotomy (A). The posterior chamber of the third ventricle can be optimally exposed through an anteriorly placed approach (B).*

Approaching the third ventricle using a transcallosal route, the third ventricular chamber can be approached via an interfornical, subchoroidal, transchoroidal or transforaminal path. Using the interfornical exposure, manipulation of the fornix must always be included; due to incision of the fornical raphe and contusion of both fornices, persistent memory loss may result (Fig. 7.0.10). In contrast to bilateral fornical dissection, unilateral damage seems to result in minor deficits, especially on the nondominant side. Therefore, in order to minimize the risk of amnesia, the subchoroidal or transchoroidal approach should be recommended for exposure of the third ventricle (Fig. 7.0.11). These exposures often require only minor mobilization of the fornical elements in addition to the displacement produced by the third ventricular mass lesion itself. The transforaminal approach may be better compared with the other perifornical routes in the case of enlarged ventricles due to chronic hydrocephalus (Fig. 7.0.12). Note that using this transforaminal approach, preoperative planning of the placement of the craniotomy is essential to avoid contusion of the fornix (Fig. 7.0.13).

However, as mentioned above in the historical overview, using the interhemispheric route not only the ventricular chamber but other very different intracranial regions can be effectively approached (Table 7.0.1). Compared with the anterior superior transcallosal interhemispheric approach for intraventricular exposure, the anterior inferior subcallosal interhemispheric exposure offers adequate visualization of the anterior skull base. In addition, the anterior part of the third ventricle can be well approached, dissecting through the lamina terminalis. By the posterior interhemispheric approach, lesions of the posterior third ventricle and the pineal region can be well exposed.

Of course, according to the individual pathoanatomical situation, the above-mentioned target regions can be also exposed using alternative approaches. An alternative approach to the anterior superior transcallosal exposure for intraventricular lesions can be the frontal transcortical approach, as described in chapter 8. Lesions of the anterior skull base and the anterior third ventricle can also be exposed via the subfrontal supraorbital approach, described in chapter 2. Instead of the posterior subcallosal interhemispheric exposure, the supracerebellar infratentorial route can be performed for approaching the pineal region and the posterior third ventricle, as discussed in chapter 6.

In the following, the basic surgical technique of the interhemispheric and transcallosal approaches are discussed exposing the lateral and third ventricles (Table 7.0.2). The anterior frontal subcallosal and the posterior (occipital) subcallosal interhemispheric approaches are described as variations of the main exposure.

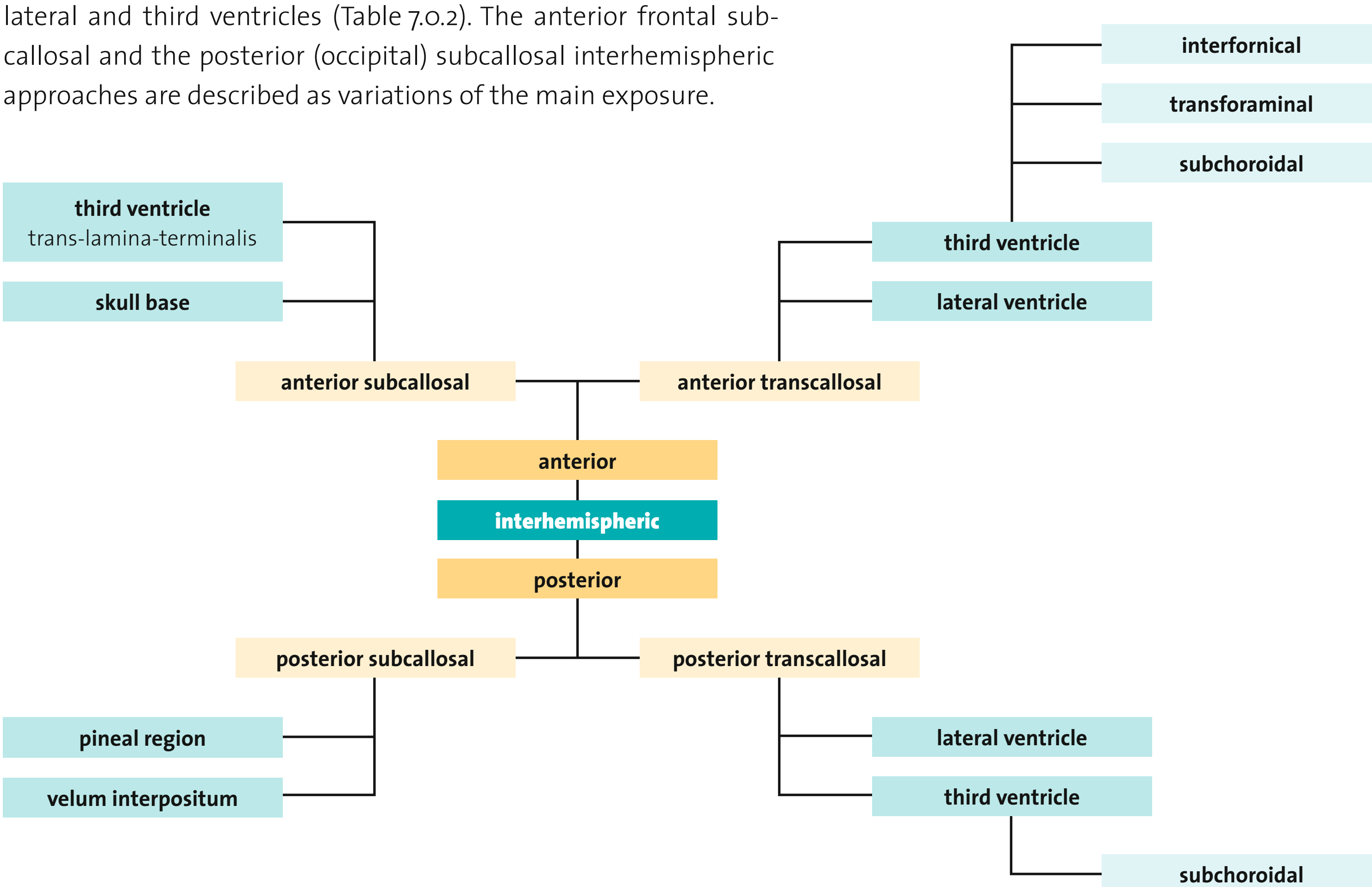


Table 7.0.1 *Different variants of interhemispheric exposures.*

Ipsilateral	Midline	Contralateral
Medial part of the frontal lobe Ipsilateral cingulate gyrus Frontal horn of the lateral ventricle Cella media of the lateral ventricle Foramen of Monro Septal vein Thalamostriate vein Choroid plexus	Superior sagittal sinus Anterior cerebral falx Distal (A3, A4) segments of the ACA Anterior corpus callosum Velum interpositum Third ventricle Interpeduncular fossa Tip of the BA, incl. perforators	Opposite cingulate gyrus Lateral aspect of the contralateral ventricle

Table 7.0.2 *Anatomical structures which can be approached through the anterior interhemispheric transcallosal procedure.*

Surgical technique

1. Patient positioning

With the patient in a supine position, the postition of the head should allow a surgical dissection near to the perpendicular plane. This provides an efficient surgical dissection and avoids an uncontrolled loss of CSF, which is an important complicating factor in all intraventricular procedures. The head is fixed using a Mayfield holder with the single pin of the head fixator placed on the opposite side to allow free surgical manipulation.

Step 1

As a first step, the head of the patient and the operating table are elevated approximately 15°, to provide sufficient venous drainage (Fig. 7.0.14).

Step 2

Thereafter, the head is carefuly anteroflected without compression of the larynx and the ventilation tube. With a flexion of ca. 15° to 45°, the craniotomy site is on the upper part of the positioned head, avoiding a large loss of CSF (Fig. 7.0.15).

Steps 3–4

Finally, the head is rotated ca. 10° to 30° (Fig. 7.0.16) and lateroflected to the side of the craniotomy (Fig. 7.0.17). This maneuvre of lateroflexion and rotation causes a significant relaxation of the frontal lobe away from the falx cerebri, allowing a minimum or even absent retraction of the cerebral hemisphere and resulting in an optimal access to the lesion. Approaching the ipsilateral side, a lateroflexion of ca. 30° and rotation of 10° is necessary, whereas exposure of the opposite side requires a lateroflexion of ca. 10° and rotation of 10° to provide an efficient working position for the surgeon.

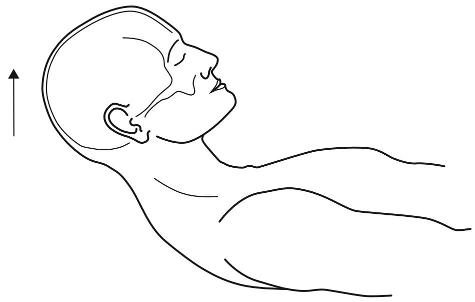


Fig. 7.0.14

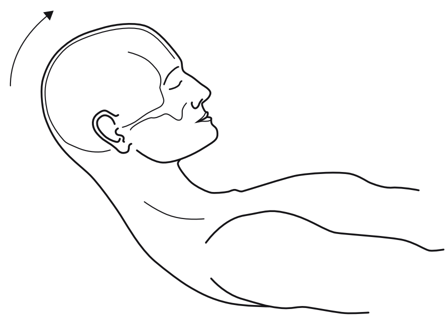


Fig. 7.0.15

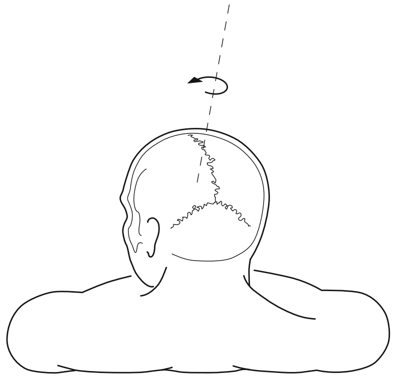


Fig. 7.0.16

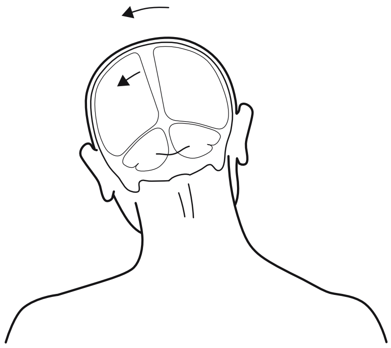


Fig. 7.0.17

2. Anatomical landmarks and orientation

For an optimal skin incision, the important anatomical landmarks of the osseous skull such as the coronary and sagittal sutures are precisely defined (Fig. 7.0.19).

After this basic orientation, the placement of the craniotomy is exactly defined according to the target area. Note that the borders of the trephination should cross the midline to gain control of the sinus sagittalis superior. After definition of the craniotomy, the individual optimum line of the skin incision is marked with a pen. The straight sagittal skin incision is placed in the precoronary region, just behind the frontal hairline (Fig. 7.0.18). After minimal or even absent shaving of the hair, the skin is carefully disinfected with alcohol solution. In bald patients or in special situations, the skin incision and the craniotomy may be placed anterior to the (imaginary) hairline. For this purpose, wrinkles in the skin may be chosen for the incision, the incision anterior the hairline should be transverse, according to the prominent wrinkles.

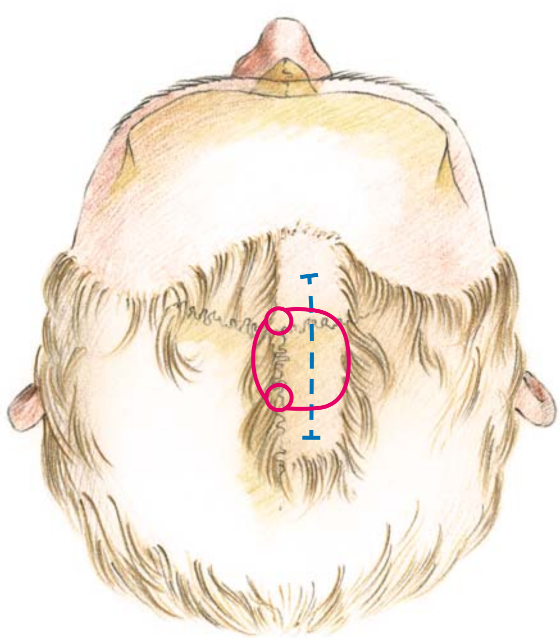


Fig. 7.0.18 *Definition of the craniotomy according to the anatomical landmarks of the frontal region. The paramedian placed craniotomy allows safe control of the midline and offers adequate interhemispheric dissection.*

3. Craniotomy

Step 1

Right side. After minimal or even absent shaving of the hair, a ca. 5 cm long straight skin incision is performed ca. 1.5 cm paramedian from the carefully defined midline (Fig. 7.0.19).

Fig. 7.0.19

Step 2

After mobilization of the subcutaneous tissue, the galea aponeurotica and the periosteal layer are incised in a curved fashion and retracted toward the midline. If necessary, this tissue can be used later for a watertight closure of the dura mater (Fig. 7.0.20).

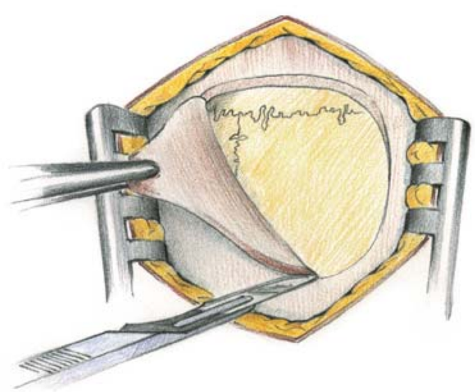


Fig. 7.0.20

Step 3

With a craniotome, two burr holes are performed according to the midline, just above the SSS. The main danger of any midline craniotomy is the tearing of the SSS; however, by this technique injury to the sinus can be effectively avoided. The first burr hole trephination should be placed frontally at the anterior-medial corner, the second burr hole parietally at the posterior-medial corner of the planned craniotomy. The argument for this form of craniotomy is that it appears to be safer to place the burr hole trephination exactly above the SSS and expose it over its full width, than to cross it with the craniotome, or to saw blind parallel to the sinus (Fig. 7.0.21).

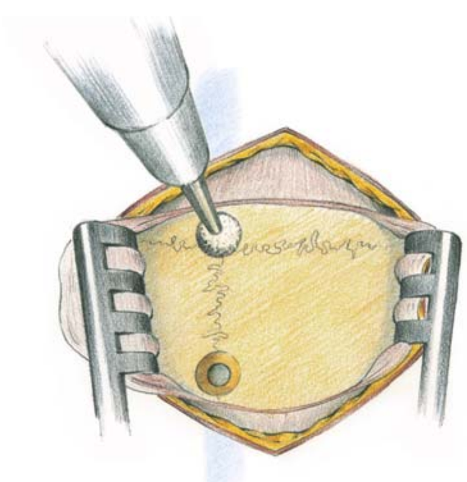
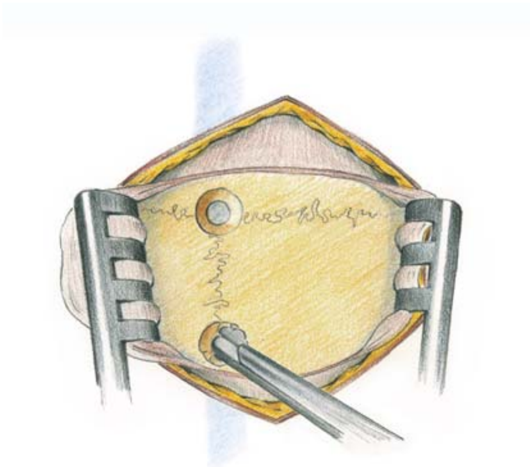


Fig. 7.0.21

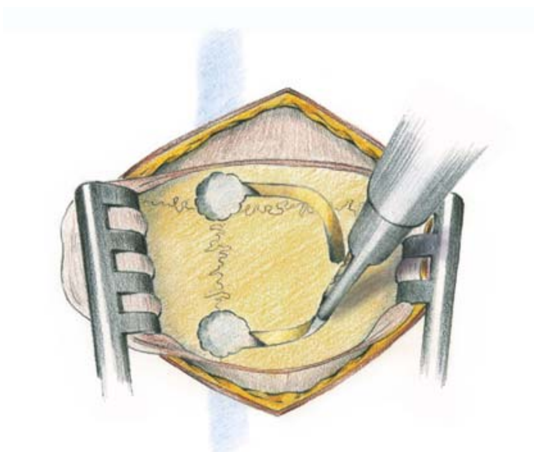
Fig. 7.0.22



Step 4

After mobilization of the dura mater with a blunt dissector, the burr holes should be enlarged using fine Kerrison rongeurs. By removal of the bony edges of the groove of the SSS, the lateral borders of the sinus can be effectively checked (Fig. 7.0.22).

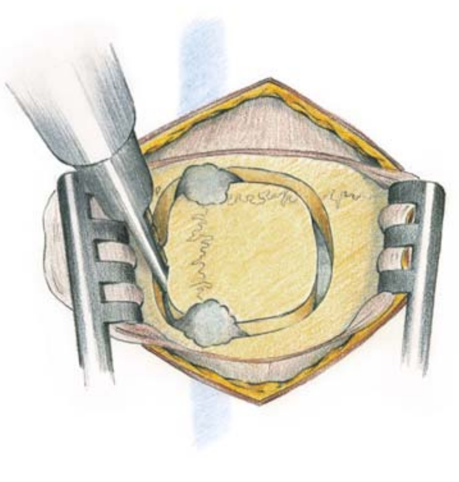
Fig. 7.0.23



Step 5

Using a craniotome, one never should cut in the direction of the SSS. According to this principle, a curved line is sawed from the frontal burr hole on the ipsilateral side. This ipsilateral cut is then completed from the parietal burr hole (Fig. 7.0.23).

Fig. 7.0.24



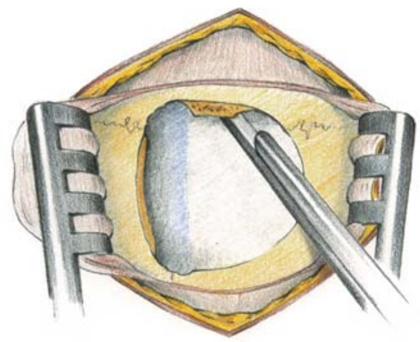
Step 6

Thereafter, the craniotome is used on the opposite side in a similar way, creating a paramedian craniotomy with an effective control of the SSS (Fig. 7.0.24).

Step 7

After removal of the bone flap with a diameter of ca. 2.0 to 3.0 cm, the inner edge of the bone should be removed using fine punches. Due to careful removal of the tabula interna anteriorly and posteriorly, the angle for intracranial visualization can significantly increase. In the further course of the operation, this trick can greatly facilitate the application of conventional microinstruments through the limited craniotomy (Fig. 7.0.25).

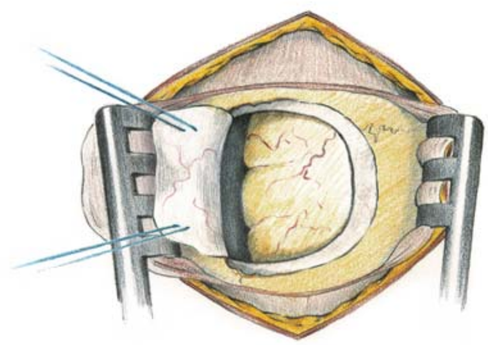
Fig. 7.0.25



Step 8

The dura should be opened in a semicircular fashion with the base of the dural flap toward the SSS. The free dural flap is fixed with two sutures; other dural elevation sutures are not required. Occasional injuries to the SSS cannot be occluded with bipolar coagulation because shrinking of the dural tissue enlarges the hole. For this reason, hemoclips and carefully placed sutures can be effective (Fig. 7.0.26).

Fig. 7.0.26



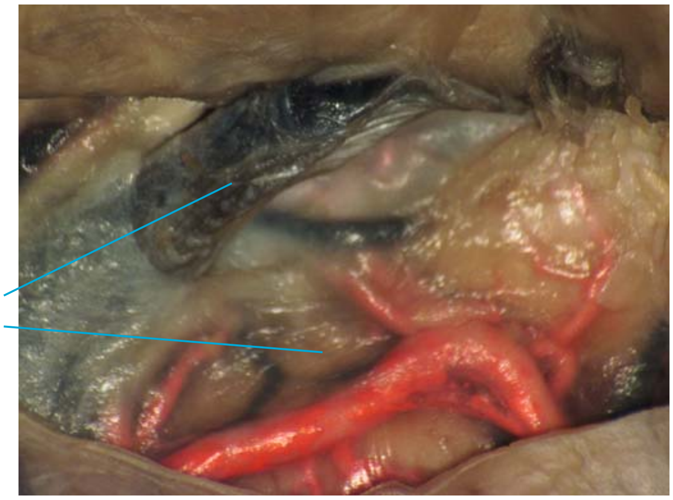


Fig. 7.0.27

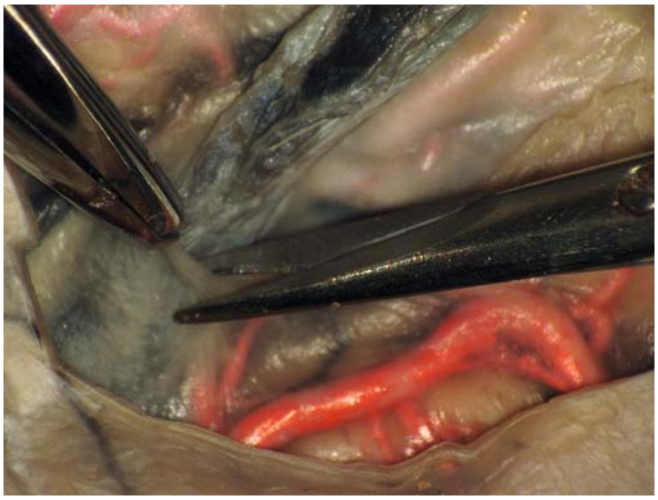


Fig. 7.0.28

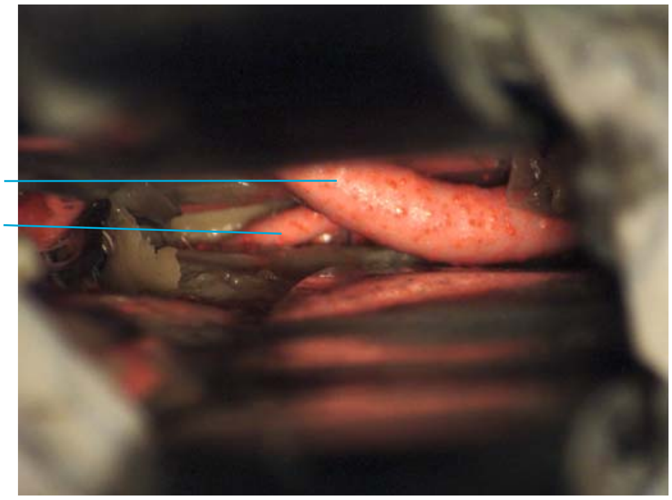


Fig. 7.0.29

4. Intradural dissection

Step 1

Right side. Dissection using a formaldehyde-fixed human specimen. Arterial vessels are prepared with a red latex solution. After dural opening, the superior frontal gyrus should be carefully dissected from the midline. If present, bridging veins run some millimeters within the convexity-dura or within the falx before entering the SSS. Using microinstruments, this part of the vein should be dissected away from the dura, allowing exposure of the interhemispheric fissure (Fig. 7.0.27).

Step 2

In addition, the superficial bridging vein should be carefully dissected from arachnoidal adhesions, gaining useful additional mobilization of the superior frontal gyrus. If the vein is injured and must be occluded, cerebral retraction should be restricted to the absolute minimum avoiding compression of the surrounding venous anastomoses. Mobilization of the frontal lobe can be successfully supplemented with a correct positioning of the head offering effective relaxation of the brain, which then, due to gravity, sinks spontaneously away from the falx cerebri (Fig. 7.0.28).

Step 3

After mobilization of the frontal lobe and the falx cerebri, the interhemispheric fissure is carefully approached. Note the callosomarginal artery; the pericallosal artery appears in the background (Fig. 7.0.29).

Step 4

With further dissection within the interhemispheric fissure, the corpus callosum is approached. The cingulated gyrus is carefully retracted on both sides. Note the indusium griseum on the surface of the corpus callosum and the mobilized arteries (Fig. 7.0.30).

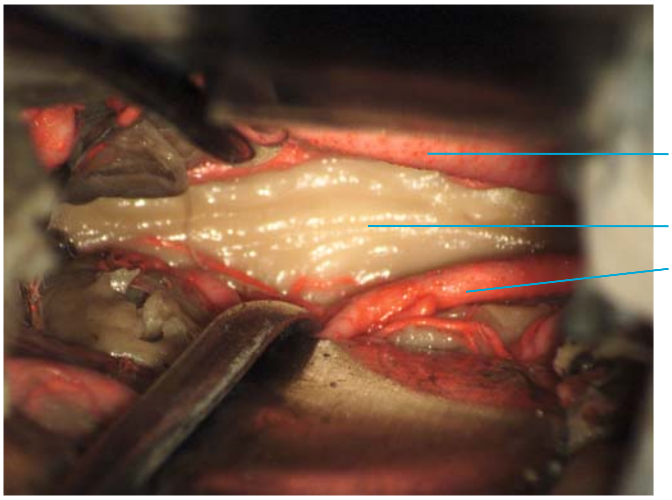


Fig. 7.0.30

Step 5

After limited callosotomy, the chamber of the right lateral ventricle is entered. The choroid plexus disappears within the foramen of Monro, the anterior part of the ventricle without plexus corresponds to the frontal horn of the lateral ventricle. Note the fornix, the head of the caudate nucleus and the lamina affixa thalami. Because of the interhemispheric approach, the foramen of Monro appears in an oblique view from above (Fig. 7.0.31).

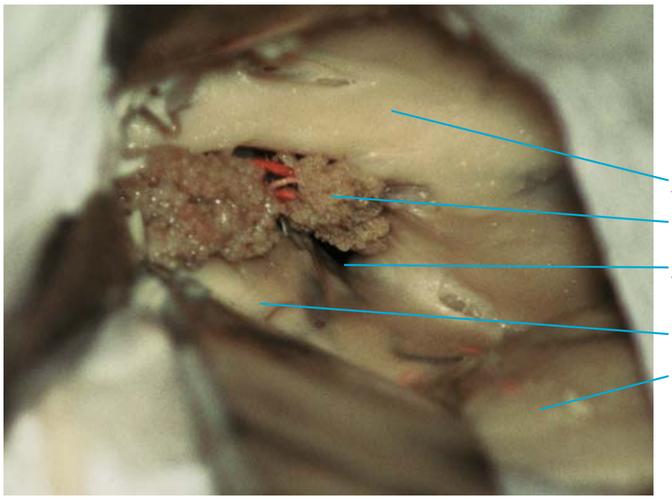


Fig. 7.0.31

Step 6

Focusing anteriorly, the foramen of Monro and the frontal horn are exposed. Note the fornix; the choroid plexus disappears into the foramen of Monro (Fig. 7.0.32).

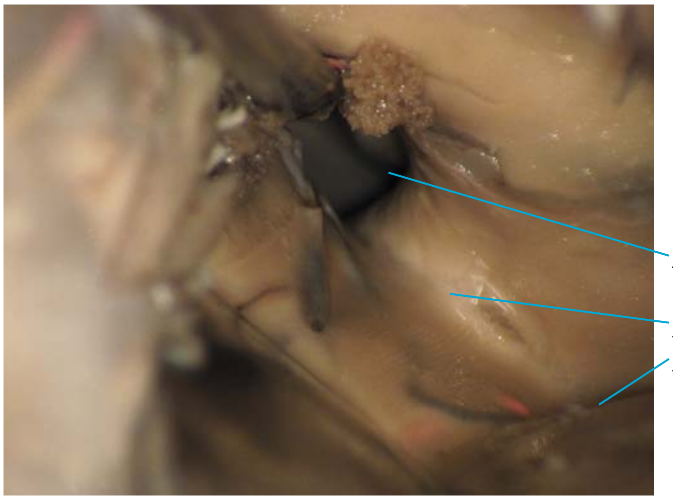


Fig. 7.0.32

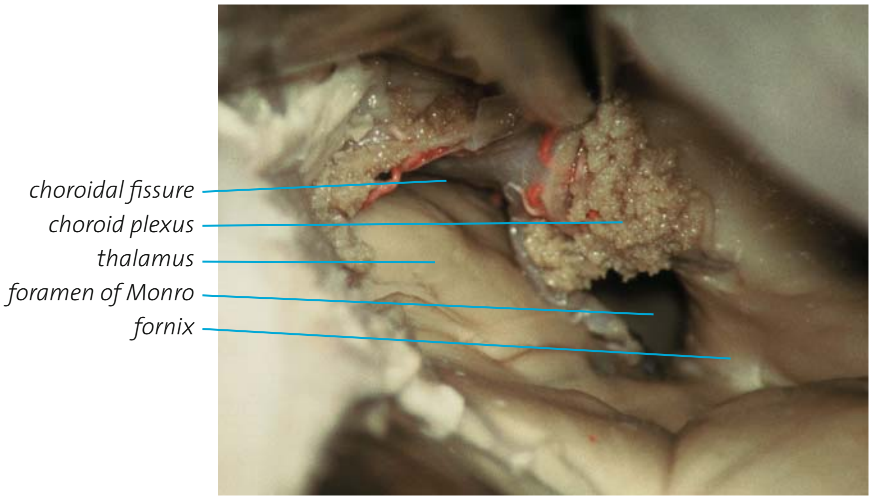


Fig. 7.0.33

Step 7

Exposure of the foramen of Monro and the cella media of the lateral ventricle. The choroid plexus is gently retracted with a microsucker allowing visualization of the choroidal fissure between fornix and thalamus (Fig. 7.0.33).

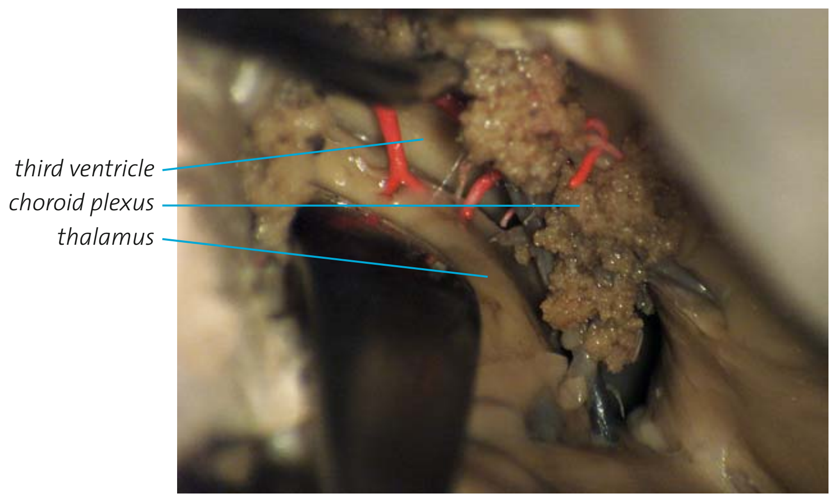


Fig. 7.0.34

Step 8

The choroid plexus is carefully dissected from the tenia thalami allowing subchoroidal exposure of the third ventricle. Note small perforators of the choroidal arteries supplying the thalamus (Fig. 7.0.34).

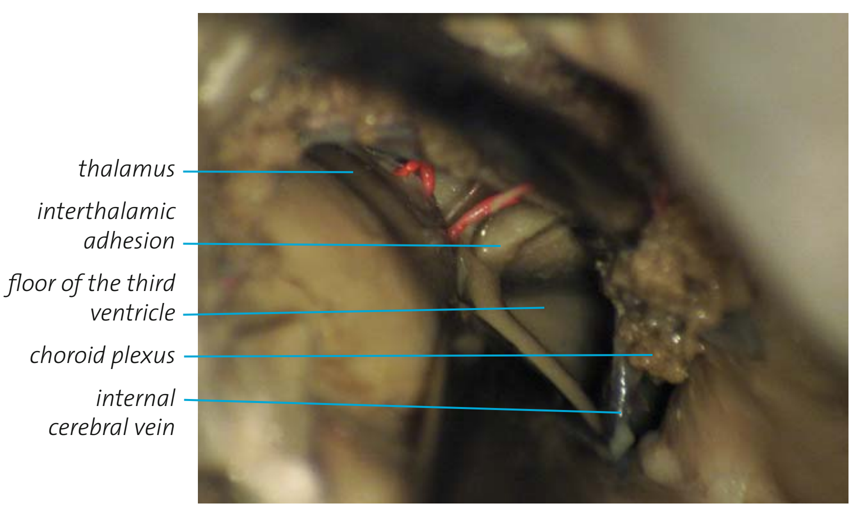


Fig. 7.0.35

Step 9

The choroid plexus and the internal cerebral vein are retracted for approaching the middle and posterior parts of the third ventricle. Note the interthalamic adhesion and the floor of the third ventricle (Fig. 7.0.35).

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intraventricular and intradural space is filled with artificial CSF solution at body temperature. For this purpose it is useful if the craniotomy is placed at the highest point of the head, otherwise severe postoperative pneumocephalus can occur. The dural incision should be closed with watertight sutures. If tension has developed in the dural plane, tissue of the galea aponeurotica can be used for sufficient closure. A plate of gelfoam is then placed extradurally; note that this gelfoam plate should not compress the superior sagittal sinus. After fixation of the bone flap and after final verification of hemostasis, the periosteum, subcutaneous layer and the skin are closed each with interrupted sutures. Due to the limited approach, a suction drain is not necessary.

Potential errors and their consequences

Most of the complications after intraventricular surgery are related to the location and nature of the primary lesion itself rather than to the surgical approach. However, some typical surgical errors and their consequences should be discussed in detail.

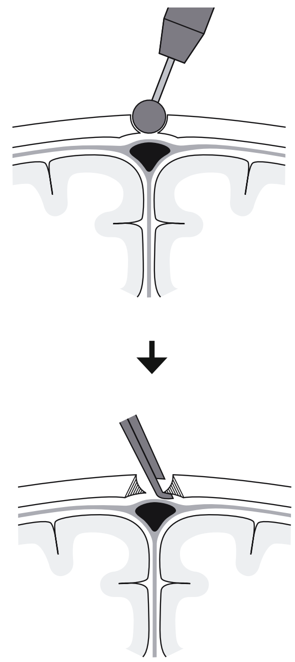
- Incorrect preoperative planning with insufficient intracranial exposure.
- Injury to the SSS during craniotomy, in some cases with severe consequences. Compression of the SSS by hemoclips may cause sinus thrombosis and subsequent venous infarction of the frontal lobe.
- Venous infarction may also occur due to occlusion of large bridging veins running into the SSS.
- Excessive frontal lobe retraction against gravity due to poor positioning of the head. Akinetic mutism can develop after rough retraction against both cingulate gyri.
- Decrease in spontaneous speech ranging from a mild slowness to frank mutism due to extended sectioning of the anterior portion of the corpus callosum.
- Contusion of the fornix approaching the third ventricle may result in temporary or in some cases persistent amnestic syndromes.
- Inadequate intracranial hemostasis with postoperative intraventricular rebleeding. Temporary insertion of a ventricular drain can be recommended.

- Incorrect positioning of the head during dural closure with severe pneumocephalus after surgery.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap with compression of the SSS and subsequent venous infarction.
- Poor hemostasis during wound closure with postoperative soft tissue hematoma.

Fig. 7.0.36

Tips and tricks

Fig. 7.0.37



- Take time for preoperative planning. The reward is excellent intracranial visualization of the target area.
- Adequate positioning of the head results in a gravity-supplemented self-retraction of the frontal lobe, avoiding excessive brain retraction (Fig. 7.0.36).
- Make careful anatomical orientation and use the three steps of planning the approach: 1. osseous structures; 2. placement of the craniotomy; 3. skin incision.
- Creating the burr hole trephination, the lateral borders of the SSS should be checked, avoiding injury during craniotomy (Fig. 7.0.37).
- Stages of craniotomy (Fig. 7.0.38): 1. frontal and 2. parietal burr hole trephinations with effective control of the SSS; 3. ipsilateral and 4. contralateral cutting from the burr hole trephinations with a high-speed craniotome.
- Another variation allowing safe exposure of the SSS corresponds to four burr hole trephinations on both sides of the sinus. By this technique, the groove of the SSS is explored laterally without danger of sinusoidal bleeding during the trephinations.
- Due to removal of the inner edge of the craniotomy anteriorly and posteriorly, the angle for intracranial visualization significantly increases (Fig. 7.0.39).

Fig. 7.0.38

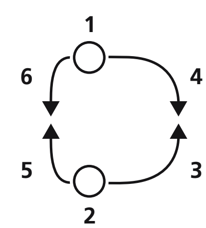


Fig. 7.0.39

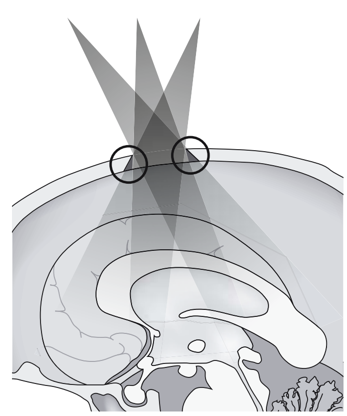


Fig. 7.0.40

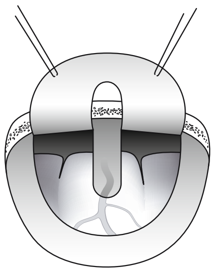


Fig. 7.0.41

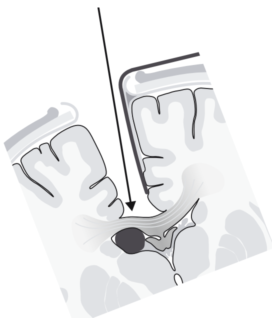


Fig. 7.0.42

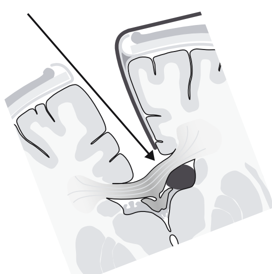


Fig. 7.0.43

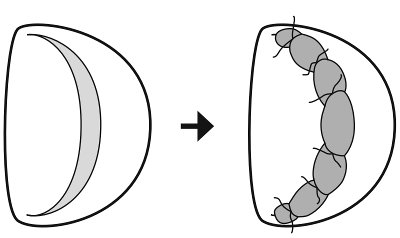
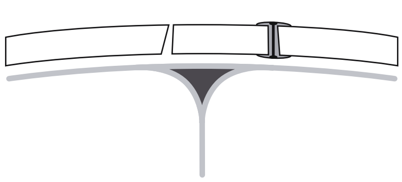


Fig. 7.0.44



- The dura should be opened in a "C" shaped, semicircular fashion with the base of the dural flap toward the midline. Preservation of bridging veins is essential to avoid cerebral venous infarction. If a large bridging vein is present, the vein should be dissected from the arachnoidea of the cerebral surface and from the dural surface of the falx cerebri. If possible, the vein should be carefully protected with a special dural opening (Fig. 7.0.40).

- Ventricular lesions located medially within the ventricular chamber should be exposed via ipsilateral interhemispheric approach (Fig. 7.0.41).

- Lesions located in the lateral part of the lateral ventricle can be effectively exposed via a contralateral interhemispheric approach (Fig. 7.0.42).

- During wound closure, the dura should be closed with watertight sutures. If necessary, tissue of the galea aponeurotica can be used for this purpose (Fig. 7.0.43).

- The bone flap should be fixed without compression of the SSS avoiding sinusoidal thrombosis (Fig. 7.0.44).

- The skin incision within the haired area can be closed with interrupted or running sutures.

- Due to the limited skin incision, a suction drain is not required.

7.1 The anterior (frontal) subcallosal variation of the interhemispheric approach

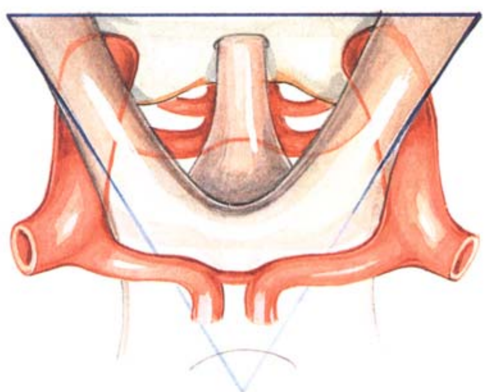


Fig. 7.1.1 *Schematic drawing of the suprasellar pyramid approaching from an anterior direction. The structures of the chiasm, the optic nerves, the pituitary stalk and the lamina terminalis can be well exposed. The carotid bifurcations, the anterior communicating artery and the proximal segments of the anterior cerebral arteries are also in direct relationship to this anterior suprasellar plane.*

The anterior inferior interhemispheric approach is one of the most frequently used techniques for lesions of the anterior cranial fossa. Using the interhemispheric exposure, extended lesions of the frontal skull base and anterior plane of the suprasellar region can be effectively approached (Fig. 7.1.1).

The exact placement of the midline craniotomy depends on the preoperative planning, taking into consideration the individual patho-anatomy, especially the relationship between the skull base and the corpus callosum, and the form of the genu and rostrum corporis callosi (Fig. 7.1.2.). Through a superiorly placed anterior interhemispheric craniotomy, the frontal skull base can be effectively approached (red arrow), and through a mid-positioned craniotomy, the anterior plane of the suprasellar can be exposed without severe retraction of the frontal lobe (green arrow). A basally placed approach (blue arrow) allows optimal access to the rostrum corporis callosi and through the lamina terminalis into the anterior third ventricle (Fig. 7.1.3).

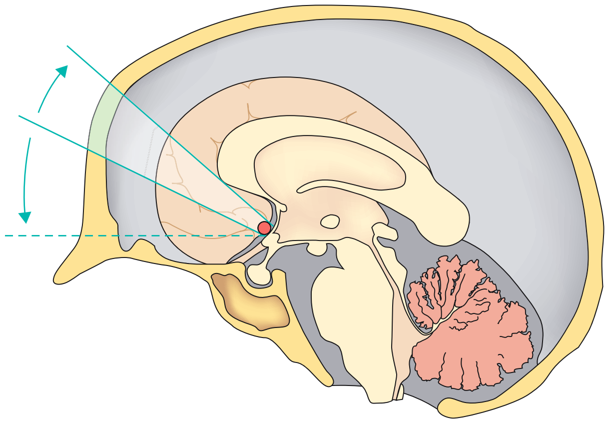


Fig. 7.1.2 *The individual form of the corpus callosum and the localization of the target area decide the placement of the midline craniotomy. After preoperative planning, the maximum height of the craniotomy should be measured from the nasion by MR investigations in the sagittal plane.*

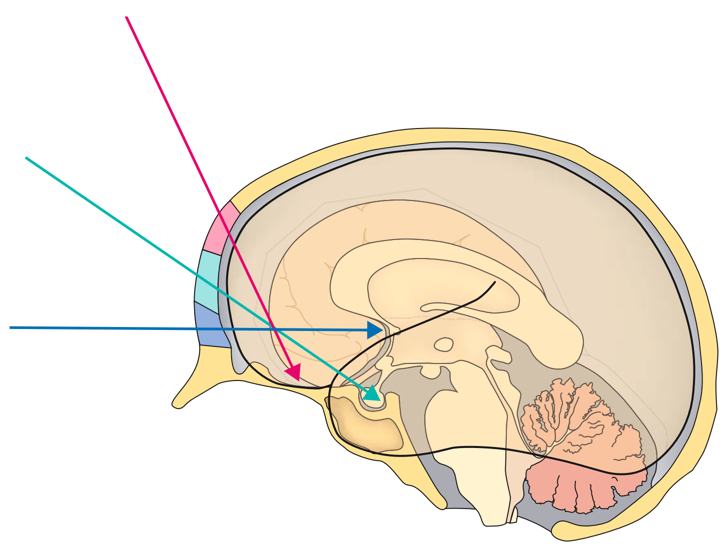


Fig. 7.1.3 *Through different variants of the anterior subcallosal interhemispheric approach, the median skull base (superior variant, red arrow), the suprasellar area (mid-variant, green arrow) and the anterior third ventricle (inferior variant, blue arrow) can be effectively approached without rough retraction of the frontal or temporal lobe.*

Superior variant	Mid-variant	Inferior variant
Anterior third of the superior sagittal sinus	Anterior superior sagittal sinus	Inferomedial frontal lobe
Anterior third of the falx cerebri	Anterior third of the falx cerebri	Anterior third of the falx cerebri
Frontal skull base	Frontal skull base	Rostrum of the corpus callosum
Tuberculum sellae	Tuberculum sellae	Lamina terminalis
Christa galli	Christa galli	Anterior third ventricle
Olfactory groove, lamina cribrosa	Olfactory groove, lamina cribrosa	Optic nerves and chiasm
Superior ethmoidal cells	Sella turcica, diaphragma sellae	ICA, A1, ACoA, A2, incl. perforators
Sphenoid sinus	Medial part of the frontal lobe	
Medial part of the frontal lobe	Genu of the corpus callosum	
Genu of the corpus callosum	Gyrus rectus	
Olfactory bulbs, olfactory tracts	Rostrum of the corpus callosum	
A3, A4	Olfactory tracts	
	Optic nerves and chiasm	
	Pituitary stalk, hypophysis	
	ICA, A1, ACoA, A2, A3, incl. perforators	

Table 7.1.1 *Anatomical structures approached through the different variants of the anterior (frontal) inferior subcallosal interhemispheric approach.*

The decision as to whether the craniotomy is placed left paramedian or right paramedian is made preoperatively with a careful analysis of the diagnostic imaging data. According to the keyhole concept for contralateral approaches (Fig. 7.1.4), deep-seated lesions located right of the midline are best exposed through a left paramedian interhemispheric approach; in contrast, lesions extending left of the midline are best approached via a right paramedian craniotomy.

In the following, the surgical technique of the anterior frontal subcallosal interhemispheric approach is described in detail.

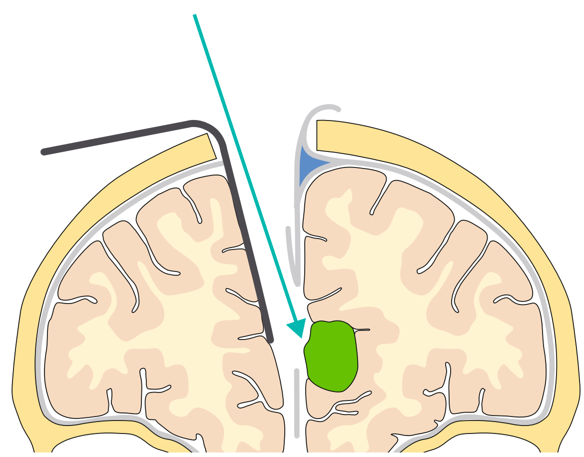


Fig. 7.1.4 *According to the concept of keyhole approaches, in selected cases deep-seated lesions can be best exposed through contralaterally performed craniotomies.*

Surgical technique

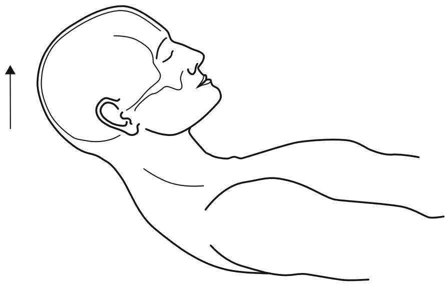


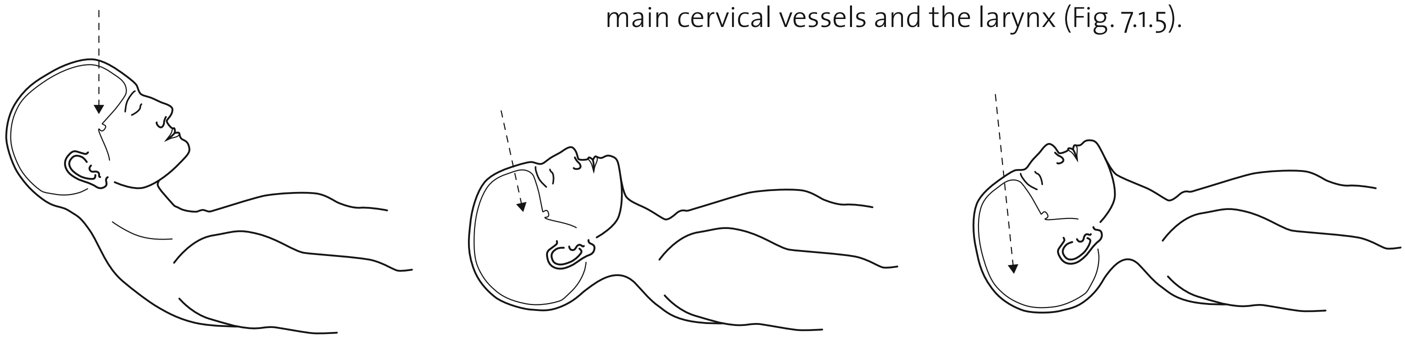
Fig. 7.1.5

1. Patient positioning

With the patient in the supine position, the head is fixed. If used, the single pin of the skull clamp should be placed allowing free dissection during surgery.

Step 1

The head of the operating table is elevated above the thorax, facilitating cranial venous drainage and avoiding compression of the main cervical vessels and the larynx (Fig. 7.1.5).



A B C

Fig. 7.1.6

Step 2

Thereafter, the head is retro- or anteroflected (Fig. 7.1.6). Basically, the more inferiorly the craniotomy is performed, the more retroflexion is needed to achieve an ergonomic surgical position. Thus, lesions with a close proximity to the frontal skull base, which can be exposed via the superior variant of the subcallosal interhemispheric approach, require a moderate anteroflexion of ca. 10° (A). For the mid-variation of the craniotomy exposing the sellar and suprasellar area, a retroflexion of ca. 10° to 20° is sufficient (B). Structures situated more cranially, for example, lesions of the lamina terminalis, rostrum corporis callosi and anterior third ventricle, can be approached through the inferior variant of the craniotomy (C) with a retroflexion of 30° to 45°.

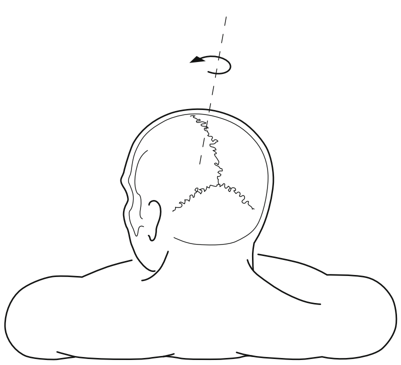


Fig. 7.1.7

Step 3

The head is rotated ca. 10° toward the side of the craniotomy. This maneuvre induces the frontal lobe to relax away from the falx cerebri due to gravity. Thus, access to deep-seated structures can be facilitated with minimum retraction of the brain (Fig. 7.1.7).

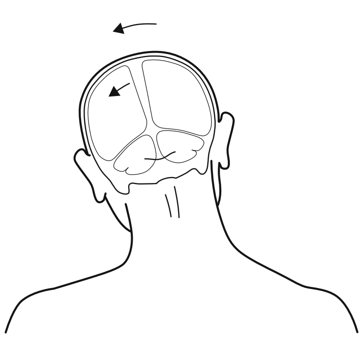


Fig. 7.1.8

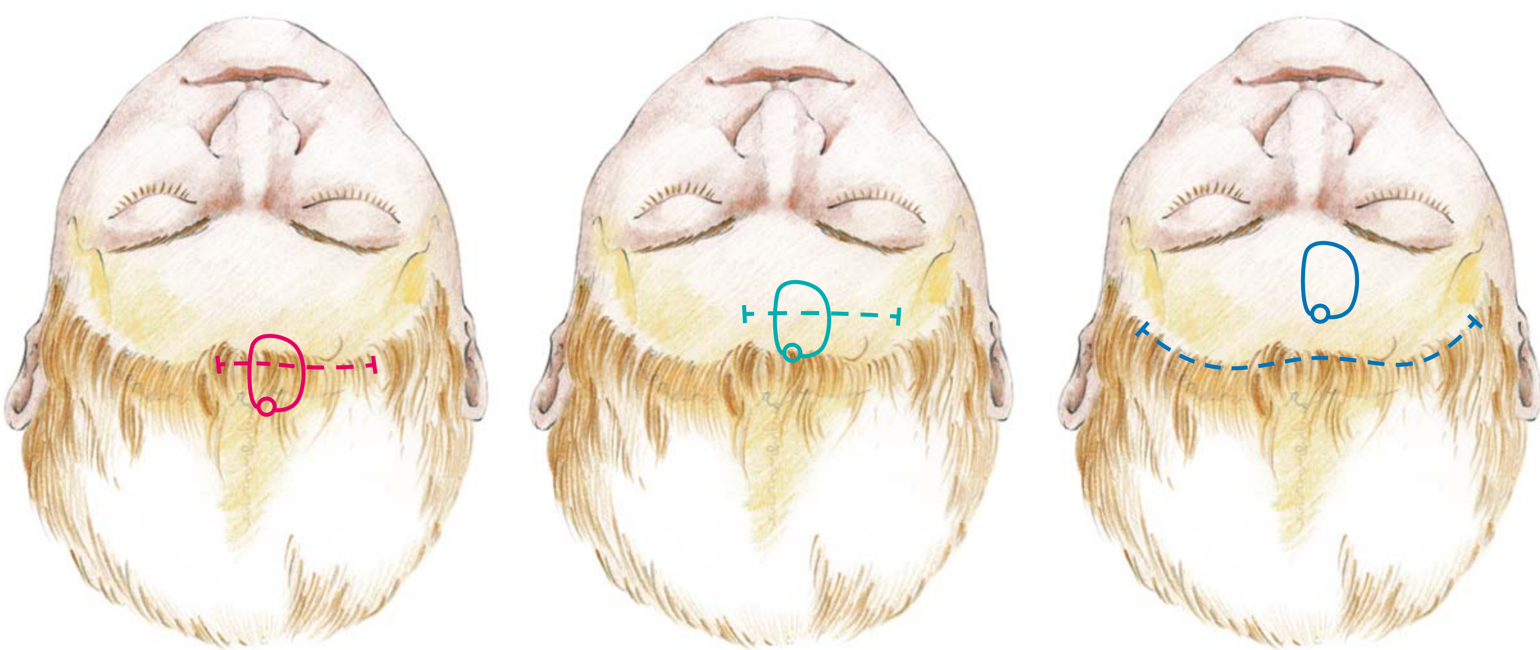
Step 4

Finally, the head should be lateroflected ca. 5° to allow an ergonomic and efficient working position for the surgeon (Fig. 7.1.8).

2. Anatomical landmarks and orientation

For the appropriate skin incision, the important anatomical landmarks of the osseous skull, such as the midline, coronary suture, orbital rim, supraorbital foramen and the frontal paranasal sinus should be precisely defined and marked with a sterile pen (Fig. 7.1.9).

The borders of the craniotomy are marked exactly with the craniotomy usually crossing the midline and the anterior superior sagittal sinus. As mentioned above, placement of the craniotomy depends on the individual shape of the corpus callosum and on the localization of the target area. After definition of the craniotomy, the optimum line of the skin incision is marked; this horizontal skin incision is usually placed at the frontal hairline (A). For bald-headed patients or more basally planned craniotomies, a wrinkle of the skin may be chosen for this purpose, achieving a pleasing cosmetic result (B). For the inferior variant of the approach, for patients without any wrinkles in the frontal area, an extended standard bicoronar skin incision can be performed (C). The surface of the skin should be disinfected carefully.



A B C

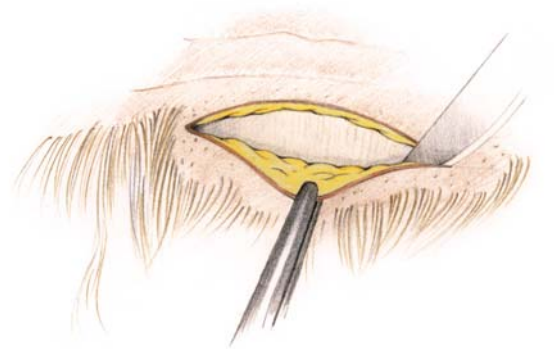
Fig. 7.1.9 *Definition of the craniotomy and skin incision according to the target region, anatomical landmarks and individual physiognomy of the patient. Superior variant with limited skin incision behind the hairline (A). Mid variant using a wrinkle for the skin incision (B). Inferior variant; for patients without any wrinkles in the forehead, an extended bicoronar skin incision can be performed (C).*

3. Craniotomy

Step 1

Right side. After minimal or even absent hair shaving, the skin is disinfected using alcohol solution. The skin and the subcutaneous tissue are incised and retracted exposing the galea aponeurotica and the frontal belly of the occipitofrontal muscle (Fig. 7.1.10).

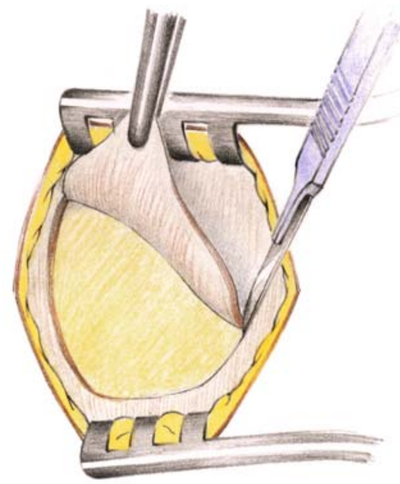
Fig. 7.1.10



Step 2

The galea and the periosteum are incised in a semicircular fashion and dissected as a common flap with the base toward nasal. This galea flap can be effectively used for dural graft as well as for closing the frontal paranasal sinus if necessary (Fig. 7.1.11).

Fig. 7.1.11



Step 3

After bilateral retraction of the soft tissue layers, a single midline burr hole trephination is created parietally at the postero-medial corner of the planned craniotomy. The dura mater is mobilized with a blunt dissector; the burr hole is enlarged using fine Kerrison rongeurs guiding the lateral borders of the superior sagittal sinus (Fig. 7.1.12).

Fig. 7.1.12

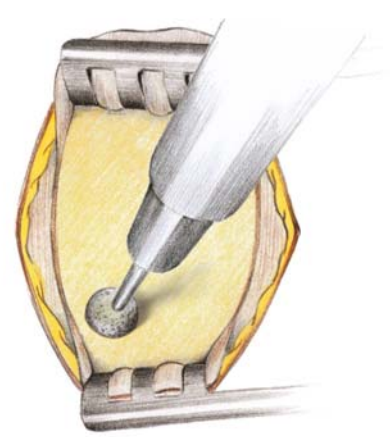
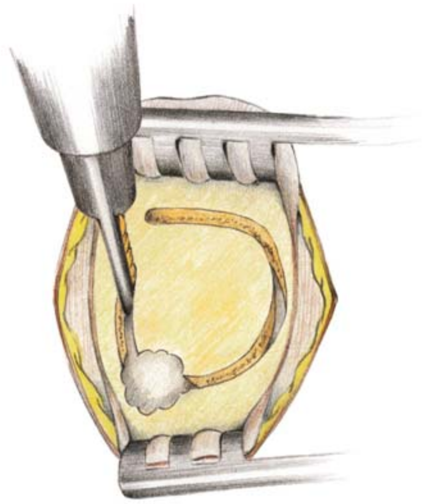


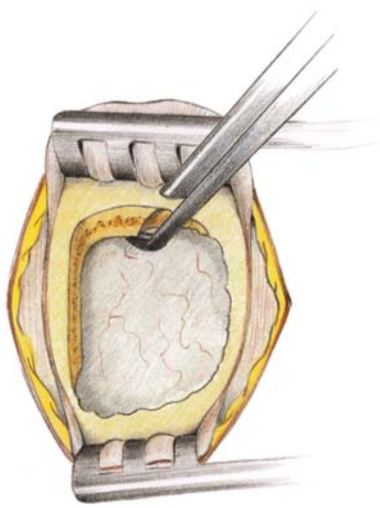
Fig. 7.1.13



Step 4

A semilunarly shaped line is then sawed with the high-speed craniotome on the ipsilateral side, from the posteriorly placed burr hole to the anterior mid-line. Thereafter, a second paramedian craniotomy line is sawed on the opposite side, just laterally from the superior sagittal sinus, thus creating a craniotomy with a diameter of 2.0–3.0 cm (Fig. 7.1.13).

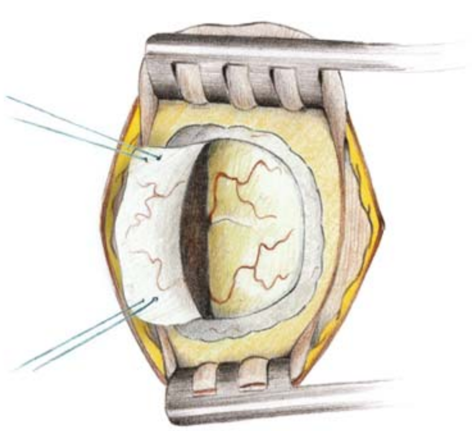
Fig. 7.1.14



Step 5

After removal of the bone flap, the inner edge of the tabula interna is removed using fine punches. Due to careful removal of this inner bone edge, the angle for intracranial visualization can be significantly increased (Fig. 7.1.14).

Fig. 7.1.15



Step 6

The dura should be opened in a semicircular fashion with the base of the dural flap towards the superior sagittal sinus. The free dural flap is fixed with two sutures; other dural elevation sutures are not necessary (Fig. 7.1.15).

4. Intradural dissection

Step 1

Right side. Dissection performed on a fresh human specimen; arteries are prepared with red, veins with blue colored latex solution. After opening the dura mater, the superior frontal gyrus and bridging veins toward the superior sagittal sinus are carefully exposed and, whenever possible, the bridging veins are preserved. The next step should be the sufficient drainage of CSF by opening the subarachnoid cisterns. In some cases, trapping of the lateral ventricle may be necessary. The frontal lobe is gently mobilized and the anterior interhemispheric fissure approached. Correct positioning of the head offers significant relaxation of the frontal lobe, which then, due to gravity, will sink spontaneously away from the falx cerebri. Therefore major retraction of the frontal lobe is usually not required. Note the microforceps gently retracting the superior frontal gyrus (Fig. 7.1.16).

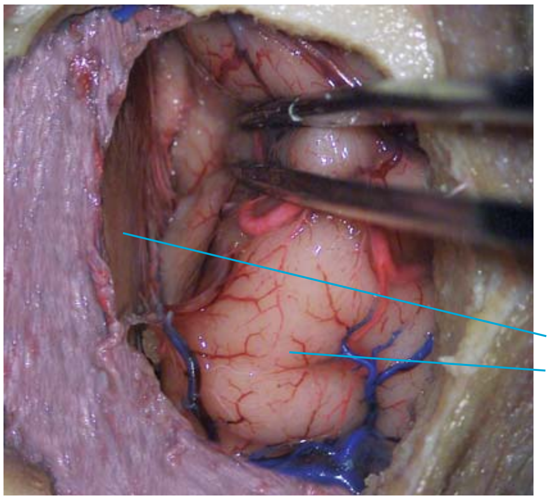


Fig. 7.1.16

Step 2

The frontal lobe is retracted with a brain spatula exposing the genu of the corpus callosum. Note the pericallosal and callosomarginal arteries. The opposite frontal lobe is protected by the falx. In the contralateral interhemispheric midline, the cingulated gyrus can be exposed (Fig. 7.1.17).

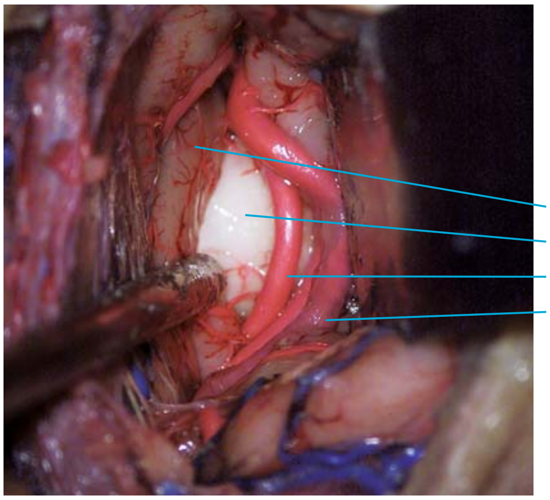


Fig. 7.1.17

Step 3

Anterior to the genu, the interhemispheric fissure is carefully opened. Note the A3 segments of both anterior cerebral arteries running around the genu of the corpus callosum (Fig. 7.1.18).

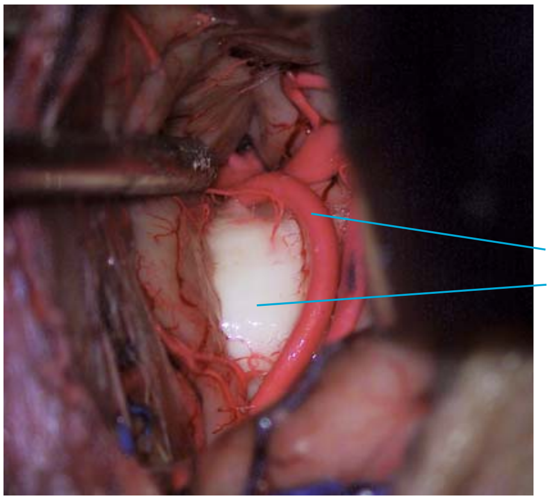


Fig. 7.1.18

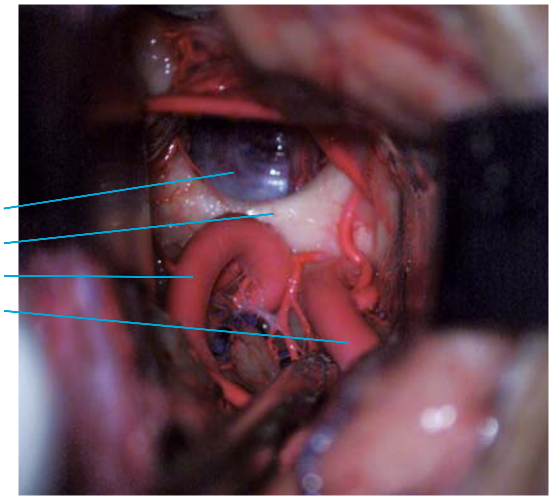


Fig. 7.1.19

Step 4

The anterior interhemispheric fissure is opened with brain spatulas, observing the base of the anterior cranial fossa through the midline route. Note the A2 segments of the anterior cerebral arteries. The optic chiasm and the diaphragma sellae appear in the background (Fig. 7.1.19).

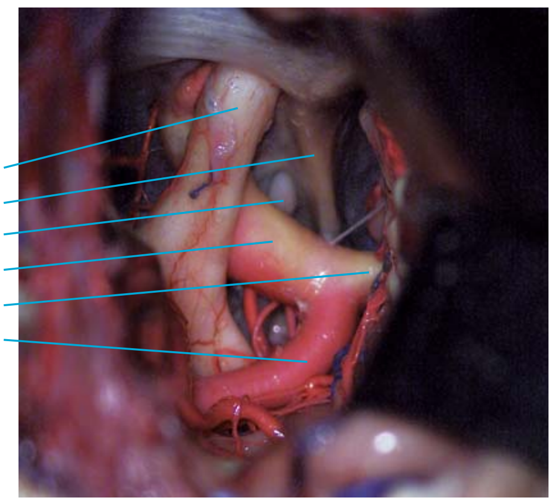


Fig. 7.1.20

Step 5

Exposure of the ipsilateral suprasellar area through the anterior interhemispheric route. Note the right optic nerve and tract and the division of the ICA into the ACA and MCA. Medial to the anterior petroclinoid fold, the CN III disappears into the roof of the cavernous sinus (Fig. 7.1.20).

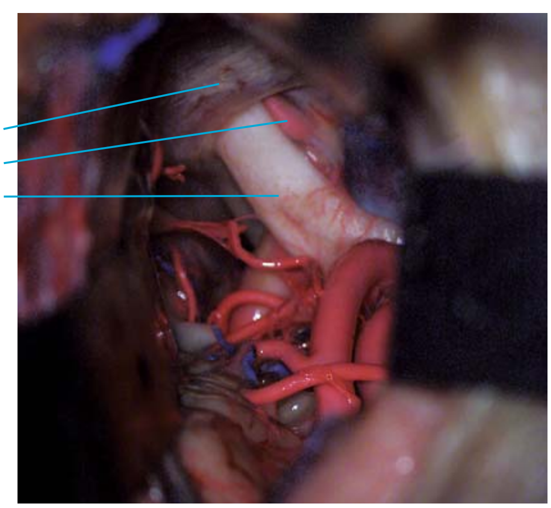


Fig. 7.1.21

Step 6

The falx cerebri and the contralateral frontal lobe are retracted, approaching the opposite CN II and ICA. Note the ophthalmic artery disappearing under the falciform ligament (Fig. 7.1.21).

Step 7

Observation of the optical chiasm and the lamina terminalis. Note the hypoplastic ACoA and the loop of the A2 segments of the ACA (Fig. 7.1.22).

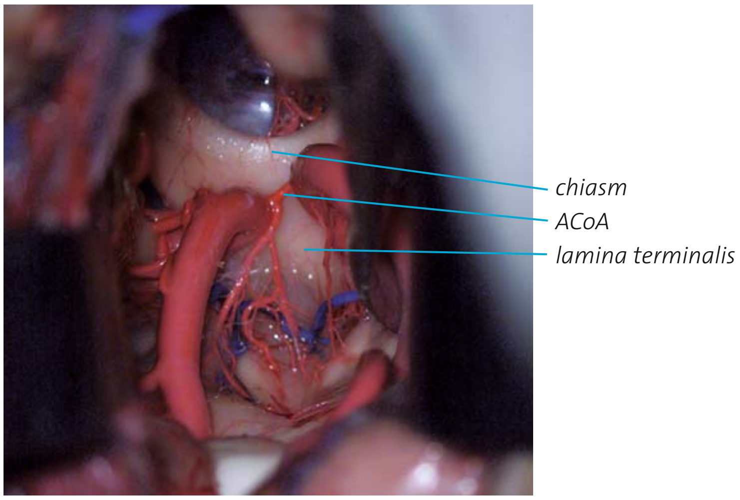


Fig. 7.1.22

Step 8

After opening the lamina terminalis and the floor of the third ventricle, the right P1 segment and the basilar apex are visualized within the interpeduncular fossa. Note the two mamillary bodies (Fig. 7.1.23).

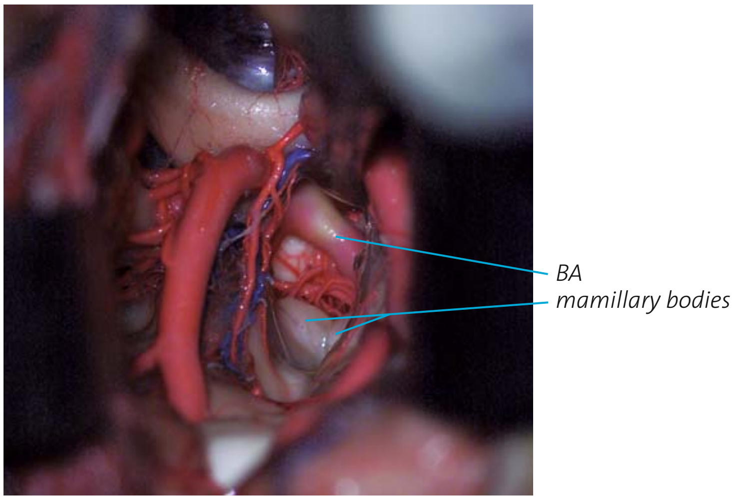


Fig. 7.1.23

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural subarachnoid space is filled with artificial CSF solution at body temperature. The dural incision is closed watertight with interrupted or continuous sutures. Dura leaks can be repaired by using a galea-periosteum graft. If opened, the frontal paranasal sinus should be closed with the galea flap as mentioned previously. A plate of gelfoam is placed extradurally and the bone flap is fixed. The burr hole should be closed with a large-sized titanium plate, allowing a pleasant cosmetic outcome after frontal craniotomy. After final verification of hemostasis, the periosteum and the subcutaneous layers, each are closed with sutures and the skin with intracutaneous sutures or adhesive tapes.

Potential errors and their consequences

- Insufficient preoperative planning and positioning of the patient with subsequent insufficient exposure of the surgical field and significant deterioration in efficiency of excising the lesion. Planning and positioning is the task of the surgeon!
- Injury to the superior sagittal sinus or frontal bridging veins during craniotomy. Usually, occlusion of the anterior part of the superior sagittal sinus does not result in severe neurological damage; however, if possible, it should be avoided.
- Excessive frontal lobe retraction due to poor head positioning.
- Injuries to numerous neurovascular structures of the interhemispheric and suprasellar region during microsurgical manipulation with postoperative neurological deficits.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap with poor cosmetic outcome.
- Inadequate intra- or extracranial hemostasis with subsequent rebleeding.

Fig. 7.1.24

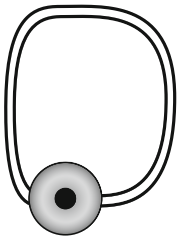


Fig. 7.1.25

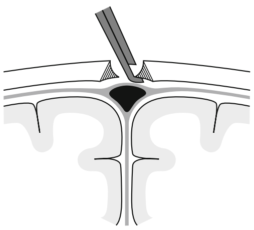


Fig. 7.1.26

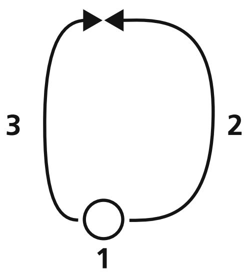


Fig. 7.1.27

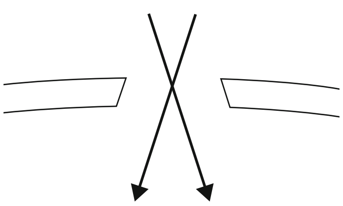


Fig. 7.1.28

Tips and tricks

- Take time for preoperative planning and positioning of patients. The reward is an excellent overview of the target area and an efficient working position.
- Performing the craniotomy, a single burr hole trephination should be performed in the posteromedial corner of the planned craniotomy. After dural closure, the burr hole should be closed with a large titanium plate, providing optimal cosmetic outcome in the frontal area (Fig. 7.1.24).
- Creating the burr hole trephination, the lateral borders of the superior sagittal sinus should be checked, avoiding injury during craniotomy (Fig. 7.1.25).
- Stages of craniotomy (Fig. 7.1.26): 1. posterior burr hole trephination with monitoring of the superior sagittal sinus; 2. ipsilateral and 3. contralateral cutting from posterior to anterior using a high-speed craniotome.
- Removal of the anterior and posterior inner edges of the craniotomy provides increased intracranial visualization (Fig. 7.1.27).
- Adequate positioning of the head results in gravity-supplemented self-retraction of the frontal lobe, avoiding excessive brain retraction (Fig. 7.1.28).
- During wound closure, the bone flap should be fixed inferiorly without bony dehiscence for a better cosmetic outcome.
- Suction drain is not required.

7.2 The posterior (occipital) subcallosal modification of the interhemispheric approach

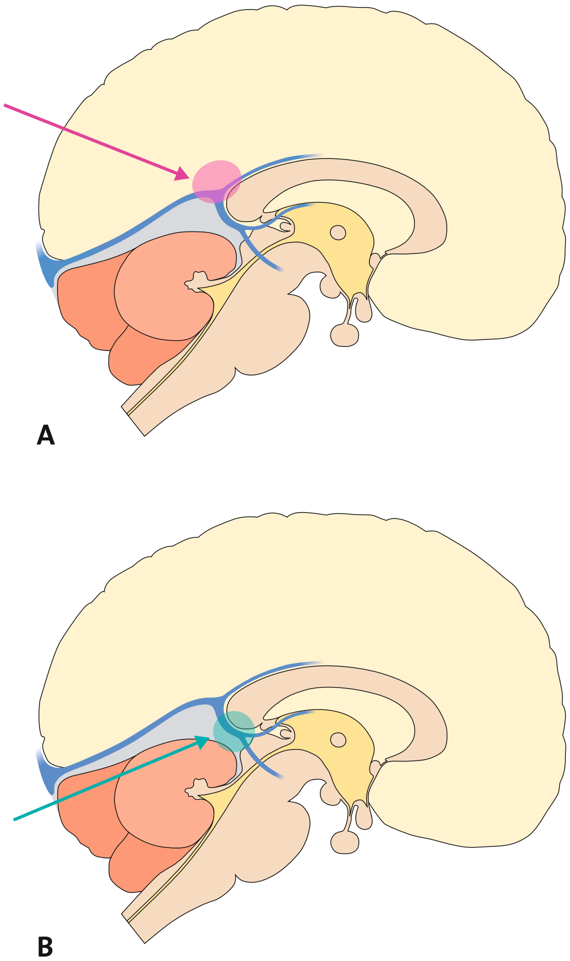


Fig. 7.2.1 *The posterior interhemispheric approach can be recommended for lesions situated above the great cerebral vein of Galen (A). Lesions situated beneath the deep venous system are reached best through the infratentorial supracerebellar approach (B).*

Using the posterior interhemispheric approach, the posterior part of the tentorial incisura can be exposed via a supratentorial route. This posterior incisural space is located posterior to the midbrain and corresponds to the region of the quadrigeminal cistern. In this way, the splenium of the corpus callosum, pineal gland, mesencephalic tectum, upper part of the vermis and the complex neurovascular relationship of the quadrigeminal cistern can be well observed. Special attention should be given to the venous contributors of the vein of Galen, the vessels of the posterior cerebral and superior cerebellar arteries, and to the trochlear nerve.

Lesions within the posterior incisural space can also be approached via the infratentorial supracerebellar route, described in chapter 6.0. The supratentorial subcallosal interhemispheric approach is described here, preferred for lesions centered at the tentorial edge, especially if they are situated above the vein of Galen (Fig. 7.2.1).

Using the posterior subcallosal approach with an additional splitting of the tentorium just parallel to the straight sinus, the supratentorial approach may also provide excellent access to the posterior fossa for lesions involving the cerebellomesencephalic fissure and the posterior part of the ambient cistern.

According to the keyhole concept, contralateral approaches can be used in several cases allowing minimal retraction and optimal exposure (Fig. 7.2.2)

In the following, the surgical technique of the posterior interhemispheric approach is described in detail.

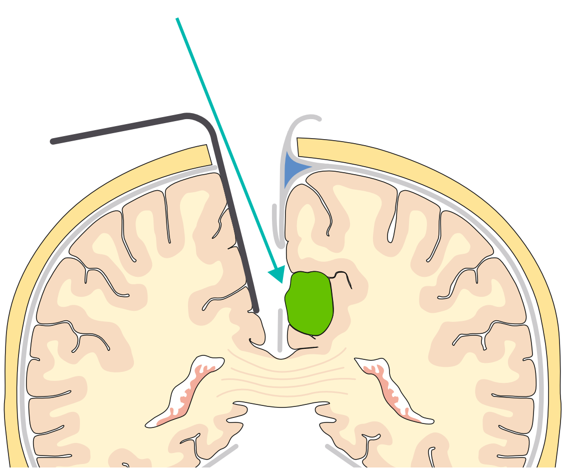


Fig. 7.2.2 *Contralateral exposure of a midline lesion using the concept of keyhole neurosurgery. Note placement of craniotomy and approaching after fenestration of the posterior part of the falx cerebri.*

Supratentorial	Infratentorial
Posterior part of the SSS Posterior part of the falx Straight sinus, tentorium Medial surface of the occipital lobe Splenium of the corpus callosum Posterior part of the ISS Posterior pericallosal artery Distal segments of the PCA Vein of Galen	Splenium of the corpus callosum Vein of Galen Basal vein of Rosenthal Internal cerebral vein Central vein of the cerebellum Pineal gland Cisterna veli interpositii Quadrigeminal plate Upper vermis CN IV Distal segments of the PCA and SCA

Table 7.2.1 *Anatomical structures exposed by the posterior interhemispheric approach.*

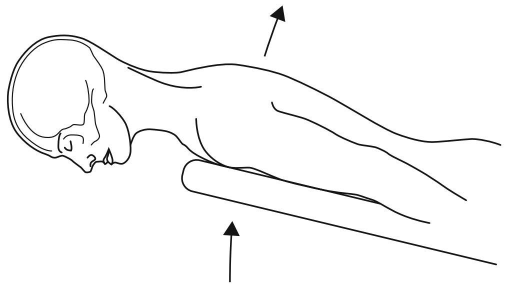


Fig. 7.2.3

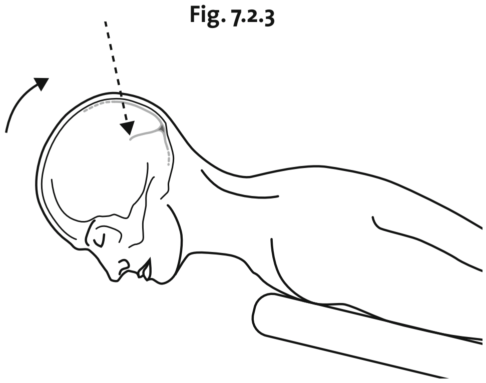


Fig. 7.2.4 A

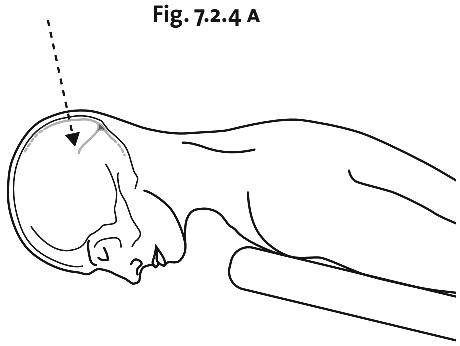


Fig. 7.2.4 B

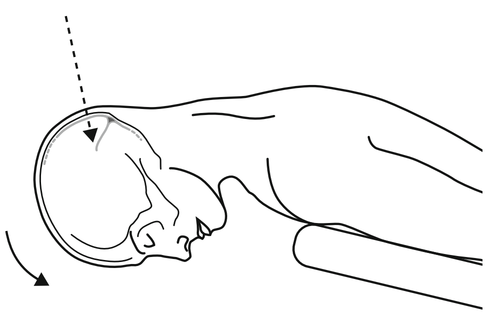


Fig. 7.2.4 C

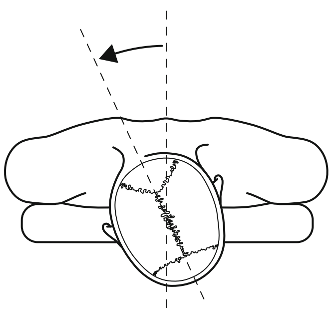


Fig. 7.2.5

Surgical technique

1. Patient positioning

Using the posterior interhemispheric approach, two different patient positions are possible. The semisitting position with forced elevation and anteroflexion of the head offers an optimal venous drainage within the quadrigeminal region; however, this position carries a risk of air embolism and requires an uncomfortable working position for the surgeon. The simple prone position allows an efficient working position during surgery without the danger of air embolism. The elevated pressure in the deep cerebral veins, according to the prone position, can be effectively improved by a sufficient elevation and retroflexion of the head. The patient is placed in a neutral prone position on the operating table. The head of the patient is fixed in a three-pin Mayfield holder so that the sagittal suture is in a near vertical position.

Step 1

The body and the head are elevated to about 15° by moving the operating table. This elevation is necessary to bring the head above the level of the thorax for better venous drainage (Fig. 7.2.3).

Step 2

Thereafter, the head may be antero- or retroflected to ca. 45° in order to bring the tentorium into a more horizontal plane. The exact degree of flexion depends on the form of the straight sinus and the height of the planned craniotomy (Fig. 7.2.4 A, B, C). If the straight sinus is more perpendicular, the retroflexion should not be particularly excessive and the craniotomy can be placed near to the external occipital protuberance.

Step 3

Using a slight rotation of ca. 10°, the occipital lobe sinks away from the falx cerebri due to a gravity-related self-retraction of the ipsilateral cerebral hemisphere. Thus, access to deep-seated structures can be obtained with a minimum of brain retraction (Fig. 7.2.5).

2. Anatomical landmarks and orientation

Before performing the skin incision, the osseous anatomical landmarks of the occipital region such as the midline, lambdoid suture, and external occipital protuberance should be localized (Fig. 7.2.6).

The exact site of the limited craniotomy depends on the individual form of the tentorium and the straight sinus and on the individual pathoanatomical situation. As mentioned above, the more perpendicular the form of the straight sinus, the nearer the craniotomy is placed to the external occipital protuberance.

The side of the craniotomy may be preferred according to the concept of keyhole approaches. Deep-seated lesions located right of the midline can be well exposed using a left paramedian interhemispheric approach; conversely, lesions extending left of the midline are in some cases better approached via a right paramedian craniotomy. However, note that a contralateral exposure can be particularly well hidden by the falx cerebri and by the venous complex of the great cerebral vein of Galen.

After anatomical orientation and planning of the craniotomy, the individual optimum line of the perpendicular skin incision is marked. The incision is placed ca. 1.5 cm from the midline with a length of ca. 5.0 cm (Fig. 7.2.6). Note carefull skin incision.

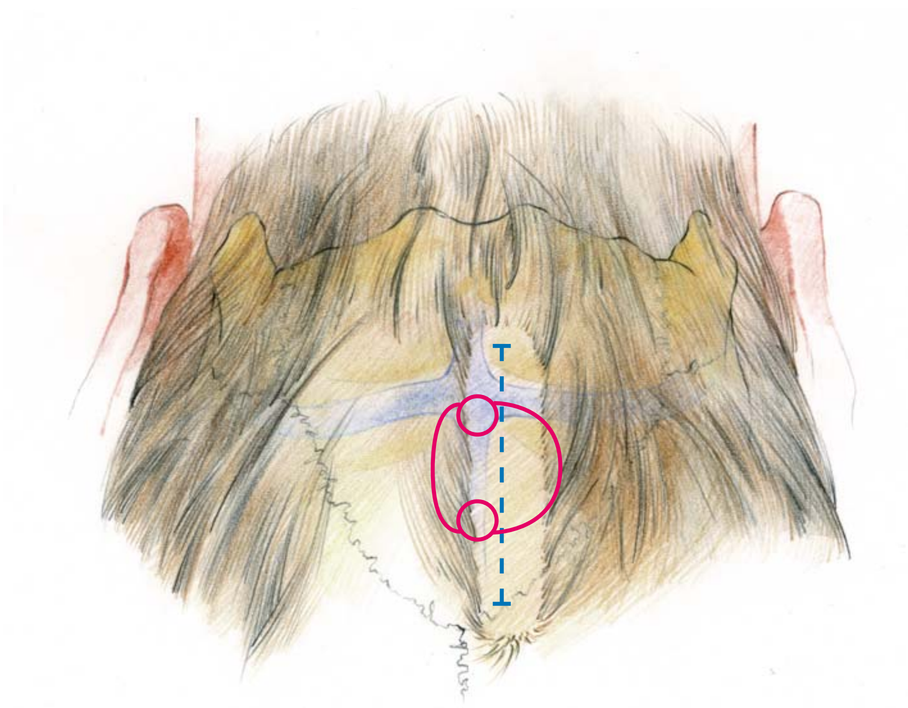


Fig. 7.2.6 *Definition of the craniotomy and skin incision according to the anatomical landmarks.*

3. Craniotomy

Step 1

Left side, prone position. After minimal shaving of the hair, the skin and the subcutaneous tissue are incised in a straight perpendicular fashion and the skin flaps are retracted exposing the occipital belly of the occipitofrontal muscle (Fig. 7.2.7).

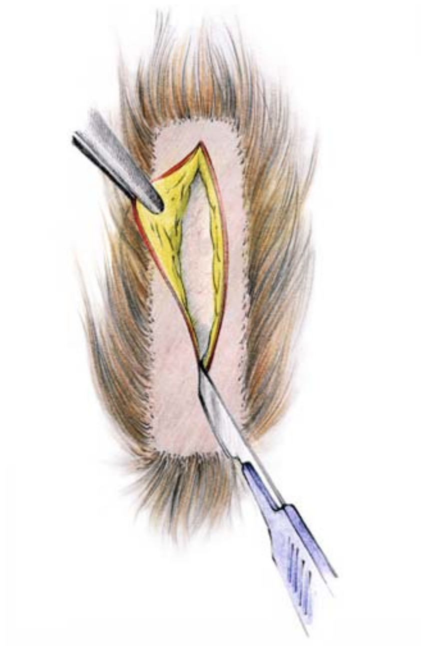


Fig. 7.2.7

Step 2

The occipital muscle and the galea aponeurotica are incised in a semicircular fashion and dissected together with the periosteum from the bony surface. This layer is then retracted as a flap with the base to the midline (Fig. 7.2.8).

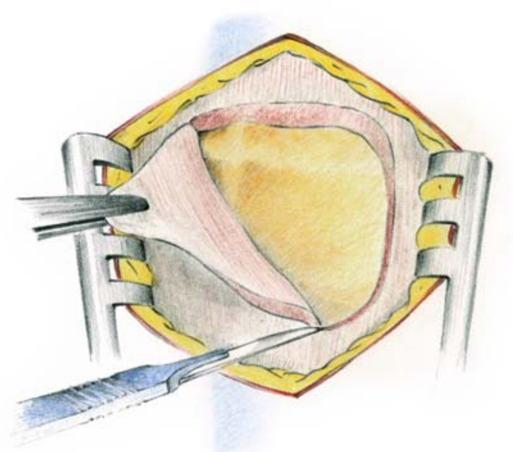


Fig. 7.2.8

Step 3

In all cases, an osteoplastic craniotomy is carried out carefully checking the superior sagittal sinus and torcular herophili. Similar to other interhemispheric approaches, we insist on performing two midline burr hole trephinations, monitoring the prominent posterior part of the sagittal sinus (Fig. 7.2.9).

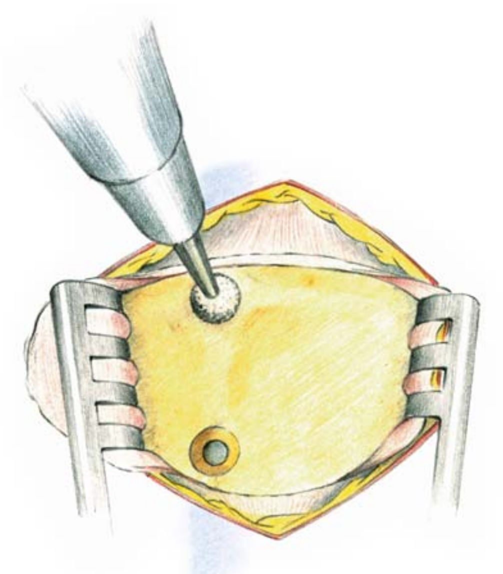
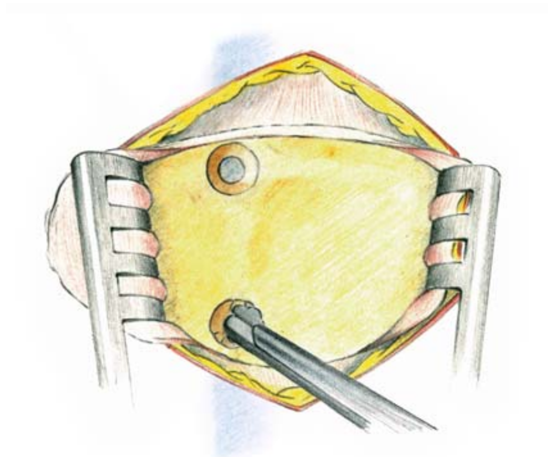


Fig. 7.2.9

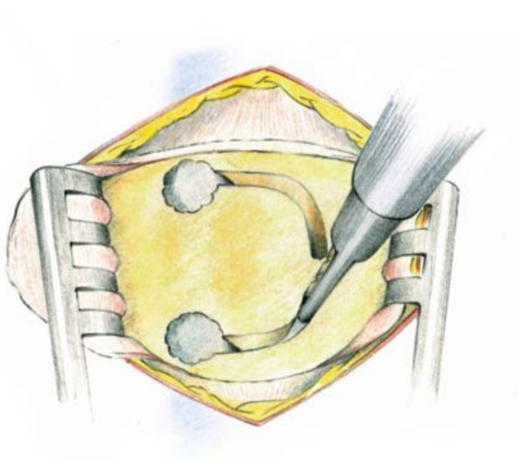
Fig. 7.2.10



Step 4

After visualization of the dural surface of the superior sagittal sinus, the dura mater should be carefully freed using blunt dissectors. With fine Kerrison rongeurs, the lateral borders of the sinus are exposed without damaging the sinus (Fig. 7.2.10).

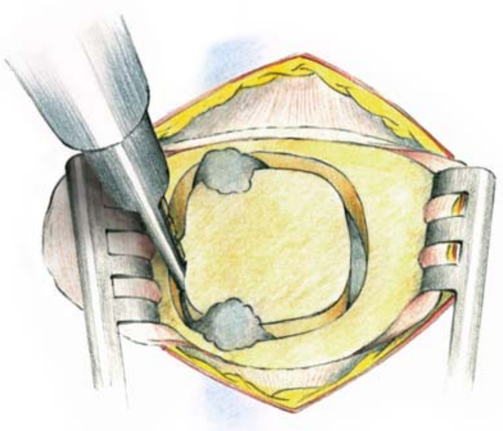
Fig. 7.2.11



Step 5

With a high-speed craniotome, a curved line is sawed from the occipital burr hole on the ipsilateral side. This ipsilateral cut is then completed from the parietal burr hole (Fig. 7.2.11).

Fig. 7.2.12



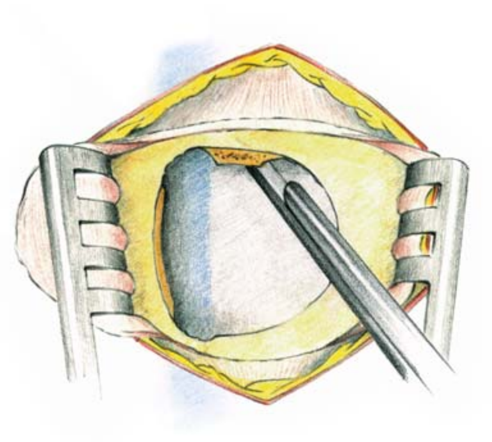
Step 6

Thereafter, the craniotome is used on the opposite side in a similar way, creating a paramedian craniotomy of 2.0 to 3.0 cm in diameter (Fig. 7.2.12).

Step 7

An important step of the craniotomy is the removal of the tabula interna using fine punches (Fig. 7.2.13).

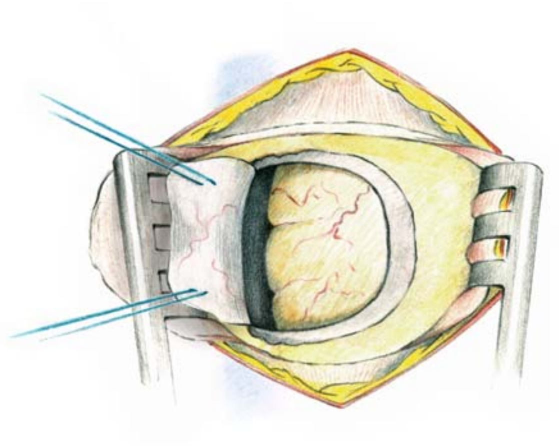
Fig. 7.2.13



Step 8

After performing the craniotomy, the dura is opened in a semicircular fashion with the base of the dural flap toward the superior sagittal sinus. The free dural flap is fixed with two sutures without the need for other elevation sutures (Fig. 7.2.14).

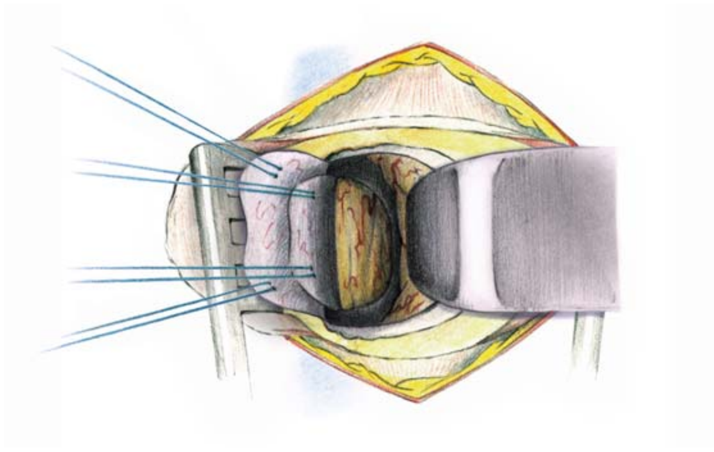
Fig. 7.2.14



Step 9

By contralateral approaches, the falx cerebri can be opened exposing the opposite parieto-occipital areas (Fig. 7.2.15).

Fig. 7.2.15



4. Intradural dissection

Step 1

Left side. Dissection using a fresh human cadaver. Arterial and venous vessels are prepared with red and blue colored latex solution respectively. After durotomy, the occipital lobe is carefully moved away from the falx with microforceps. Compared with the frontal and parietal area, occurrence of prominent bridging veins in the occipital region is uncommon, and, if present, they run several millimeters along the interhemispheric fissure, making an arachnoidal dissection and movement easier. With adequate positioning of the patient, the spatula pressure can be sufficiently minimized, dictated by the gravity-enhanced relaxation of the occipital lobe (Fig. 7.2.16).

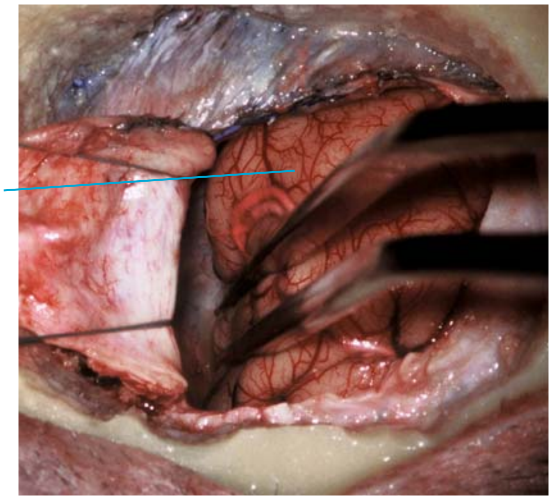


Fig. 7.2.16

Step 2

As usual, an important step of the intracranial dissection is the sufficient drainage of CSF by opening the subarachnoid cisterns. In the case of elevated intracranial pressure, the posterior horn of the lateral ventricle can be punctured with a ventricular cannula. Note the retracted occipital lobe (Fig. 7.2.17).

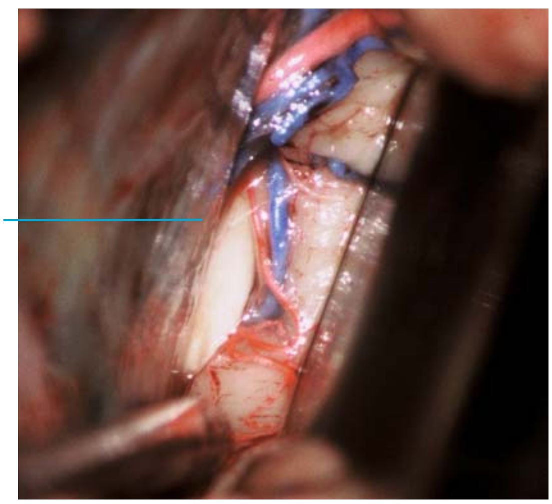


Fig. 7.2.17

Step 3

With additional retraction of the occipital lobe, the transition between the posterior ambient and quadrigeminal cisterns can be approached. Note the veins running to the great cerebral vein of Galen, which is, at this stage of the surgery, hidden behind the gently retracted tentorium. Note the splenium of the corpus callosum (Fig. 7.2.18).

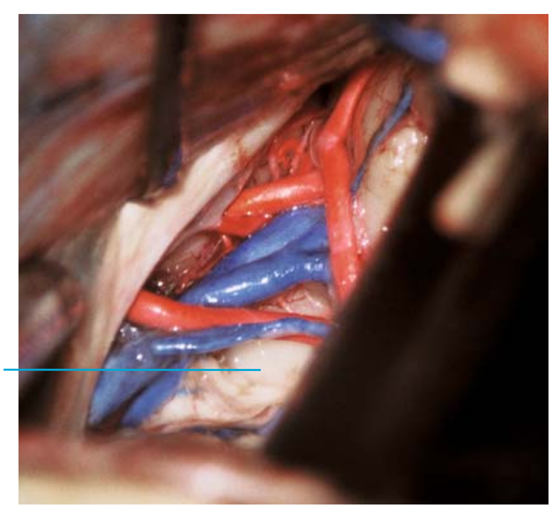


Fig. 7.2.18

Step 4

The arachnoid sheets of the quadrigeminal cistern are opened exposing the quadrigeminal plate and the pineal gland. Note the doubled basal vein of Rosenthal disappearing within the ambient cistern. The white tissue corresponds to the inferior surface of the splenium corporis callosi (Fig. 7.2.19).

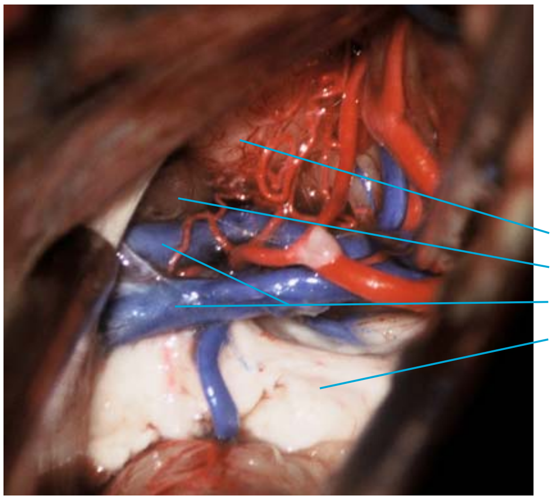


Fig. 7.2.19

Step 5

The transition between the falx and tentorium is retracted with a sucker allowing better exposure of the pineal gland and the quadrigeminal plate (Fig. 7.2.20).

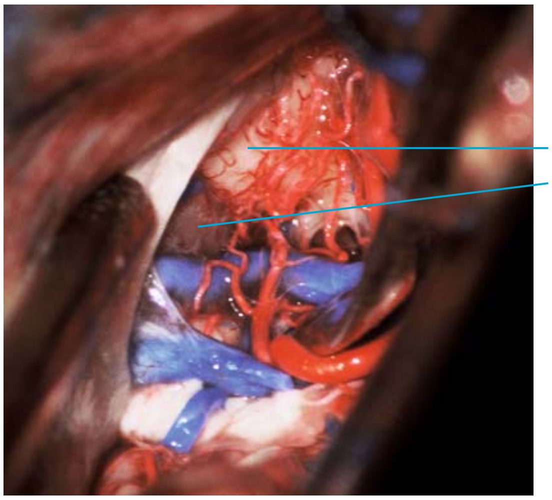


Fig. 7.2.20

Step 6

Open the tentorium parallel to the course of the straight sinus using a sharp microknife. The tentorial surface of the cerebellum appears through the gap (Fig. 7.2.21).

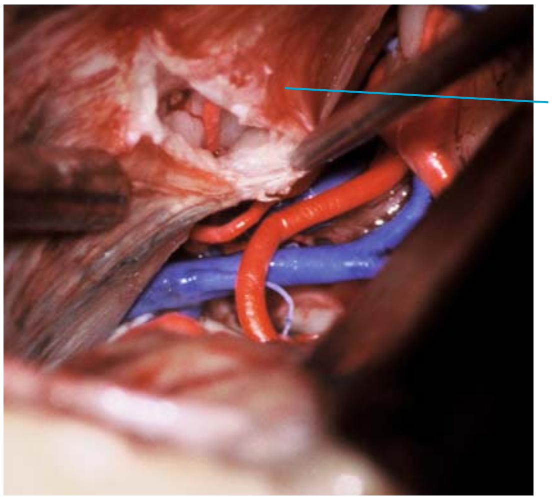


Fig. 7.2.21

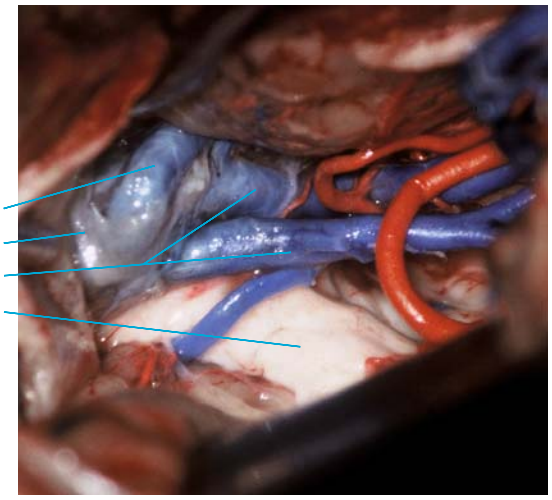


Fig. 7.2.22

Step 7

After splitting the tentorium, the confluence of the great vein of Galen into the straight sinus can be exposed. Note the venous branches of the basal vein of Rosenthal, the internal cerebral vein and the central cerebellar vein (Fig. 7.2.22).

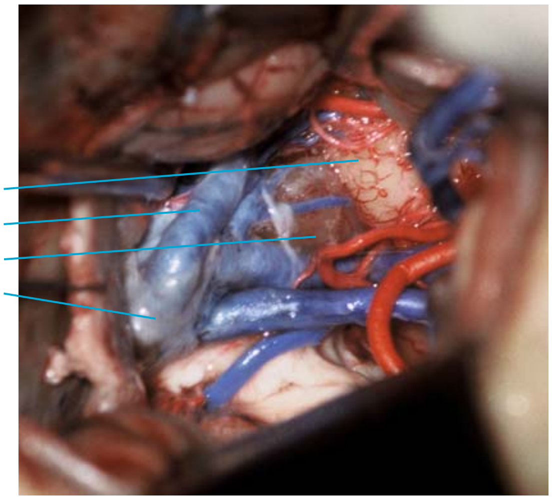


Fig. 7.2.23

Step 8

The tentorium is raised with holding sutures and the cerebellum is gently retracted with a sucker and a dissector. Note the internal cerebral vein and the pineal gland (Fig. 7.2.23).

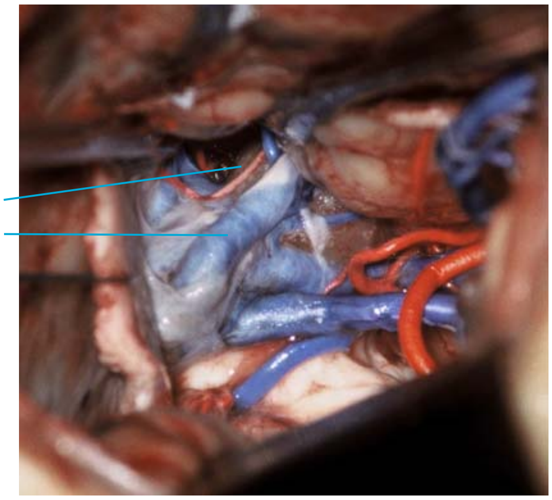


Fig. 7.2.24

Step 9

Following the internal cerebral vein, structures of the velum interpositum can be exposed (Fig. 7.2.24).

Step 10

Dissection of the velum interpositum according to the posterior interhemispheric approach. Note the medial surface of the contralateral thalamus according to the opening of the posterior third ventricle (Fig. 7.2.25).

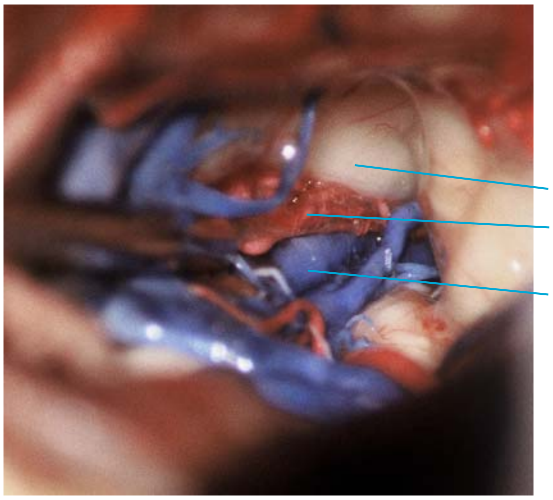


Fig. 7.2.25

Step 11

Dissecting in a lateral direction, the transition of the quadrigeminal and ambient cisterns is approached. Note the fine vasculature of the posterolateral mesencephalon, the brachium colliculi inferioris and the trigonum lemnisci (Fig. 7.2.26).

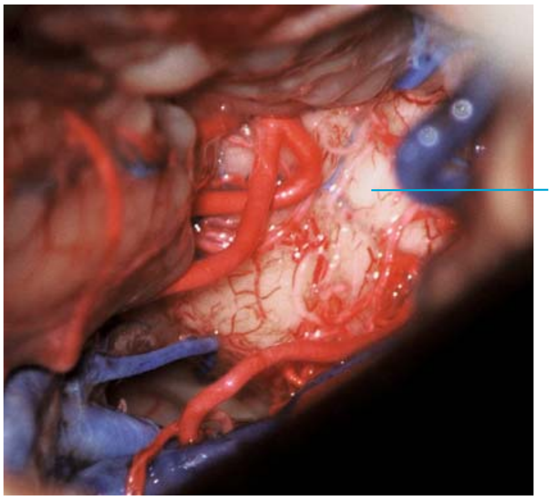


Fig. 7.2.26

Step 12

The trigonum lemnisci of the midbrain with the SCA and the CN IV (Fig. 7.2.27).

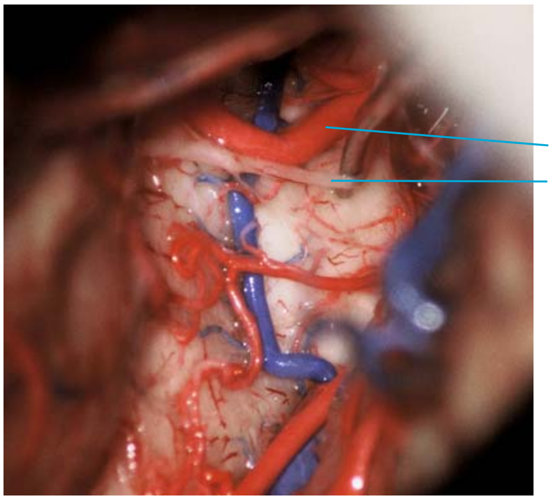


Fig. 7.2.27

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with arteficial CSF and the dural opening is closed with interrupted or continuous sutures. Dura leaks can be repaired by using a galea-periosteum graft. A plate of gelfoam is placed extradurally and the bone flap is fixed with titanium plates. After final verification of hemostasis, the periosteum, subcutaneous layer and the skin are closed with interrupted sutures.

Potential errors and their consequences

- Incorrect preoperative planning with insufficient intracranial exposure.
- Injury to the superior sagittal sinus or torcular herophili during craniotomy, in some cases with severe bleeding and fatal consequences. Note the galea-periost flap for repair.
- Excessive compression of the superior sagittal sinus by the self-retaining retractor with thrombosis of the sinus and subsequent brain infarction.
- Venous infarction due to occlusion of an occipital bridging vein running into the superior sagittal sinus.
- Excessive occipital lobe retraction against gravity due to poor patient positioning. Contusion of the occipital lobe may result in visual disturbances.
- Injury to the splenium corporis callosi may cause left hemialexia, the inability to read in the left visual hemifield, and a broad array of behavioral abnormalities.
- Injuries to numerous vessels and the CN IV within the quadrigeminal and posterior ambient region during microsurgical manipulation with postoperative neurological deterioration.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate hemostasis with subsequent intra- or extracranial rebleeding.

Fig. 7.2.28

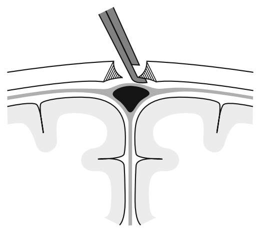


Fig. 7.2.29

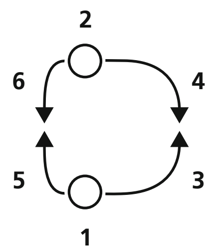


Fig. 7.2.30

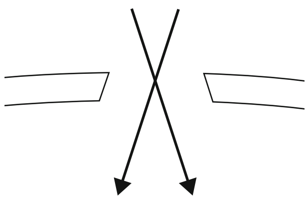


Fig. 7.2.31

Fig. 7.2.32

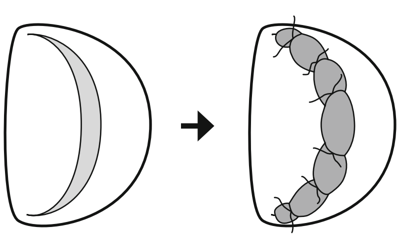
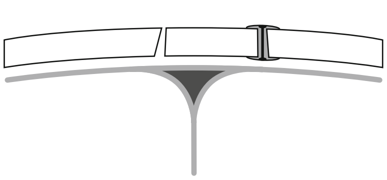


Fig. 7.2.33



Tips and tricks

- Take time for preoperative planning and positioning of patients. The result is an excellent overview of the target area and an efficient working position during surgery. For planning the exact placement of the craniotomy, preoperative imaging of the bridging veins using CT or MRA is recommended. In special cases DSA can be performed.

- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures; 2. placement of craniotomy; 3. skin incision.

- Creating the burr hole trephination, the lateral borders of the superior sagittal sinus should be carefully checked avoiding injury during craniotomy (Fig. 7.2.28).

- Stages of craniotomy (Fig. 7.2.29): 1. parietal and 2. occipital burr hole trephinations checking the superior sagittal sinus; 3.–4. ipsilateral and 5.–6. contralateral cutting from the parietal to the occipital burr hole with a high-speed craniotome. The craniotome should never cross the sinus area.

- Removal of the inner edge of the craniotomy offers increased intracranial visualization due to a sector-like surgical dissection (Fig. 7.2.30).

- Adequate positioning of the head results in gravity-enhanced self-retraction of the occipital lobe, avoiding excessive brain retraction (Fig.7.2.31).

- During wound closure, the dura should be closed with watertight sutures. If necessary, tissue of the galea aponeurotica can be used for this purpose (Fig. 7.2.32).

- The bone flap should be fixed without compression of the SSS avoiding sinusoidal thrombosis (Fig. 7.2.33).

- The skin incision within the haired area can be closed with interrupted or running sutures.

- Using a limited skin incision, a suction drain is not required.

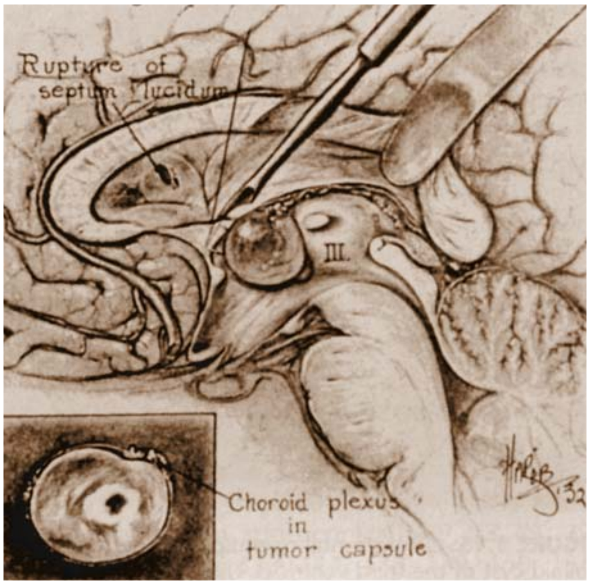


Fig. 8.0.1 *The posterior transcallosal approach for surgical access to third ventricular lesions described by* Dandy *in 1933. Note incision of the ascending fornix and opening the roof of the third ventricle allowing adequate exploration of the deep-seated site.*

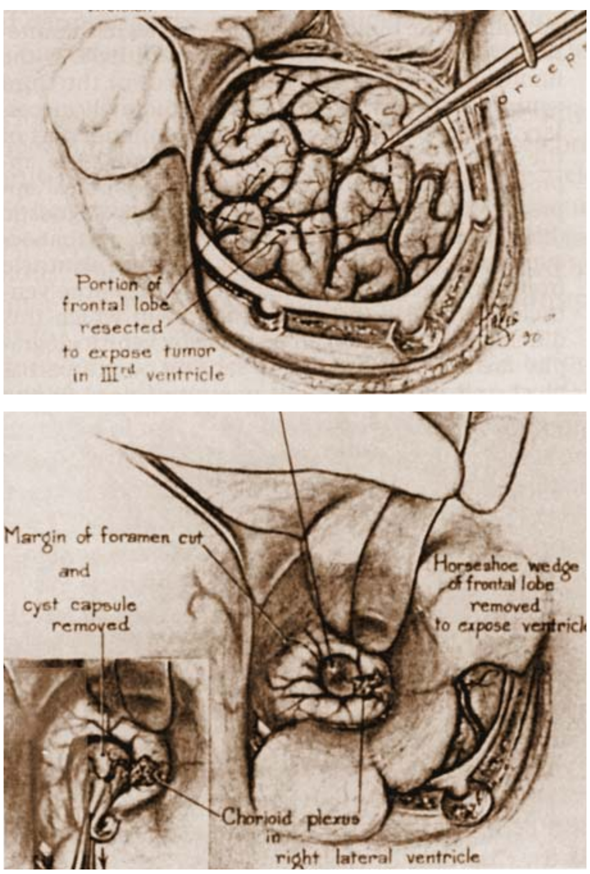


Fig. 8.0.2 *Dandy's frontal transcortical approach exposing a colloid cyst of the third ventricle. Note the "horseshoe wedge" incision and partial removal of the frontal lobe to expose the lateral ventricle and foramen of Monro.*

8.0 Transcortical approach exposing the lateral and third ventricles

History of the frontal transcortical transventricular approaches

When discussing approaches to the ventricular system, special attention should be given to Walter E. Dandy, who had unique interest in ventricular lesions and an unprecedented experience in dealing with them. In 1922, he described the first successful removal of a benign tumor in the third ventricle, occluding the foramen of Monro. Historically, two approaches were described by Dandy to reach the region of the anterior lateral and third ventricles: the posterior interhemispheric transcallosal and the anterior transcortical transventricular exposures [Dandy 1922, 1927, 1933, 1936]. The choice between either the anterior or the posterior approach was decided by the position of the tumor, diagnosed by ventriculographic investigations. If the lesion occupied only the posterior part of the third ventricle, the posterior transcallosal (Dandy's "pineal" exposure) approach was carried out (Fig. 8.0.1). If the tumor occupied the anterior third ventricle and foramen of Monro, the anterior transcortical ("hypophyseal" exposure) approach was superior (Fig. 8.0.2). Exposing the ventricular chamber via the frontal approach, Dandy used an oval resection or transverse section of the frontal lobe, usually on the right, nondominant side. He did not use the anterior transcallosal exposure because of the supposedly severe clinical effects resulting from sectioning the anterior part of the corpus callosum.

In his monograph "Benign Tumors in the Third Ventricle of the Brain: Diagnosis and Treatment", published in 1933, Dandy reported a mortality rate of 33.3% among patients from the entire series covering a period of 11 years. Despite a significant improvement in later publications, these results prompted some neurosurgeons to avoid such operations. Arne Torkildsen emphasized palliative management in treating patients with intraventricular tumors, using ventriculocisternostomy in hydrocephalic patients before any other surgical procedures were undertaken [Torkildsen 1939].

The most frequently discussed complication of the transcortical approach was postoperative seizures because of the extended cortical incision (Fig. 8.0.3). The incidence of seizures was reported to be as high as 27% according to Hugh Cairns, using macrosurgical techniques, probably resulting from the cortical incision itself [Patterson 1935, Poppen 1953, Gurdjian 1964, Kempe 1968, Cairns 1971]. The introduction of the microscope in neurosurgical techniques allowed decreased surgical traumatization and better visualization of the deep-seated lesions (Fig. 8.0.4). However, in a series in the 1980s, other postoperative complications were also described: hemiparesis after retraction of the centrum semiovale occurred in up to 20% of patients [Hirsch 1979, Antunes 1980]. Other patients had memory deficits depending on the degree of retraction and infarction of the nucleus caudatus. Confusion and mutism were also reported. The authors mentioned that neurological deterioration among these patients resulted from the extended cortical incision and the retraction necessary to visualize the ventricular chamber.

The high mortality and morbidity ratio in the literature could well indicate that the transcortical approach to the lateral and third ventricle should be disregarded. However, a critical analysis of these above mentioned approaches shows that in every case, extended craniotomies and cortical exposures with rough retraction of the frontal lobe were performed. In contrast, the technique of limited keyhole exposures causes minimal damage to brain tissue which is almost comparable to the injury caused by ventricle puncture. On the other hand, a limited cortical incision is also sufficient to visualize different parts of the ventricular chamber and expose large intraventricular lesions due to a sector-like surgical dissection.

In the following, the importance of the keyhole concept is discussed using frontal transcortical approaches to the ventricular system.

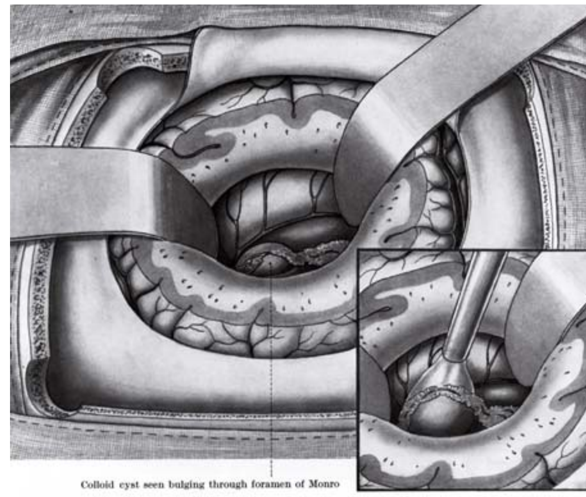
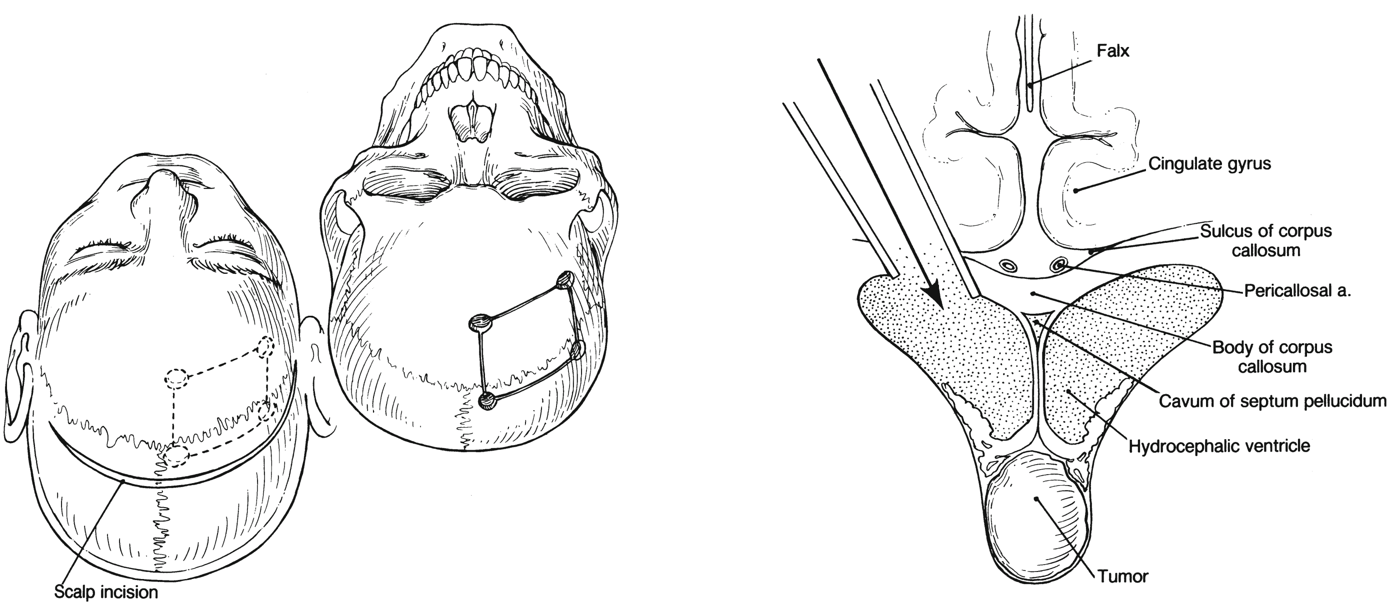
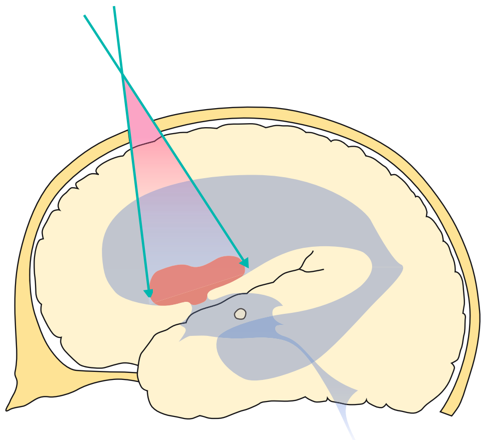


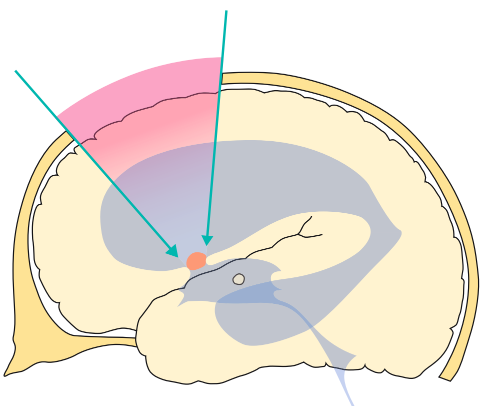
Fig. 8.0.3 *Kempe's frontal transcortical approach exposing ventricular lesions. Note the extended macrosurgical cortical incision.*

Fig. 8.0.4 *The frontal transcortical approach to the third ventricle described by William Shucart in Michael L.J. Apuzzo's comprehensive book entitled "Surgery of the Third Ventricle", published in 1987 and in a second edition in 1998. Note the relationship of the scalp incision to the burr holes and the craniotomy. The transcortical exposure for intraventricular lesions was used in the case of hydrocephalic enlarged ventricles.*





A



B

Fig. 8.0.5 *The use of the keyhole concept in transcortical approaches. Generally, lesions of the lateral and third ventricles are deep-seated. Compared with a standard surgical approach (B), entering the intracranial chamber through a limited craniotomy, the visual field shows a sector-like widening (A). A short distance allows a limited overview; in contrast, a long surgical corridor to a deep-seated field often provides a better monitoring of the dissection.*

Use of the keyhole concept in frontal transcortical transventricular approaches

The schematic cartoons of the ventricular structures demonstrate that a limited exposure approach can be sufficient to visualize large intraventricular areas, especially in hydrocephalic patients. According to this concept, the surgical dissection should be similar to the observation through a virtual keyhole. Dissecting in a sector-like direction through a small, precisely planned and accurately placed cortical incision, the surgeon is also able to visualize and remove extended intraventricular lesions (Fig. 8.0.5 A). This concept is the true opposite of the common funnel-like surgical dissection with an extended cortical incision for a relatively small target lesion (Fig.8.0.5 B).

Using a transforaminal approach to the third ventricle, the optimal placement of the craniotomy is essential to avoid fornical contusion. In the preoperative planning, the individual anatomy of the foramen of Monro, and the size and site of the interthalamic adhesion should be determined in comparison with the target point (Fig. 8.0.6).

The limited keyhole exposure resulting in reduced damage to important cortical structures may minimize the postoperative neurological deterioration in patients. In this respect, the frontal transcortical transventricular approach is par excellence the full realisation of the keyhole strategy in neurosurgery.

In the following, the anatomical basis of the frontal transcortical approach is discussed in detail.

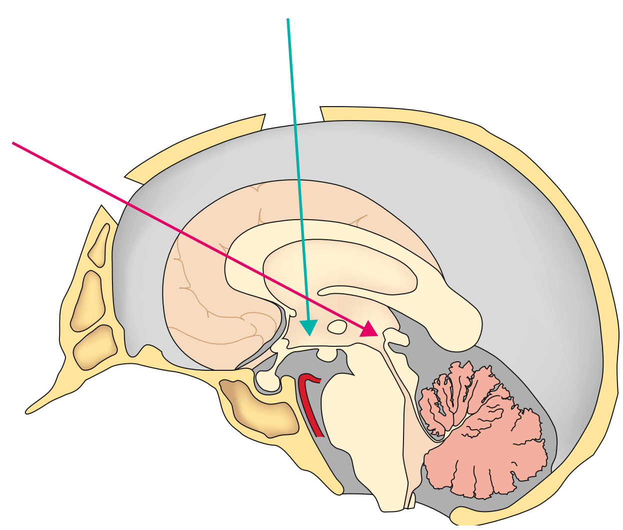


Fig. 8.0.6 *To expose the third ventricle through the intraventricular foramen, the optimum placement of the craniotomy should be determined preoperatively. The anterior third ventricle can best be approached through a coronarly placed craniotomy (green arrow). For exposing the region of the posterior commissure and aqueduct, the craniotomy should be placed more frontally (red arrow).*

General anatomical construction of the ventricular chamber and anatomical basis of the frontal transcortical transventricular approach

When considering surgical approaches for lesions of the anterior part of the lateral and third ventricle, opinions vary because of the well-known iatrogenic complications of the interhemispheric and transcortical exposures. The reason for the high rate of complications is the possible injury to important neuroanatomical structures. However, it is important to consider complications associated with the surgery in relation to the corridor, manipulation at the target area, and in relation to the pathology of the lesion itself. Independent of the pathology, the basis of minimizing damage is the choice of an approach which allows safe manipulation due to optimal visualization of the operative area through a safe corridor without injury to neighboring structures.

Concerning the operative corridor, the transcortical route is better compared with the interhemispheric approach via enlarged ventricles making the transcortical dissection less traumatic (Fig. 8.0.7). The approach is best performed from the right, nondominant side, unless it is being used for lesions of the left lateral ventricle or for third ventricular lesions with significant extension into the left lateral ventricle. According to the concept of contralateral keyhole approaches, a left-sided craniotomy can be also used for lesions located within the right side of the third ventricular chamber.

Special attention should be given to the fact that the transcortical transventricular approach to the third ventricle makes sectioning of the anterior corpus callosum and manipulation of the fornix unnecessary. The midline interfornical approach, described by Edward Busch and refined by Michael L.J. Apuzzo, requires separation of the close and very vulnerable fornical structures [Busch 1944, Apuzzo 1982]. Functions of the fornix and other parts of the limbic system in memory, motivation, emotion, and other important features of the human nature suggest that it is prudent to avoid fornical manipulation if at all possible.

The transcortical approach offers excellent observation of the lateral ventricle without injury to fornical structures with the additional possibility to investigate the third ventricular chamber via the hydrocephalically enlarged foramen of Monro (Fig. 8.0.8 A).

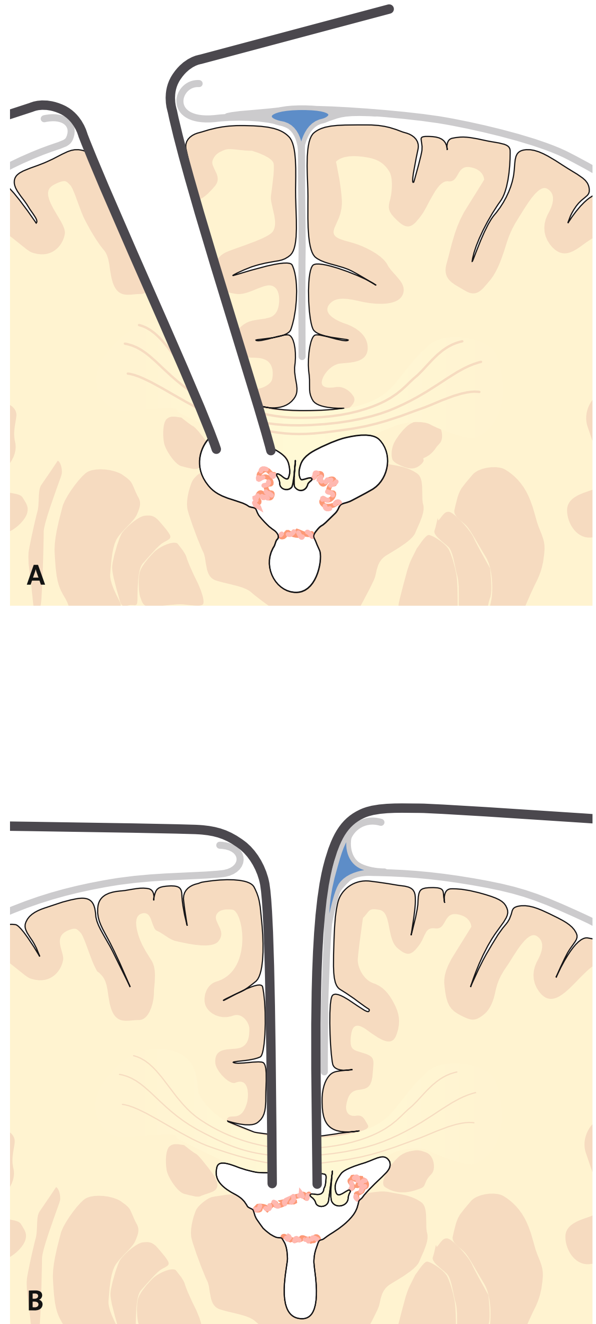
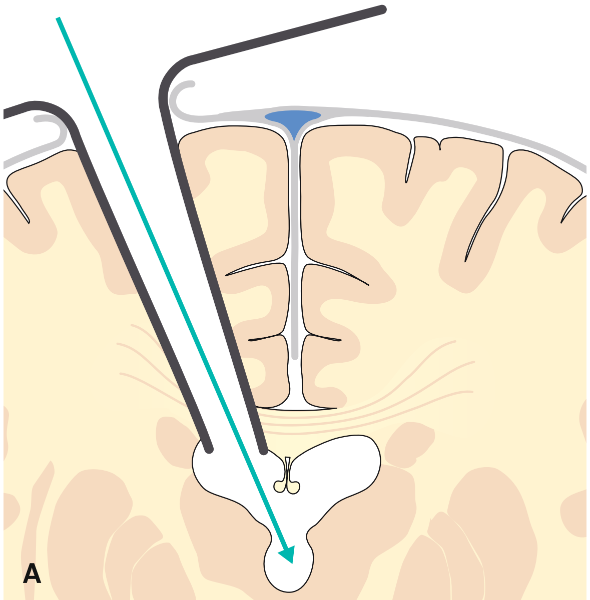


Fig. 8.0.7 A, B *Schematic drawing comparing the transcortical (A) and interhemispheric approaches (B) to the lateral ventricle. The transcortical route should be used in the case of hydrocephalically enlarged ventricles making the transcortical dissection less traumatic. The interhemispheric approach is better for normal sized or narrow ventricles.*



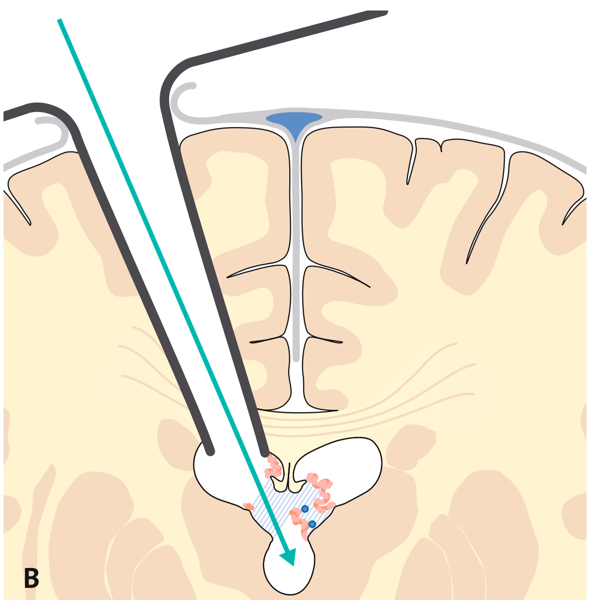


Fig. 8.0.8 A,B *Transforaminal investigation of the third ventricle using the frontal transcortical approach (A). This approach allows wide exposure of the third ventricular chamber without sectioning the anterior corpus callosum and risky dissection of the fornix. Using the subchoroidal route, the exposure of the third ventricle can be successfully enlarged (B). Here, the third ventricle is approached through the velum interpositum after gentle dissection of the internal cerebral veins.*

Extended lesions may be exposed through an additional posterior extension of the foramen of Monro, the goal of this approach being the opening of the choroid fissure and entering the third ventricle through the cisterna veli interpositii (Fig. 8.0.8 B). The basis of the subchoroidal approach is a careful observation of the deep medial and lateral subependymal venous system, draining the anterolateral aspect of the ventricular boundary. The septal and thalamostriate veins shed their subependymal coat near to the foramen of Monro and join directly with the internal cerebral vein. This confluence of the septal and thalamostriate veins together with the superior choroidal vein is the so-called angulus venosus, situated within the leaves of the arachnoid membranes of the velum interpositum. After mobilization of the angulus venosus, the choroid plexus should be dissected from the tenia thalami. The choroid plexus with the fornix is then gently retracted and the velum interpositum and the choroidal roof of the third ventricle are mobilized gaining access to the third ventricular chamber. These subchoroidal or transchoroidal approaches have been described by several authors [Delandsheer 1978, Hirsch 1979, Lavyne & Patterson 1983, Wen & Rhoton 1998].

Concerning the manipulation at the target area, we should emphasize the dangers of exposure of the deep diencephalic area, in particular the limbic system. This system, first described by Paul Broca as the "grand lobe limbique" in 1878, lies phylogenetically between the oldest parts of the brain and the neocortex. James W. Papez in 1937 demonstrated the connections between the main parts of this system, the so-called Papez circuit. His anatomical theory was supported by the clinical investigations of Heinrich Klüver and Paul C. Bucy [Papez 1937, Klüver and Bucy 1939]. The limbic system is concerned with motivation, emotion, moods relating to eating and smell, sexual behavior, and behavioral responses to external and internal stimuli that contribute greatly to personality, memory, and mental competence. Injury of anatomical structures, such as the body and columns of the fornix, the mamillary bodies, the termination of the mamillothalamic tract of Vicq d'Azyr and the anterior nuclei of the thalamus may lead to severe neurological deterioration for the remainder of the patient's life. Thus the neurosurgeon should be aware of this and aim to inflict as little damage as possible.

Using the frontal transcortical approach, several anatomical structures of the lateral and third ventricle can be approached. In addi-

Lateral ventricle	Third ventricle	Cistern of the interpeduncular fossa
Frontal horn and cella media of the lateral ventricle Septum pellucidum Head and body of the caudate nucleus Anterior upper part of the thalamus Foramen of Monro Fornix Choroid plexus of the lateral ventricle Thalamostriate vein Septal vein Caudate vein	Chamber of the third ventricle Interthalamic adhesion Fornix Anterior commissura Triangular recess Lamina terminalis Chiasmatic recess Optic chiasm Infundibular recess Tuber cinereum Mamillary bodies Hypothalamus Habenular region Posterior commissura Pineal and suprapineal recesses Cranial part of the aqueduct	Anterosuperior part of the mesencephalon Tip and distal part of the BA, incl. perforators P1 segments of the PCA, incl. perforators Proximal segments of the SCA PCoA CN III, CN VI

Table 8.0.1 *Anatomical structures exposed through the frontal transcortical approach.*

tion, after opening the floor of the third ventricle, the cistern of the interpeduncular fossa can be exposed (Table 8.0.1).

In the following, the basic surgical technique of the frontal transcortical transventricular approach is described as a step-by-step dissection. The transforaminal and subchoroidal trans-velum interpositum exposures of the third ventricle are also discussed.

Surgical technique

1. Patient positioning

The patient is in the supine position. If used, the single pin of the Mayfield head holder should be placed in the opposite frontotemporal area to allow free surgical manipulation. Note that the pin should not be placed in the temporalis muscle to avoid instability of the system.

Step 1

The head is anteroflected approximately 30° above the horizontal line to bring the precoronary area of the frontal bone, which will be the entry point of the craniotomy, to the highest point. Using this maneuvre, uncontrolled loss of CSF during surgery, which can cause collapsing of the ventricles and tearing of bridging veins, can be effectively avoided. The exact degree of inclination depends on the form of the lateral ventricle, on the site and size of the foramen of Monro and on the target region (Fig. 8.0.9).

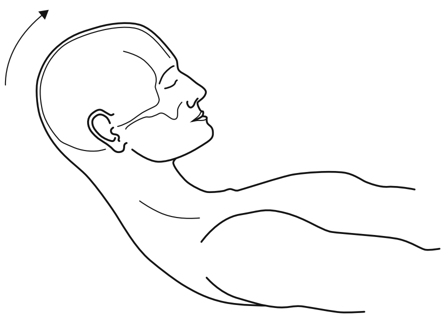


Fig. 8.0.9

Step 2

The head is elevated in this angulation to about 5 cm in total and minimally retroflected in order not to compromise the trachea and the larynx and to facilitate venous drainage (Fig. 8.0.10).

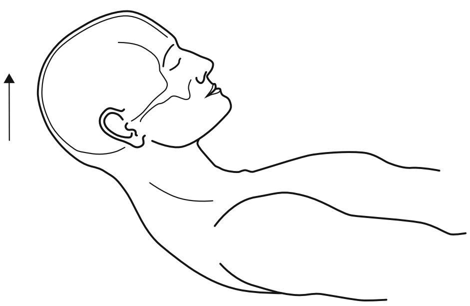


Fig. 8.0.10

Step 3

In a third step, the head is guided with a slight rotation of 10° to 15° to the contralateral side. While the positioning of the head in a strictly vertical position may facilitate intraoperative orientation, the head position with a slight rotation, according to the handedness of the surgeon, may enable a more ergonomic position (Fig. 8.0.11).

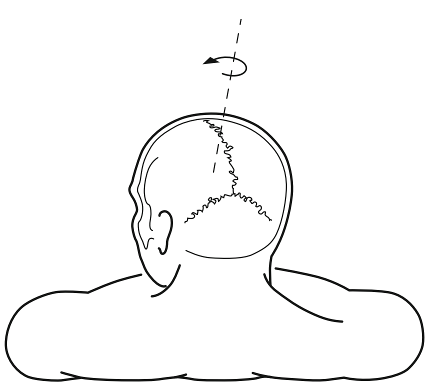


Fig. 8.0.11

Step 4

Finally, the head is lateroflected ca. 10° to the contralateral side, providing an efficient working position for the surgeon (Fig. 8.0.12).

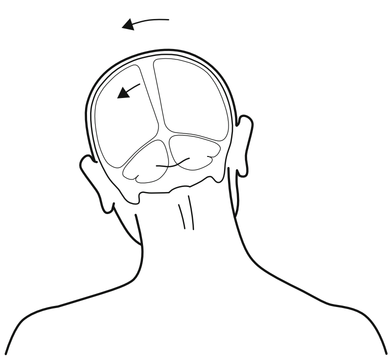


Fig. 8.0.12

2. Anatomical landmarks and orientation

For an optimal skin incision, the important anatomical landmarks of the osseous skull, such as the nasion, coronar suture, sagittal suture and the medio-pupillar sagittal line are precisely defined and drawn on the skin with a sterile pen (Fig. 8.0.13). In some patients, the coronar suture may not be palpable. In this situation the preoperative MR imaging can help to define the position of the suture. In addition, in individuals with a nonpathologic skull configuration, the position of the coronar suture can be measured at ca. 12.0 cm posterior to the nasion.

The craniotomy area of about 20 mm in diameter is usually placed at the level of the coronar suture with the center of the anticipated bone flap in the medio-pupillar sagittal line (Fig. 8.0.13). However, the exact placement of the craniotomy depends on the individual pathoanatomical situation. The sagittal and coronar plane of the preoperative MR data define the best trephination allowing optimal direction for surgical dissection.

After definition of the craniotomy, the straight sagittal skin incision should be planned, usually behind the frontal hairline, in the mediopupillary plane (Fig. 8.0.13). For bald-headed patients, the skin incision should be performed in the coronar plane. For this purpose, a wrinkle of the skin may be chosen to achieve a pleasing cosmetic outcome. The skin should be disinfected carefully.

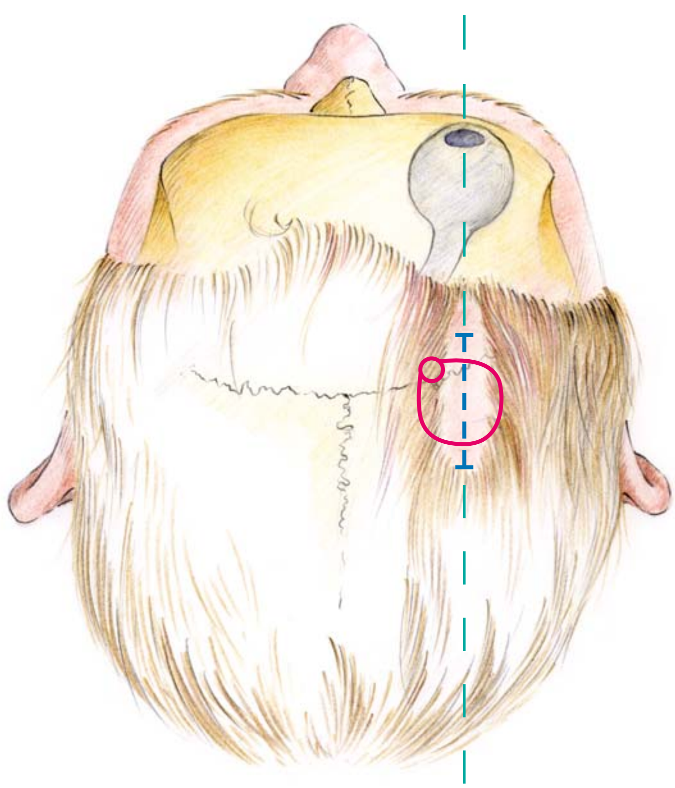


Fig. 8.0.13 *Definition of the craniotomy and skin incision according to anatomical landmarks. Note the medio-pupillar sagittal line, marking the center of the craniotomy.*

3. Craniotomy

Step 1

Right side. After anatomical orientation and minimal or even absent hair shaving, the skin should be meticulously disinfected using alcohol solution. The skin is incised straight in the mediopupillar line in a longitudinal direction in one layer with the subcutaneous tissue (Fig. 8.o.14).

Fig. 8.o.14

Step 2

The galea-periost layer is dissected medially as a flap, the soft tissue layers are then retracted bilaterally, exposing the bony surface (Fig. 8.o.15).

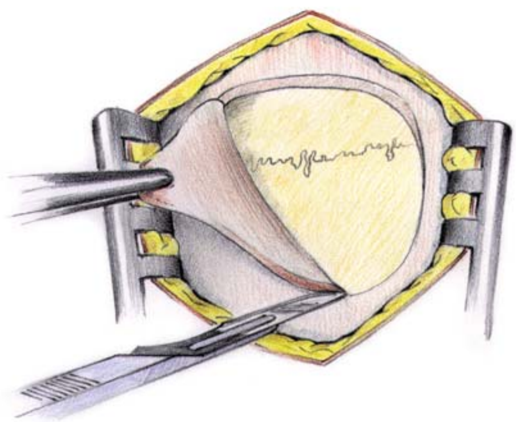


Fig. 8.o.15

Step 3

After drilling a hole at the medial margin of the planned craniotomy, the dural surface is mobilized with a blunt dissector (Fig. 8.o.16).

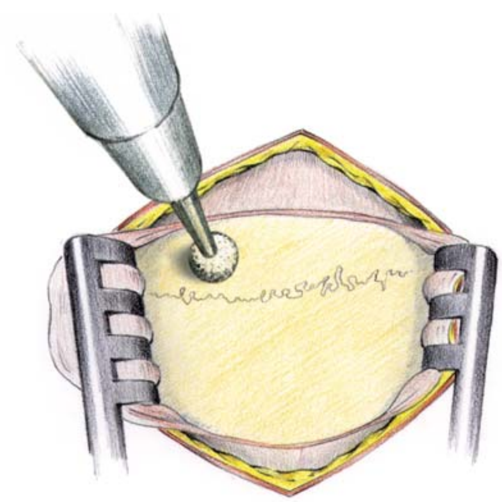
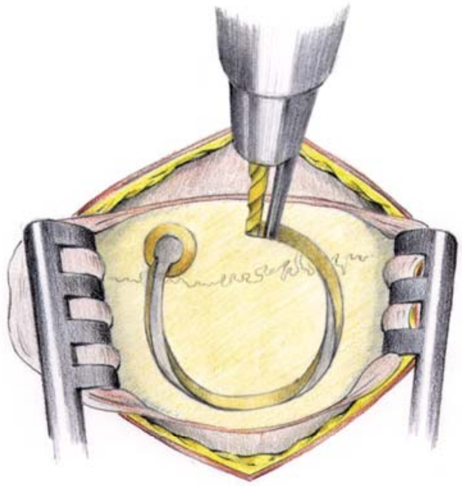


Fig. 8.o.16

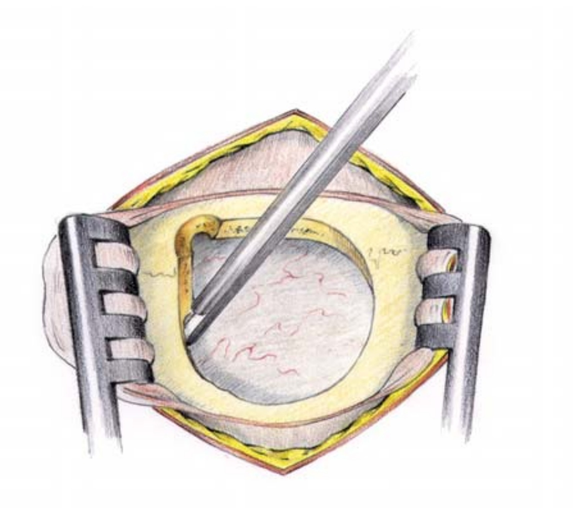
Fig. 8.0.17



Step 4

Thereafter a bone flap with a diameter of about 2.0 cm is cut out using a high-speed craniotome. In all cases, an osteoplastic craniotomy is carried out. Hemorrhages occurring during the craniotomy can be controlled by bipolar coagulation and bone wax (Fig. 8.0.17).

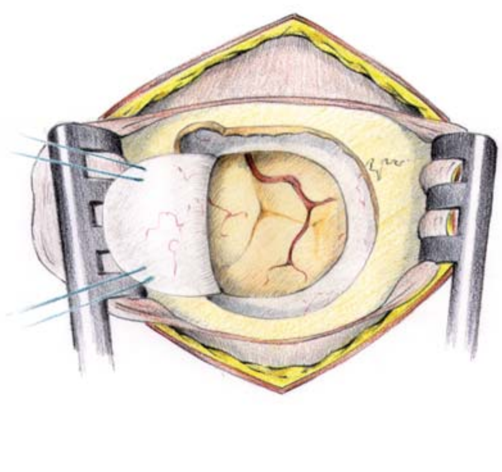
Fig. 8.0.18



Step 5

An important step of the approach after removal of the bone flap is the removal of the inner edge of the craniotomy with fine punches. With careful removal of the internal table, the angle for surgical dissection can significantly increase (Fig. 8.0.18).

Fig. 8.0.19



Step 6

The dura is incised in a semicircular fashion with the base of the dural flap towards the midline or in a cruciate fashion along the diagonal. The free dural flaps are fixed with sutures; other elevation sutures are not required (Fig. 8.0.19).

4. Intradural dissection

Step 1

Right side. Dissection performed on a fresh human specimen, without arterial or venous injection. After dural opening, the arachnoid is coagulated and incised with a diamond knife followed by a small corticotomy of about 10 to 15 mm in length. The anterior horn of the lateral ventricle is first punctured with a ventricular cannula. After reducing the intraventricular pressure, the cannula may be removed. Dissecting along the punction canal, the lateral ventricle is entered. Note the opening of the ependyma of the right lateral ventricle (Fig. 8.0.20).

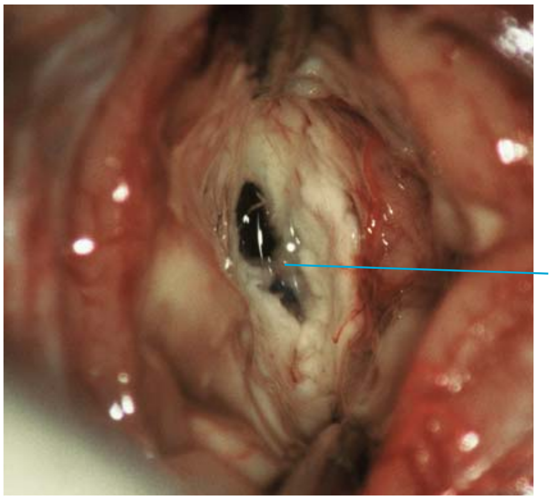


Fig. 8.0.20

Step 2

The first anatomical landmark to be encountered is the choroid plexus. By following the choroid plexus anteriorly, we can indentify the foramen of Monro, the lamina affixa thalami, and the fornix (Fig. 8.0.21).

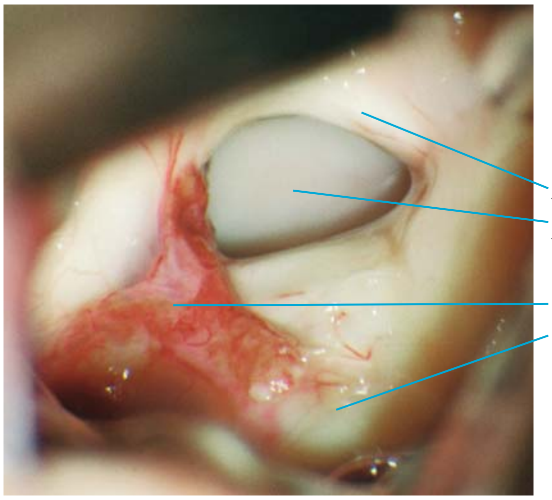


Fig. 8.0.21

Step 3

According to the concept of keyhole approaches, we can follow the choroid plexus in a posterior direction, approaching the cella media. Note the lamina affixa thalami, choroid plexus and the fornix of the lateral ventricle (Fig. 8.0.22).

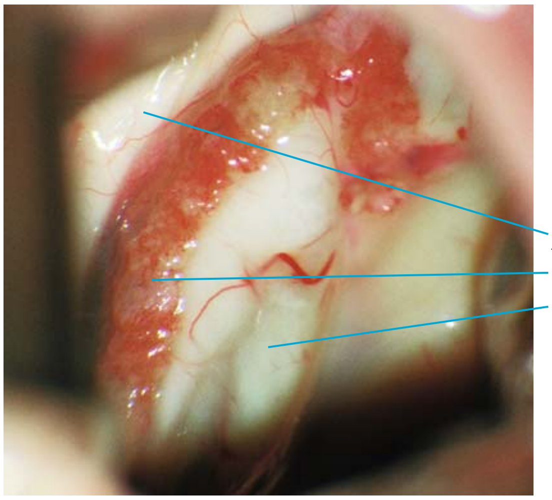


Fig. 8.0.22

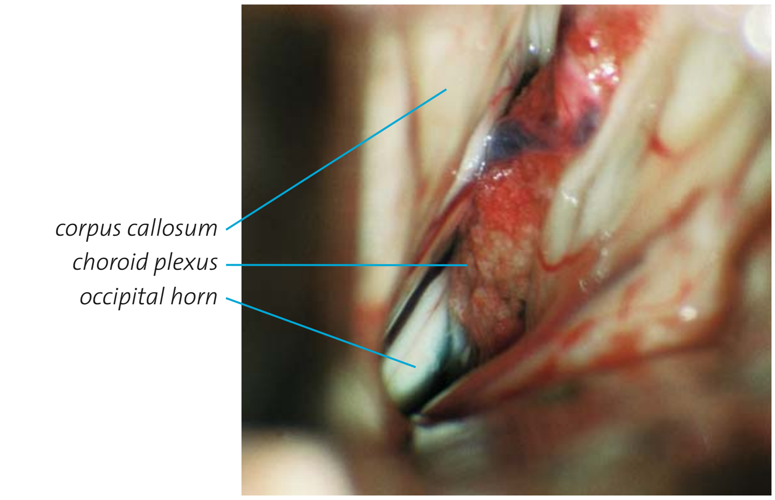


Fig. 8.0.23

Step 4

Dissecting more posteriorly, the occipital horn can be exposed. Note the typical subependymal veins of the inferior surface of the corpus callosum (Fig. 8.0.23).

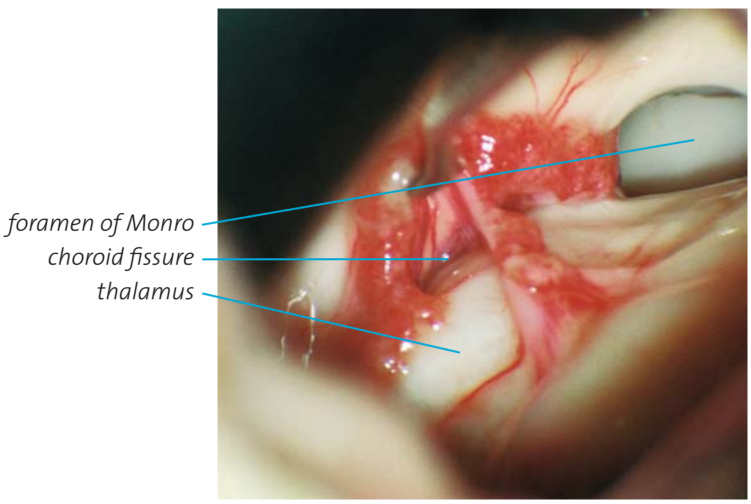


Fig. 8.0.24

Step 5

In cases of a normal-sized interventricular foramen, the foramen of Monro can be enlarged surgically in a posterior direction. Note gentle dissection of the choroid fissure (Fig. 8.0.24).

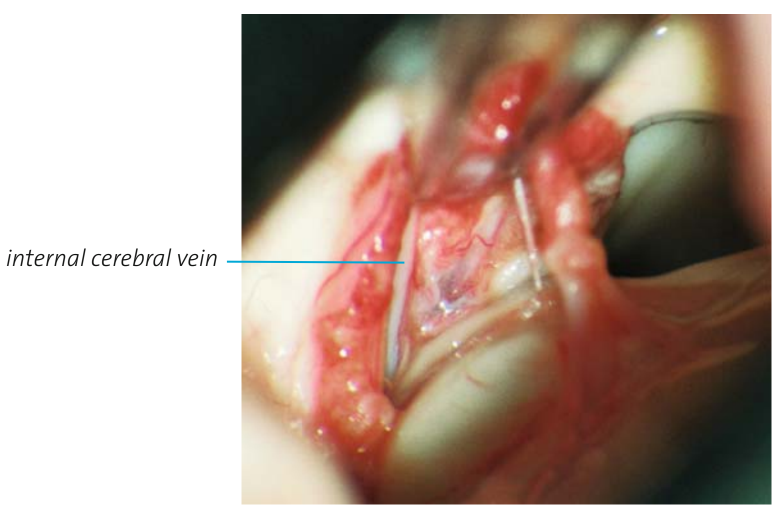


Fig. 8.0.25

Step 6

Careful dissection of the subchoroid pathway. Note the internal cerebral vein within the velum interpositum (Fig. 8.0.25).

Step 7

Dissecting posteriorly, we can investigate the region of the posterior third ventricle with structures of the posterior commissure and the aqueduct of Sylvius. Note the superior observation through the subchoroidal route (Fig. 8.0.26).

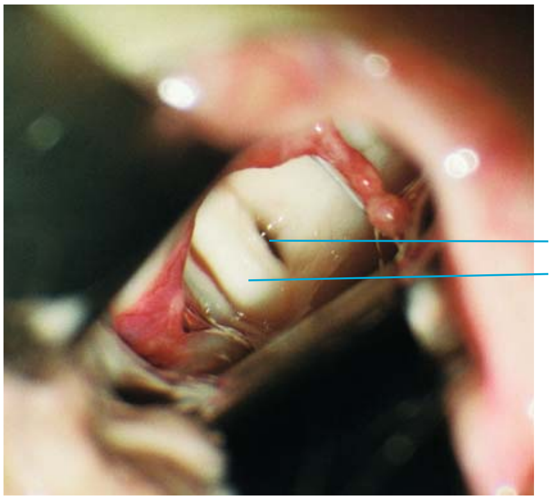


Fig. 8.0.26

Step 8.

Focusing again in anterior direction, the floor of the third ventricle is visualized in front of the interthalamic adhesion. Note the mamillary bodies (Fig. 8.0.27).

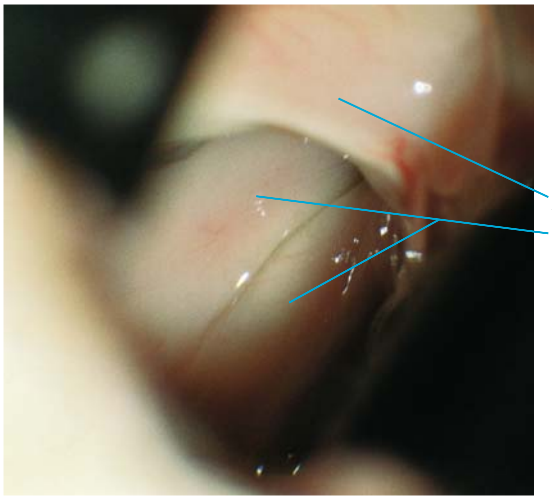


Fig. 8.0.27

Step 9

After opening the premamillar recess, we can enter the interpeduncular cistern and observe the basilar tip. Note the CN III appearing between the contralateral PCA and SCA (Fig. 8.0.28).

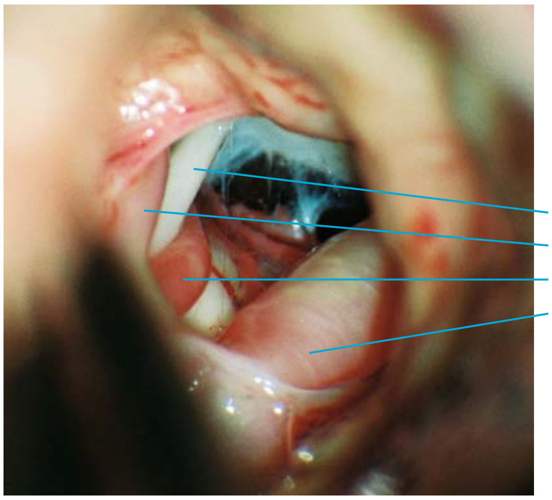


Fig. 8.0.28

5. Dura, bone and wound closure

After completion of the intracranial procedure, the intradural space is filled with artificial CSF solution at body temperature. For this purpose it is useful if the craniotomy is placed at the highest point of the head, otherwise large air bubbles may be caught in the lateral ventricles or in the subdural space. Such intracranial air bubbles can become space-occupying and may impair postoperative recovery for a few days. In addition, an extensive loss of CSF may result from a ventricular collapse with possible tearing of bridging veins.

The dura is closed watertight with interrupted or running sutures. If dehiscence has developed, a piece of muscle should be sewn into the dural opening. An epidural gelfoam plate is placed before fixation of the bone flap. The bone flap should be tightly fixed with a titanium plate, covering the burr hole trephination. The periosteum, subcutaneous layer and the skin are closed each with interrupted sutures.

Potential errors and their consequences

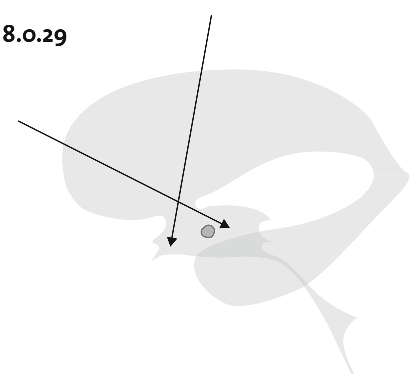
Most of the complications of intraventricular operations are related to the location and nature of the lesion rather than to the surgical approach. However, some typical surgical errors and their consequences should be discussed in detail.

- Inadequate preoperative planning with inadequate exposure of the intracranial target region and significant deterioration in efficiency of surgically excising the lesion. Planning is the task of the surgeon!
- Inadequate placement of the craniotomy with decreased visualisation of the ventricular chamber and a physiologically uncomfortable job during surgery. Especially when using a transforaminal approach to the third ventricle, an incorrect direction of surgical dissection may cause severe injury to the fornix with subsequent postoperative memory deficits.
- Penetration of the dura during craniotomy, usually without severe consequences.
- Postoperative seizures due to extended cortical incision.
- Postoperative hemiparesis due to rough cortical retraction or postoperative hemorrhage within the transcortical route.

- Injury to parts of the limbic system may result in serious functional impairment causing behavioral and emotional disturbance and memory loss.
- Diabetes insipidus and akinetic mutism after exposure of the anterior third ventricle due to injury of the hypothalamus.
- Postoperative aseptic meningitis can develop in patients who had tumors such as malignant astrocytomas or colloid cysts, which spill blood, colloid or necrotic tissue into the CSF. Careful surgical dissection may decrease the frequency of this complication. We do not recommend the routine administration of corticosteroids or antibiotics.
- Postoperative acute hydrocephalus due to aqueductal or third ventricular occlusion. A ventriculostomy created by opening the third ventricular floor may avoid hydrocephalus in the unshunted patient. However, the cortical incision as a connection between intraventricular and subarachnoidal spaces may function in the same manner. In addition, with fenestration of the septum pellucidum we are able to avoid the problem of a trapped or isolated ventricle secondary to unilateral foramen of Monro occlusion.
- Inadequate dural closure with postoperative CSF fistula.
- Inadequate positioning and fixation of the bone flap with suboptimal cosmetic results.
- Inadequate hemostasis causing postoperative intracranial or extracranial hematoma.

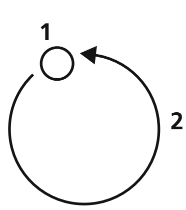
Tips and tricks

Fig. 8.0.29



- Using a transforaminal approach, the individual anatomy of the foramen of Monro and the size and site of the interthalamic adhesion should be determined in comparison with the target point. Defining the optimum placement of the craniotomy, the sagittal and coronar planes of the preoperative MR should be thoroughly investigated. The reward of the optimal planning is an excellent overview of the target area and an efficient working position during surgery (Fig. 8.0.29).

Fig. 8.0.30



- Make a careful anatomical orientation and use the three steps of marking with a sterile pen: 1. osseous structures; 2. placement of craniotomy; 3. skin incision.

- Stages of craniotomy (Fig. 8.0.30): 1. frontal burr hole trephination; 2. circular craniotomy with a high-speed craniotome.

- By retracting the soft tissue, the osseous surface should be optimally exposed. However, retraction and mobilization of the skin flap should be restricted to the necessary minimum to prevent postoperative necrosis.

- Following craniotomy, removal of the inner edge of the craniotomy provides increased intracranial visualization (Fig. 8.0.31).

- Open the dura in a "C" shaped fashion and hold the dural flap with sutures (Fig. 8.0.32).

- Approaching the ventricular chamber transcortically, the corticotomy should be performed on the cerebral surface. Dissection through a prominent sulcus causes more cortical injury with possible postoperative deficits (Fig. 8.0.33).

- Exposing the third ventricle, the foramen of Monro can be enlarged posteriorly with a subchoroidal dissection, allowing wide surgical exposure.

- After completion of the intracranial procedure, the intradural space is filled with artificial CSF solution at body temperature. For this reason, the craniotomy should be placed at the highest point of the head, avoiding postoperative pneumocephalus or space-occupying air bubbles within the subdural space.

- The dural closure should be made watertight to avoid postoperative nasal CSF fistula. If tension or dehiscence has developed in the dural plane, a piece of muscle can be sewn into the dural closure (Fig. 8.0.34).

- After dural closure, the bone flap should be tightly fixed to achieve optimal cosmetic results. A titanium plate can be successfully used for closure of the burr hole trephination (Fig. 8.0.35).

Fig. 8.0.31

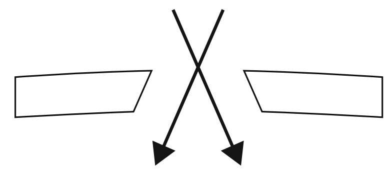


Fig. 8.0.32

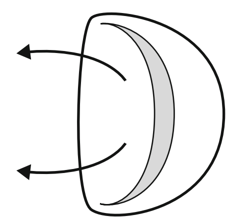


Fig. 8.0.33

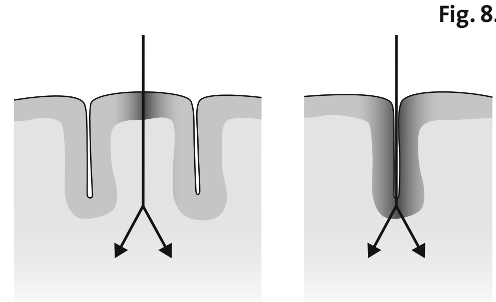


Fig. 8.0.34

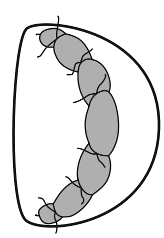
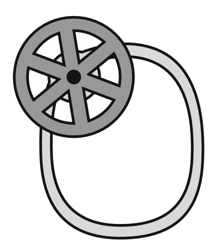


Fig. 8.0.35



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