In this landmark text, the distinguished authors provide detailed descriptions of surgical anatomy and the major neurosurgical approaches to the intracranial tumors. The procedures are organized according to regions: supratentorial, skull base, and infratentorial. Each broad category is divided further into specific locations, such as the pituitary region, the ventricles, the cerebellar pontine angle, and many more. All procedures are illustrated with beautiful line drawings and full-color photographs of stunning quality. A wealth of professional experience has gone into this detailed atlas to demonstrate key techniques, procedures, and approaches. More than 2,500 illustrations clearly depict operative strategies and complex three-dimensional spatial relationships. Here is the most detailed and comprehensive microneurosurgical atlas ever compiled—an essential reference for practicing neurosurgeons and residents alike!

Robert F. Spetzler, M.D., is Director of the Barrow Neurological Institute at St. Joseph’s Hospital and Medical Center, Phoenix, Arizona and Professor, Section of Neurosurgery at University of Arizona, Tucson, Arizona.

Wolfgang T. Koos, M.D. (deceased), was Professor and Director at University Clinic of Neurosurgery, Vienna, Austria.

Johannes Lang, M.D. (deceased), was Professor Emeritus and Director of the Anatomical Institute at University of Würzburg, Germany.
Color Atlas
of Microneurosurgery
Second Edition
J. Cruveilhier: "Anatomie pathologique du corps humain"
J.B. Baillère, Paris; 1829–1835
Microanatomy • Approaches • Techniques

Second edition, revised and expanded

Volume 1: Intracranial Tumors
W. T. Koos, R. F. Spetzler, J. Lang
with contributions by G. Pendl and A. Perneczky

2512 illustrations, most in color
Drawings by I. Dobsak and G. Spitzer
Preface

The first edition of this book was produced to take account of the phenomenal number of changes that had occurred in neurosurgery in the preceding two decades. Is there any justification for a revised edition within scarcely half a dozen years?

There is indeed. Refinements in the neurosurgical armamentarium continue to push forward the frontiers of neurosurgery. Lesions that were considered inoperable even a few years ago can now be resected, particularly in the region of the skull base, with acceptable rates of morbidity and mortality. Unprecedented multidisciplinary collaboration between otolaryngologists, craniofacial surgeons, ophthalmic surgeons, plastic-reconstructive surgeons, head and neck surgeons, and neurosurgeons, has contributed greatly to these developments. The introduction of simple intraoperative localization devices, coupled with preoperative magnetic resonance imaging, computed tomography, and angiography, has further enhanced the operability of lesions that are deep or difficult to locate. Indeed, the same reasons that impelled us to produce the original edition, i.e., the introduction of new procedures and the updating of old procedures—both based on advances in instrumentation diagnostic technique, and neuroanesthesia—have also been the motivation for this revised edition.

The reader will find that many aspects of the new edition have been improved. Much more space has been devoted to a detailed and clearly organized presentation of all the major approaches to the regions of the cranium relevant from the neurosurgeon’s point of view. All neurosurgical approaches have been updated, and many new ones have been added. Special attention has been given to the microsurgical neuroanatomy of all the intracranial regions, which constitute the very basis for carrying out these often technically challenging operations. The plethora of new approaches has necessitated dividing this second edition into two volumes. The first volume is devoted to the surgical resection of intracranial tumors, and the second volume to cerebrovascular and spinal pathology.

As in the original volume, we have avoided discussions of the indications, efficacy, and outcome of any given procedure, and have concentrated on presenting, in detail, the surgical steps required to complete each operation. We still believe that a complex three-dimensional spatial task such as neurosurgery can only be appreciated visually, and the present edition has retained a generous number of schematic illustrations to enhance appreciation of the operative photographs. And, as in the previous edition, the text is unreferenced. Once again, we must acknowledge the ideas and technical innovations of numerous neurosurgical colleagues from around the world, whose ideas have become ingrained in our own experience and are incorporated here.

These volumes have benefited greatly from the technical expertise and critical suggestions of Dr. Phillip C. Daspit, neuro-otolaryngologist, and Dr. Stephen P. Beals, cranial reconstructive surgeon, Division of Neurological Surgery, Barrow Neurological Institute (BNI), Phoenix, who, along with numerous other colleagues, have been major contributors to our ability to perform skull-base procedures. This book would not have been possible without the constant self-sacrifice and understanding of our medical illustrator, Mrs. Ingrid Dobsak, Department of Neurosurgery, University of Vienna, who has worked for years on the production of thousands of sketches and illustrations of all the anatomical and surgical photographs. We are grateful to Mr. Steve J. Harrison, former BNI medical illustrator, and Mark Schornak, current BNI medical illustrator, for their excellent work. Tribute for the success of the present volumes is due to Mrs. Pamela Smith, BNI photographer, and Mrs. Margarethe
Baumann, photographer, Department of Neurosurgery, University of Vienna, for their painstaking daily efforts in producing photographic documentation of all the operations. We would also like to extend our appreciation to the staff of the secretariat for Scientific Affairs of the Department of Neurosurgery, University of Vienna, who typed and edited the first volume; and to the staff of the BNI Editorial Office, who typed and edited the second volume under the capable direction of Shelley A. Kick, Ph. D.

We express our thanks to the publishers, Thieme, above all Dr. Günther Hauff, and his colleagues, for the superb quality of the production and their excellent cooperation in the preparation of this book. In particular, Mr. Achim Menge deserves recognition for his guidance, patience, prudence, and support during the growth of this second edition.

We hope that these new volumes will help established neurosurgeons to maintain their surgical skill at the “cutting edge,” as it were, and will help aspiring neurosurgeons to acquire the expertise needed to make their own contributions to our common goal—providing the best possible care to all patients afflicted with neurological disorders. We gratefully dedicate these volumes to our patients, our residents, and our families—each of whom has supported, in their own way, our efforts over the years.

February 1993

W.T. Koos, R.F. Spetzler, J. Lang
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Volume Two:
Cerebrovascular and Intraspinal Lesions
By R.F. Spetzler, W.T. Koos, J. Lang with Contributions by A. Perneczky, B. Richling, J.M. Zabramski

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Organizing various surgical approaches, anatomical specimens, and pathological processes into a logical sequence presents difficulties, due to the overlapping of many regions. The diagram below indicates the way in which the present volume is arranged.

In general, we have attempted to organize the book into three logical sections. The supratentorial section (1) starts with lesions in the pituitary region, then continues superiorly and rostrally to the ventricular system, and concludes with the pineal region. The second section, on the skull base (2), begins with the floor of the anterior fossa, continues through the cavernous sinus, and ends with the upper, middle, and lower clivus. The third, infratentorial, section (3) deals with lesions in the cerebellar hemispheres and the brain stem. Obviously, the anatomical and surgical borders for these regions overlap significantly, and the reader is urged to cross-check overlapping areas.

1.1 Organization of this volume. The numerals indicate the corresponding sections of the book.
1 Supratentorial Tumors
Introduction

The feasibility and safety of any surgical intervention depend on the surgeon’s familiarity with neuroanatomy. The appropriate anatomical preparations are, therefore, included in each chapter. Each actual anatomical specimen is accompanied by a schematic drawing identifying the various structures. The specimens were chosen because of their relevance to neurosurgical anatomy. The arteries have been injected with red and the veins with blue latex for demarcation and identification. By reviewing the anatomical specimens the reader can better appreciate the neuroanatomical limits of any specific operative intervention as well as the options for enlarging a surgical exposure.

1.2 A midline section through the head.
1.3 Falx and tentorium, viewed from the right.
1.4 A transverse section through the head at the level of the splenium of the corpus callosum.

1.5 A transverse section at a slightly different angle seen through the tentorial notch.
1.6 A transverse section through the transverse sinuses.

1.7 A transverse section through the midclivus from below.
1.8 Right frontal fossa, viewed from above. The olfactory tract has been separated from its arachnoidal adhesion. The same procedure is performed intraoperatively to gain exposure of the optic nerve without requiring the resection of the first cranial nerve.

1.9 Angled transverse section at the level of the olfactory bulb parallel with the olfactory tract. The distance from the olfactory bulb to the optic nerve and its relationship to the gyrus rectus and anterior cerebral artery can be appreciated.
1.10 A view of the orbital contents after removal of the orbital roof from above. A view from above demonstrates the course of the optic nerve through the orbit. The nerves and muscles are displaced laterally.

1.11 Orbital contents and the optic nerve viewed from above.
1.12 A view of the optic nerve and orbital contents from a superior lateral view.
Position and Approach

Unilateral Subfrontal Approach to the Orbital Roof and Optic Nerve

1.13 The patient is placed on the surgical table in a supine position with the head flexed 40 degrees and rotated 15 degrees off the vertical axis from the side to be exposed.

1.14a,b The degree of head flexion is greatest (40 degrees) when the anterior orbital roof is to be exposed. The farther posterior the orbital exposure proves to be necessary, the less flexion is required. For the intracranial portion of the optic nerve, the head is basically neutral. The scalp incision is made behind the hairline, extending to the zygomatic process on the ipsilateral side and, if preferred, to the superior aspect of the temporalis muscle on the contralateral side. A craniotomy is performed with the inferior burr holes placed as close to the floor of the frontal fossa as possible.
Unilateral or Bilateral Subfrontal Approach

1.15a For the unilateral subfrontal approach, the head is turned slightly from midline. The option of using a bifrontal approach still remains.

1.15b Outline of unilateral and bifrontal craniotomy and the relationship to the underlying frontal lobes, optic chiasm, and optic nerves.

Frontolateral Approach

1.16a The patient is rotated 30 degrees off the vertical axis, with the head slightly extended. The incision is made behind the hairline from the midline to the zygomatic process. A craniotomy is performed along the floor of the frontal fossa, extending to the pterion. Every attempt is made to expose the floor of the fossa without leaving a rim of bone.

1.16b The relationship between the craniotomy and the underlying neural structures is presented.
Clinical Material

Case 1
Diagnosis: Intracanalicular optic nerve glioma with intracranial extension
Approach: Left unilateral subfrontal

1.17a Exposure of the left optic nerve with tumor.

1.17b The optic canal has been opened, and the intracanalicular tumor is exposed.

1.17c The optic nerve has been cut and resected until normal, histologically verified, optic nerve tissue was identified. The tumor was then followed anteriorly into the optic canal and completely resected.
Case 2  
Diagnosis: Optic nerve arachnoiditis  
Approach: Right frontolateral subfrontal

1.18a Displacement and traction of the optic nerve is present due to extensive arachnoidal adhesions.

1.18b The left optic nerve after significant resection of arachnoidal adhesions.
Case 3
Diagnosis: Optic nerve compression from tumor within the sphenoid sinus
Approach: Right unilateral subfrontal

1.19a Exposure of flattened optic nerve and thickened arachnoid.

1.19b Coagulation of the dural investiture of the roof of the optic canal and beginning of dural opening.

1.19c The optic canal has been opened and the expanded, thinned-out optic nerve is visualized.

1.19d Higher magnification reveals the pale ischemic changes.
Case 4
Diagnosis: Optic nerve compression from trauma
Approach: Frontolateral subfrontal

1.20 a After the optic nerve has been decompressed, as in the previous case, the marked ischemic changes between the traumatized and the normal optic nerve are apparent.

1.20 b Higher magnification after further decompression.
Tumors of the Optic Chiasm, Pituitary Region, and Hypothalamus

Microanatomy

1.21 Subfrontal view of optic chiasm and pituitary stalk.
1.22a Similar operative view, visualizing the pituitary stalk.

1.22b Pituitary region viewed from above. The diaphragma sellae has been removed.
1.23 A view along the frontal floor and the edge of the pterion, with mild elevation of the frontal lobe.
With greater elevation of the frontal lobe, the entire optic chiasm becomes visible.
1.25 A view along the frontal fossa demonstrates the vascular and neural elements of the region, and provides good exposure of the pituitary stalk.

1.26 A view slightly more off midline permits appreciation of the course of the third nerve.
1.27a Zygomatic approach. After further dissection of the internal carotid artery, posterior communicating artery, and anterior choroidal artery, their relationship to the third nerve can be seen.

1.27b Zygomatic approach. After the Sylvian fissure has been opened further, the thalamoperforate branches are readily appreciated.
1.28 Sella turcica and right parasellar region; retrosellar region (seen from above).

1.29 Paramedian section through the sphenoid sinus.
1.30 Midsagittal section through the pituitary region (with partially empty sella).
1.31 Microvascular relations of the pituitary region.

1.32 Median sagittal section through the pituitary and third ventricle. Oculomotor nerve displaced and stretched by posterior communicating artery.
1.33 A paramedian section of the pituitary gland demonstrates Liliequist’s membrane (partial septum in the basal cisterns).

1.34 A good demonstration of the medial aspect of Liliequist’s membrane.
1.35 Midsagittal section through the pituitary gland (displaced superiorly), exposing the internal carotid artery.
1.36 Paramedian section exposing the internal carotid artery, with the remaining portion of the pituitary gland displaced interiorly.
Position and Approach to the Sellar Region

Unilateral or Bifrontal Subfrontal Approach

1.37a The patient is positioned as in the previous approach, except that a bilateral frontal craniotomy is performed.

1.37b Outline of bifrontal craniotomy and relationship to underlying frontal lobes and optic nerve.
Frontolateral Approach

1.38a The patient is rotated 30 degrees off the vertical axis, with the head slightly extended. The incision is made behind the hairline from the midline to the zygomatic process. A craniotomy is performed along the floor of the frontal fossa, extending to the pterion. Every attempt is made to expose the floor of the frontal fossa without leaving a rim of bone.

1.38b The relationship between the craniotomy and the underlying neural structures.

Pterional Approach

1.39a The skin incision for the pterional approach is extended from the midline or midpupillary line along the hairline down to the zygomatic process. A craniotomy is performed to expose the lateral aspect of the temporal fossa and a portion of the adjacent frontal fossa. The pterion is resected to the degree required for the particular exposure, e.g., if the area of interest is the lateral and posterior parasellar region, then the pterion is resected virtually to the anterior clinoid process to obtain as much access as possible for maximum exposure along the sphenoid wing without requiring significant brain retraction. If, however, the area of interest is lateral to the optic nerve where it enters the optic canal, then the pterion resection is minimal.

1.39b Relationship between the craniotomy and the underlying neural structures.
Midfixed or Postfixed Chiasm

1.40a With a midfixed or postfixed chiasm, the tumor can readily be removed between the optic nerves, anteriorly to the chiasm.

1.40b Tumor removal.

Prefixed Chiasm

1.41a With a prefixed chiasm, the dura over the tuberculum is opened to expose the tuberculum sella.

1.41b A drill is used to enter the sphenoid sinus and create a space from which to approach the tumor.

1.41c Tumor removal. The sphenoid sinus is stripped of its mucosa and packed with fat. A graft is placed over the dural incision and closed with fibrin glue.

Technical Note
Pituitary adenomas are typically removed using the transsphenoidal approach, unless specific indications suggest the subfrontal approach would be more appropriate. The transsphenoidal approach is described in Section 2 under the heading Skull Base.
1.42a Through a left transfrontal approach the optic nerves, internal carotid artery and tumor are visualized. Notice the pale, flattened optic nerve.

1.42b Following partial tumor resection, the posterior portion of the dorsum sellae can be visualized. Both internal carotid arteries and the right posterior communicating artery are exposed.

1.42c Following complete removal of the pituitary adenoma, the left optic nerve and internal carotid artery resume their normal anatomical positions.
Case 2
Diagnosis: Suprasellar and retrosellar adenoma with hemorrhage
Approach: Right unilateral subfrontal

1.43a The pituitary tumor is exposed through a right unilateral subfrontal approach. Notice the displacement and splaying of the right optic nerve and the lateral displacement of the right internal carotid artery.

1.43b The tumor capsule has been opened and a large hematoma (responsible for the pituitary apoplexy which was present clinically) is evacuated by suction.

1.43c After removal of the tumor, the optic nerve and internal carotid artery assume their normal anatomical position.

1.43d A more medial view than in the previous picture visualizes the empty pituitary fossa.
Case 3
Diagnosis: Suprasellar, retrosellar, and parasellar adenoma
Approach: Right unilateral subfrontal

1.44a The right optic nerve, right internal carotid artery and pituitary adenoma are visualized.

1.44b The pituitary stalk can be seen as it enters the tumor capsule.
Case 4

Diagnosis: Suprachiasmal, retrochiasmal, and prechiasmal adenoma with postfixed chiasm

Approach: Right frontolateral subfrontal

1.45a Both optic nerves and the tumor are visualized through a frontolateral subfrontal approach.

1.45b The tumor capsule has been opened and a portion of the tumor has been removed.

1.45c The left optic nerve at the level of the chiasm reveals ischemic changes due to chronic tumor compression.

1.45d After complete tumor removal, the junction of the capsule and pituitary stalk is held by the forceps to demonstrate the longitudinal vascular pattern of the pituitary stalk.
Case 5
Diagnosis: Suprachiasmal, retrochiasmal, and infrachiasmal adenoma with midfixed chiasm
Approach: Frontolateral subfrontal

1.46a Through a right frontolateral exposure, the pituitary tumor and optic chiasm are visualized. As opposed to the previous case, the optic chiasm is midfixed and allows much less exposure between the optic nerves for access to the tumor.

1.46b The tumor has been resected bilaterally between the internal carotid artery and the optic nerve, as well as between both optic nerves.
Case 6
Diagnosis: Recurrent suprasellar, retrosellar, and parasellar adenoma
Approach: Bilateral subfrontal

1.47a The pituitary region is visualized through a bifrontal approach. The optic nerve and arachnoid adhesions are evident. Medial to the right optic nerve, the tumor capsule has ruptured from a hemorrhage within the tumor. The sudden onset of unilateral blindness heralded the pituitary apoplectic event in this patient. A resection of the adenoma had been performed five years previously.

1.47b After complete removal of the recurrent pituitary adenoma, the lamina terminalis is clearly visualized bulging into the pituitary fossa due to hydrocephalus.

1.47c With the microscope focused slightly deeper than in the preceding figure, the empty pituitary fossa is appreciated.
Case 7
Diagnosis: Recurrent suprasellar and retrostellar adenoma with optic nerve atrophy
Approach: Frontolateral subfrontal

1.48a Gradual unilateral visual loss indicated the frontolateral approach to this recurrent pituitary adenoma. The dense arachnoidal adhesions and marked compression and elevation of the right optic nerve are evident.

1.48b After complete removal of the pituitary tumor, the free-standing right optic nerve is visualized. Despite the appearance of the optic nerve, partial vision returned.
Through a subfrontal approach, the suprasellar extension of the pituitary adenoma and right optic nerve is visualized.

After resection of the suprasellar extension of the pituitary tumor, the dura overlying the planum sphenoidale is coagulated.

After resection of the overlying dura, a drill was used to thin the planum sphenoidale.
1.49d The planum sphenoidale was completely removed, as well as the posterior edge of the tuberculum sellae, exposing the intrasellar tumor.

1.49e The intrasellar portion of the pituitary tumor has been removed, exposing the dorsum sellae.

1.49f After obliterating the sphenoid sinus with fat and covering the dura with fascia lata, the retractor has been removed to expose the frontal lobe. Observe that the craniotomy was performed flush with the floor of the frontal fossa. This requires only minimal elevation of the frontal lobe to obtain good exposure, accounting for the normal appearance of the cortex at the end of the procedure.
Craniopharyngiomas

Introduction: Origin and Growth Pattern

a) Origin of craniopharyngiomas
b) Group I: Intrasellar craniopharyngiomas. Origin: Sella turcica; the arrows indicate infra-, para- and suprasellar tumor growth.
c) Group II: Suprasellar craniopharyngiomas. Origin: Pituitary stalk; the arrows indicate growth in direction of the infundibulum, the floor of the 3rd ventricle, the sellar entrance, and in the paramedian region.
Choice of Approach

1.50a, b The appropriate approach to craniopharyngiomas depends on their specific anatomical location. Similar to pituitary adenomas, the various ways of exposing a craniopharyngioma depend on their location and extension. Commonly, the complete resection of a craniopharyngioma requires access through various anatomical structures: through the lamina terminalis for the tumor portion extending into the third ventricle, between the optic nerves for the intrasellar portion, below the optic nerve and carotid artery above the third nerve for the lateral extension, and finally below the third nerve for the lateral and posterior extension. The following clinical cases are divided according to the approach used: the unilateral subfrontal approach, the intracranial subfrontal transsphenoidal approach, the unilateral subfrontal approach through the lamina terminalis, the frontolateral subfrontal approach between the optic nerve and carotid artery, the frontolateral subfrontal approach between the carotid artery and the oculomotor nerve, and finally the pterional approach or the frontotemporal access below the oculomotor nerve.

1.50c Similarly, head positioning depends not only on the approach selected but also on the specific area of interest. This diagram illustrates how the surgeon would position the patient’s head so that the vision through the microscope is in the vertical axis in relationship to the exposure. With a 45 degree rotation off the vertical axis, a frontolateral or pterional approach would give excellent visualization of the sellar region. However, if the surgeon were interested in a region lateral to the sella, such as the sphenoid wing, less rotation would be desired. Alternatively, if the area of interest were the tuberculum sellae, more rotation would be required.
Clinical Material
Intracranial Subfrontal Transsphenoidal Approach

Case
Diagnosis: Intrasellar, partially cystic craniopharyngioma
Approach: Subfrontal transsphenoidal

1.51a Through a subfrontal exposure, the optic nerves and chiasm are visualized. The tumor is covered with bone between the optic nerves.

1.51b The dura over the planum sphenoidal has been cauterized and resected.

1.51c The planum sphenoidale and anterior wall of the dorsum sellae have been resected.
Following the incision of the tumor capsule, the typical cholesterol crystal-containing fluid emerges.

The tumor has been removed, revealing the optic chiasm and sella.
Unilateral Subfrontal Approach

Case 1

Diagnosis: Suprasellar cystic craniopharyngioma
Approach: Unilateral subfrontal

1.52a Unilateral subfrontal exposure of a cystic craniopharyngioma expanding under the right optic nerve.

1.52b Following the incision of the tumor capsule, the tumor collapses with suction. Notice the right optic nerve as it assumes its normal anatomical position.
Case 2
Diagnosis: Suprasellar prechiasmal cystic craniopharyngioma
Approach: Unilateral subfrontal

1.53a Exposure of a postfixed chiasm and tumor through a unilateral subfrontal approach.

1.53b The tumor capsule has been opened and the cystic portion of the tumor resected. In contrast to the previous case, the tumor capsule has not collapsed.
Case 3
Diagnosis: Suprasellar and retrosellar cystic craniopharyngioma
Approach: Right unilateral subfrontal

1.54a A CT scan demonstrates a large suprasellar craniopharyngioma.

1.54b A slightly higher cut demonstrates the extent of the craniopharyngioma.

1.54c To obtain adequate exposure for this large cystic craniopharyngioma, the frontal lobe must be elevated significantly. Through a right unilateral subfrontal approach, the olfactory nerve is dissected free from its arachnoid adhesions to allow retraction of the frontal lobe while preserving the continuity of the olfactory nerve.
1.54d  Further retraction of the frontal lobe rostrally reveals the thinned optic nerve, internal carotid artery, and large cystic craniopharyngioma.

1.54e  Puncturing the tumor capsule reveals the typical crystal-containing cholesterol fluid.

1.54f  The tumor capsule is markedly relaxed after some of the contents of the tumor have been removed.
1.54g After the tumor has been evacuated, the optic nerve relaxes completely.

1.54h A postoperative CT scan reveals excellent removal of the craniopharyngioma.

1.54i A greater magnification of the sellar region demonstrates that there is no residual craniopharyngioma.
Case 4
Diagnosis: Suprasellar solid craniopharyngioma
Approach: Right unilateral subfrontal

1.55a  A CT scan demonstrates a partially calcified mass, consistent with craniopharyngioma.

1.55b  A midline reconstruction of the CT scan shows the location of the craniopharyngioma in relationship to the pituitary fossa.

1.55c  Through a right subfrontal unilateral approach, the tumor and both optic nerves are clearly visible.
1.55d After the tumor has been completely resected, the infundibulum is visible from the hypothalamus to the diaphragm, adjacent to the retracted optic nerve. Superiorly, a small portion of the contralateral internal carotid artery can be seen.

1.55e A tilt of the microscope clearly visualizes the contralateral internal carotid artery and its branches.

1.55f A CT scan and reconstruction demonstrate the area of tumor removal.
Case 5
Diagnosis: Suprasellar and parasellar cystic craniopharyngioma
Approach: Right unilateral subfrontal

1.56a A midline magnetic resonance image reveals the large suprasellar and parasellar cystic craniopharyngioma.

1.56b CT reconstruction delineates the extent of the tumor mass.

1.56c Using right unilateral subfrontal approach, the stretched optic nerve and tense tumor capsule can be seen.

1.56d Entering the tumor capsule between the optic nerve and internal carotid artery permits typical cholesterol crystal-containing fluid to escape.
1.56e The tumor is resected between the optic nerve and internal carotid artery.

1.56f The contents of the tumor have been evacuated, and the tumor capsule is now elevated, exposing the basilar artery underneath.

1.56g The tumor capsule has been separated from the infundibulum by working between the two optic nerves; the contralateral internal artery is now visible.
1.56h After the tumor has been completely excised, the infundibulum, ipsilateral optic nerve, ipsilateral carotid artery, and posterior communicating, posterior cerebral, and basilar arteries are all visible.

1.56i A postoperative CT scan shows minimal residual blood.

1.56j A higher CT section demonstrates that the tumor has been removed.
Case 6
Diagnosis: Suprasellar and parasellar subchiasmal, partially cystic craniopharyngioma (prefixed chiasma)
Approach: Right unilateral subfrontal

1.57a A CT scan demonstrates a large craniopharyngioma.

1.57b A higher CT section demonstrates tumor extension high into the third ventricle, causing hydrocephalus.

1.57c Through a right unilateral subfrontal exposure of the optic chiasm, a dramatic groove is visible in the chiasm, which is compressed by the anterior cerebral artery from above and by the tumor from below.

1.57d More exposure is gained by drilling away part of the optic canal, planum sphenoidale, and tuberculum sellae.
1.57e The tumor can now be approached through the resected tuberculum sellae as well as between the right optic nerve and right internal carotid artery. Despite the limited exposure, space is sufficient to permit almost complete extirpation of the tumor.

1.57f A postoperative CT scan shows a small residual tumor.
Case 7
Diagnosis: Interhemispheric tumor extension, suprasellar and suprachiasmal cystic craniopharyngioma
Approach: Unilateral subfrontal

1.58a Through a left subfrontal approach, a very large suprasellar and interhemispheric extension of a craniopharyngioma is exposed.

1.58b The tumor is incised, exposing a cystic component.

1.58c After complete extirpation of the tumor, the left optic nerve, chiasm, and contents of the sella can be visualized.
Case 8

Diagnosis: Suprasellar and parasellar mainly cystic craniopharyngioma (midfixed chiasm), juvenile case

Approach: Right unilateral subfrontal

1.59a Using a right unilateral subfrontal approach, the midfixed chiasm, two optic nerves, the internal carotid artery, and A-1 are clearly visible. The tumor, located directly below the chiasm, is difficult to expose between the optic nerves, or between the optic nerve and the internal carotid artery, as there is so little space.

1.59b Sacrificing the anterior cerebral artery as it emerges from the internal carotid artery enlarges the space between the optic nerve chiasm and optic tract and the internal carotid artery.

1.59c A generous exposure is obtained by retracting the internal carotid artery laterally. The tumor has been almost entirely removed, and the posterior communicating artery and its many branches are now exposed. Sectioning the anterior cerebral artery in this manner may occasionally improve the exposure, especially in children. Obviously, excellent collateral flow from the opposite anterior cerebral artery is a prerequisite for this maneuver.
Subfrontal Frontolateral Approach, Between the Optic Nerve and Internal Carotid Artery

Case 1
Diagnosis: Suprasellar and parasellar partially cystic craniopharyngioma
Approach: Between optic nerve and carotid artery

1.60a Using frontolateral approach, the right optic nerve is visualized, with tumor extending between the optic nerve and the internal carotid artery.

1.60b The tumor capsule has been opened, and part of the tumor has been evacuated. The internal carotid artery can now be visualized.

1.60c After complete removal of the tumor, the gentle elevation of the right optic nerve allows visualization of the pituitary stalk and empty sella.
Case 2
Diagnosis: Suprasellar and parasellar, partially cystic craniopharyngioma
Approach: Between right optic nerve and internal carotid artery

1.61a Using a frontolateral approach to the pituitary region, the cystic portion of the craniopharyngioma can be seen as it emerges between the optic nerve and internal carotid artery.

1.61b Following considerable tumor resection, the optic nerve has been partially decompressed.

1.61c A slightly different angle of the microscope visualizes the residual tumor wall interiorly with good exposure of the contralateral internal carotid artery as seen between the two optic nerves.
Case 3  
Diagnosis: Parasellar solid craniopharyngioma  
Approach: Frontolateral subfrontal between the optic nerve and carotid artery

1.62a Using a frontolateral subfrontal approach, a thinned and elevated optic nerve and tumor are visualized.

1.62b After significant tumor resection, the optic nerve is partially decompressed and the internal carotid artery can now be visualized.

1.62c With the microscope focused on the internal carotid artery, the right optic nerve, chiasm and optic tract can be clearly identified following complete tumor extirpation. More deeply, the basilar artery, the posterior cerebral artery and the superior cerebellar artery can be seen.
1.62d A slightly more posterior exposure demonstrates an unusual anatomical variation, in that the anterior cerebral artery perforates the optic tract.

1.62e By repositioning the microscope and looking between the two optic nerves, the empty tumor cavity is in focus.
Frontolateral Subfrontal Approach, Between the Internal Carotid Artery and Oculomotor Nerve

Case

Diagnosis: Parasellar partially cystic craniopharyngioma

Approach: Frontolateral subfrontal, between the right internal carotid artery and oculomotor nerve

1.63a The optic nerve, chiasm, and right internal carotid artery are exposed using a frontolateral approach.

1.63b By mobilizing the temporal lobe, the cystic portion of the tumor can be seen below the internal carotid artery.

1.63c The exposed tumor below the internal carotid artery has been removed.

1.63d By repositioning the microscope, the basilar artery comes into view. Further tumor resection can now be performed between the optic nerve, the carotid artery and the two optic nerves.
Pterional exposure of the internal carotid artery and its surrounding structures. The tumor cyst which elevated the third nerve has already been opened. The relationship between the optic nerve, internal carotid artery, anterior and middle cerebral arteries, and the third nerve are well visualized. The distortion of these structures by the tumor led to the use of the approach below the oculomotor nerve.
Suprasellar Meningiomas

Clinical Material

Case 1

Diagnosis: Suprasellar, parasellar, and planum sphenoidale meningioma

Approach: Right unilateral subfrontal

1.65a Using a unilateral subfrontal approach, the planum sphenoidale, the tumor, and the displaced right optic nerve are visualized. Notice the typical vascular pattern on the dura of the planum sphenoidale at the edge of the meningioma.

1.65b Under high magnification, the tumor extension can be appreciated as it invests the lateral and superior lateral aspect of the optic nerve.

1.65c Partial tumor extirpation has effectively decompressed the optic nerve, and allows visualization of the right internal carotid artery.

1.65d After the meningioma has been completely removed, both optic nerves and the pituitary stalk are clearly seen.
Case 2
Diagnosis: Suprasellar and planum sphenoidale meningioma
Approach: Right subfrontal frontolateral

1.66a Using a frontolateral approach, a meningioma is seen to extend above the planum sphenoidale and emerge between the optic nerves.

1.66b The meningioma has been removed and its dural attachment on the inferior edge of the tuberculum sellae has been cauterized.

1.66c Slight lateral retraction of the right optic nerve allows inspection of the pituitary stalk.
Case 3
Diagnosis: Suprasellar meningioma
Approach: Right subfrontal frontolateral

1.67a Using a right frontolateral approach, a meningioma severely compromising the right optic nerve is visualized.

1.67b After complete removal of the meningioma, the arachnoid-covered pituitary stalk comes into view.

1.67c By focusing on the optic nerves and tuberculum sellae, the damage from the tumor compression of the right optic nerve can be appreciated.
Case 4
Diagnosis: Suprasellar meningioma
Approach: Left unilateral subfrontal

1.68a A coronal MR image through the sellar region demonstrates a sellar meningioma.

1.68b A midline sagittal section in an MR image demonstrates the sellar meningioma.

1.68c Using a left subduralpterional approach, the internal middle anterior artery and communicating artery become visible, along with the optic nerve and the tumor.

1.68d After the tumor has been resected, the entire optic chiasm can be seen. The infundibulum is between the optic nerves.
Case 5
Diagnosis: Parasellar meningioma
Approach: Right unilateral subfrontal

1.69a A CT scan demonstrates a right parasellar mass with a few flecks of calcification.

1.69b The MR image demonstrates a slight distortion of the brain stem by the tumor.

1.69c Using a right unilateral subfrontal approach, the typical encasement of the optic nerve and carotid artery by meningioma is visualized.

1.69d Gradual resection of the tumor between the optic nerve and the internal carotid artery, and between the internal carotid artery and third nerve, allows further definition of the tumor planes.
1.69e After the tumor has been completely extirpated, the relationship among the anterior cerebral artery, optic nerve, optic chiasm, internal carotid artery, and brain stem can be appreciated.

1.69f When the right internal carotid artery is retracted laterally, the basilar artery and both posterior cerebral arteries can be visualized.

1.69g Higher magnification permits clear identification of the tip of the basilar artery and the origins of both posterior cerebral arteries.
Teratomas

Clinical Material

Case

Diagnosis: Suprasellar teratoma

Approach: Right unilateral subfrontal

1.70a A CT scan and CT reconstruction demonstrate a suprasellar teratoma.

1.70d A postoperative CT scan verifies tumor extirpation.

1.70b Through a unilateral right subfrontal approach, the optic nerves and chiasm, distorted by the tumor, are clearly visible.

1.70c After the tumor has been extirpated, the optic nerves and chiasm and both carotid arteries are clearly visible.
Epidermoids (Cholesteatomas)

Clinical Material

Case

Diagnosis: Suprasellar and parasellar epidermoid (cholesteatoma)

Approach: Left combined subfrontal frontolateral and pterional

1.71a The epidermoid, left optic nerve, and a small segment of the ophthalmic artery (through an exposure along the sphenoid wing) are exposed.

1.71b After partial removal of the epidermoid, the underlying internal carotid artery emerges.

1.71c After extensive tumor removal, the internal carotid artery and its branches, the optic nerve, the superior cerebellar artery, and the tentorial edge are seen. A portion of epidermoid remains below the tentorial edge.

1.71d By repositioning the microscope more subfrontally, the remaining portion of the epidermoid is observed and removed. This allows complete exposure of the ipsilateral and contralateral carotid arteries, the optic nerves and chiasm, the right middle fossa with the third nerve, and, most interiorly, the left superior cerebellar artery.
Infundibulomas

Clinical Material

Case

Diagnosis: Infundibuloma (pilocytic astrocytoma of juvenile type of the infundibulum)

Approach: Right unilateral subfrontal

1.72a. Using a unilateral subfrontal approach, the optic nerve and tumor are exposed.

1.72b. After removal of this pilocytic astrocytoma, the adhesions of the tumor capsule to the pituitary stalk or infundibulum are seen.

1.72c. After complete resection of the tumor capsule, observe the residual sectioned pituitary stalk in the sella.
The internal carotid artery lateral to the optic nerve, the anterior cerebral artery, and the aneurysm extending into the sella are visualized.

The inclusion of this case of a giant aneurysm is to emphasize that despite the typical clinical picture of an intrasellar tumor with pituitary dysfunction (including elevated prolactin levels, a visual field defect, and an expanded sella turcica on X-ray), an aneurysm cannot be excluded. Obviously, transsphenoidal or transcranial biopsy of this lesion is to be discouraged.
Gliomas of the Optic Chiasm and Hypothalamus

Clinical Material

Case 1

Diagnosis: Suprasellar glioma of the optic chiasm and hypothalamus

Approach: Right unilateral subfrontal

1.73a Using a right subfrontal approach, the optic nerves and chiasm are seen. The left optic nerve and chiasm are clearly enlarged and infiltrated with tumor.

1.73b Higher magnification of the same area reveals the biopsy site and tumor extension into the hypothalamus and frontal lobe.
1.74a The optic nerves and chiasm are exposed through a unilateral subfrontal approach. Of particular interest in this case is the obvious chiasmatic distortion and the patient's clinical presentation, which, on initial inspection, suggested significant hypothalamic tumor infiltration (Simmonds' cachexia).

1.74b A large portion of the glioma has been removed below the chiasm, making it evident that the tumor has originated from the hypothalamus rather than the chiasm. Further resection of the tumor demonstrated no direct involvement of the chiasm by the glioma.

1.74c By repositioning the microscope laterally, further tumor could be resected between the optic nerve and the internal carotid artery. This patient recovered full vision, and remains alive and well with normal neurologic and pituitary function 19 years following surgery.

Case 2
Diagnosis: Solid glioma of the hypothalamus with chiasmal distortion
Approach: Right unilateral subfrontal
Tumors of the Supratentorial Ventricular System

Tumors of the Anterior Third Ventricle

Trans-Lamina Terminalis Approach

Microanatomy

1.75 A midsagittal section through the third ventricle demonstrates the anterior communicating artery and anterior cerebral artery. Notice the basilar bifurcation and the posterior communicating artery with its multiple perforating branches.
1.76a A paramedian section through the third ventricle illustrates the lamina terminalis and its relationship to the anterior third ventricle.
1.76b This anatomic specimen demonstrates the relationships among the optic chiasm, the two internal carotid arteries, the anterior cerebral arteries, and the lamina terminalis. The orientation is through a bilateral subfrontal approach, viewed slightly from the right.
1.76c The resection of the frontal lobe through the third and lateral ventricles demonstrates the relationship of the third ventricle to the anterior cerebral artery and the lamina terminalis.
Position and Approach

Subfrontal Approach to the Third Ventricle through the Lamina Terminalis

1.77a The arrow depicts the approach to the anterior third ventricle through the lamina terminalis.

Bilateral Subfrontal Approach to the Third Ventricle through the Lamina Terminalis

1.77b Bilateral craniotomy with the coronal incision (schematically presented). The patient is placed supine on the operating table with the head slightly extended. If a unilateral subfrontal approach is utilized, the head may be turned 15 degrees off the midline. If a bilateral subfrontal approach is utilized, the head should be maintained in the neutral position. Again, it is important to emphasize that the bone should be removed as flush as possible to the floor of the frontal fossa to minimize retraction of the frontal lobes.

1.77c Relationship between the craniotomy, the cerebral hemispheres, and the ventricular system.
1.78a Using a subfrontal approach, the prefixed optic chiasm, the right internal carotid artery, the anterior cerebral artery, and the lamina terminalis (expanded by tumor) are visualized.

1.78b The lamina terminalis has been opened. A small portion of tumor capsule remains and the third ventricle and sella are visualized.

1.78c With all the tumor removed and the microscope focused on the deeper structures the third nerve and posterior communicating artery are well visualized.
Case 2
Diagnosis: Suprasellar retrochiasmal partially cystic craniopharyngioma (prefixed chiasm)
Approach: Unilateral subfrontal lamina terminalis

1.79a With a slightly more lateral subfrontal approach than in the previous case, the optic nerves, optic chiasm and lamina terminalis (distended by tumor) are exposed.

1.79b The lamina terminalis has been opened, exposing the cystic portion of the tumor.

1.79c A jet of cystic fluid escapes following the puncture of the cyst wall.
1.79d After removal of the cyst, the tumor, studded with cholesterol crystals, is visualized.

1.79e After tumor removal, the tumor cavity, chiasm, and optic nerves are seen.
Tumors of the Lateral Ventricles and Third Ventricle

Transcortical and Transcallosal Approaches

Microanatomy

1.80 Corpus callosum, viewed from above and from behind (millimeter scale on surface of corpus callosum).
Left lateral ventricle, paramedian section, viewed from the left.
1.82 Right lateral ventricle, viewed from above.

1.83 Right lateral ventricle, central portion, viewed from above.
1.84a A view of the left lateral ventricle demonstrates the key landmarks that lead to the foramen of Monro, the septal vein, the choroid plexus, and the thalamostriate vein.
The same ventricular exposure with a view into the atrium demonstrates a choroidal cyst, which is an incidental finding often observed on routine MR imaging studies.
1.85 Occipital horn of the right lateral ventricle, viewed from the dorsolateral aspect.
1.86 Right internal cerebral vein and its tributaries, viewed from above.

1.87 Third ventricle and right lateral ventricle, viewed from the right side. The corpus callosum is split.
1.88 Deep cerebral veins from above.

1.89 Third ventricle, viewed from the right dorsal aspect.
1.90 Third ventricle, viewed from above.

1.91 A parasagittal section through the corpus callosum visualizes the third ventricle, aqueduct, and an extremely large perforated septum pellucidum (viewed from the left). With this specimen, the exposure obtained from the various approaches to the third ventricle (i.e., through the lamina terminalis, through the lateral ventricle via the foramen of Monro, and, finally, into the posterior third ventricle via the pineal approach) can be appreciated.
The reflected septum reveals the contralateral lateral ventricle and the choroid plexus. The choroid plexus is an easily identified structure that can be followed to the foramen of Monro.
1.93 Median sagittal section of the corpus callosum, viewed from the left.
1.94 From a coronal section looking anteriorly, the relationships between the interhemispheric fissure, corpus callosum, and septum pellucidum are easily recognized. As the two fornices separate anteriorly, their relationship to the anterior commissure can be appreciated. The relationship of the choroid plexus to the fornix as it traverses through the foramen of Monro is also apparent.

1.95 A frontal section, viewed from in front with the lateral ventricles and third ventricle, demonstrates the common finding of a cavum septum pellucidum (Verga's ventricle).
1.96 A transverse section through both thalami and the pineal gland demonstrates the relationship of the third ventricle to the foramina of Monro, the interthalamic adhesion (massa intermedia), the fornix, and the pineal gland.

1.97 A view from above, exposing the floor of a wide, horizontally-sectioned third ventricle, nicely demonstrates the relationships between the lamina terminalis, anterior commissure, posterior commissure, pineal recess, and quadrigeminal plate.
Position and Approaches

For exposure of an intrahemispheric mass, the patient should be positioned in such a way that access from a vertical direction is possible. The relationship between the craniotomy and the mass should allow the surgeon to assume a comfortable sitting position to minimize fatigue. The head is placed so that the tumor is easily exposed for the surgical approach. The exposed brain is routinely covered with a moistened thin Gelfoam to prevent drying. Strict hemostasis is an important and obvious criterion for any microsurgical procedure.

Transcortical Approaches

- Transfrontal
- Transfrontal transventricular
  - Transfrontal
  - Transseptal
  - Transfornical
  - Subchoroidal or interthalamus-trigonalis
- Transparietal transventricular
  (Parieto temporal)
  Parietal

Transfrontal Transcortical Transventricular Approach to the Lateral Ventricle and Foramen of Monro

1.99a For the transfrontal transcortical approach to the lateral ventricle and to the foramen of Monro, the head is rotated 30 degrees off the vertical axis.

1.99b The scalp incision, burr hole, and craniotomy.

1.99c The relationship between the craniotomy, the cerebral hemisphere, and the ventricular system.
Tumors of the Supratentorial Ventricular System

Transfrontal Transcortical Approach to the Lateral Ventricle

1.101 A view through the transcortical approach into the lateral ventricle. The anatomical structures are easily identified, and provide a reliable pathway to the foramen of Monro. The choroid plexus or thalamostriate vein is followed anteriorly until it enters the foramen of Monro. To enlarge the foramen of Monro, we prefer opening the choroidal fissure instead of sacrificing the fornix. This enlargement is best accomplished by coagulating the choroid plexus right at the foramen of Monro. This maneuver exposes the choroidal fissure, and provides easy access to the anterior portion of the third ventricle.

1.100a The foramen of Monro can be located by drawing a line 1 cm in front of the coronal suture to the external meatus.

1.100b When the line is 3.5 cm from midline and aimed toward the inner canthus of the contralateral eye, it will traverse the foramen of Monro.

1.100c This coronal diagram shows the line pointing toward a tumor in the third ventricle.
Transcortical Approach to the Trigone Region of the Lateral Ventricle

1.102a The patient is placed supine on the operating table, with one shoulder elevated and the head horizontal.

1.102b Scalp incision and craniotomy for exposure of the angular gyrus.

1.102c Relationship of craniotomy to lateral ventricles.
Transcallosal Approach in the Vertical Position

1.103a Skin incision and craniotomy. A small burr hole is placed lateral to the midline or in the posterior inferior corner. Through the small burr hole, the craniotomy is drilled anteriorly, with the Midas Rex footplate toward the sagittal sinus. Immediately before the sagittal sinus is reached, the drill is stopped and pulled back slightly, and the bone dust is irrigated out. While the light is directly above the bone cut, the dura is inspected to ascertain that the footplate is located extradurally. The cut is then continued across the sagittal sinus. This maneuver is repeated again just prior to crossing the sagittal sinus the second time.

1.104 Scalp incision and standard placement of multiple burr holes. Using this technique, the sagittal sinus gradually is exposed.

1.103b The craniotomy is schematically outlined to demonstrate the relationship of the ventricles to the corpus callosum.

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Midline Transcallosal Approaches
- Interhemispheric transcallosal (unilateral and/or bilateral, medial)
  - Anterior transcallosal
  - Transforaminal
  - Transseptal
  - Transfomical
  - Subchoroidal or interthalamus-trigonals
  - Interforimal
- Posterior transcallosal
1.105a, b With the body supine and the appropriate shoulder slightly elevated, the head is placed in the horizontal position and raised 30 to 45 degrees from the table. This position offers several advantages. First, it allows both hands to work in the same horizontal plane along the interhemispheric fissure, rather than in an awkward vertical relationship. Second, it allows the ipsilateral hemisphere to be retracted by gravity, thereby reducing the need for retractors.

1.105c The skin incision, burr hole, and craniotomy.

1.105d The relationship of the craniotomy to the corpus callosum and ventricular system.
The transcallosal approach to the lateral ventricle between the two hemispheres. The contralateral hemisphere is minimally retracted along with the falx, with care being taken not to compress and occlude the sagittal sinus. The ipsilateral hemisphere is gently retracted between the draining veins. The exact point of retractor placement depends on the venous drainage, choosing the portion of hemisphere that is most appropriate for the location of the tumor and that has no major draining veins which join the sagittal sinus.

Contralateral midline transcallosal approach to the lateral ventricle. Particularly for left lateral ventricular lesions, a contralateral midline approach may be considered. The ipsilateral sinus and falx are retracted, and the ipsilateral corpus callosum is approached from the opposite side. If extensive exposure is required and maximum visualization is needed, an approach on both sides of the sagittal sinus can be used. Sometimes a portion of the falx may need to be resected.

The interhemispheric transcallosal approach to both lateral ventricles. This approach may be considered in cases of bilateral ventricular tumors and tumor extension from the third ventricle through both foramina of Monro.
Using the interhemispheric transcallosal approach, the foramen of Monro is exposed.

A view through the opened corpus callosum depicts the two means of enlarging the foramen of Monro, if required. Anteriorly, a single fornix can be sacrificed or, as we prefer, the foramen of Monro can be enlarged posteriorly by opening the choroidal fissure.

The coronal exposure of the transcallosal approach is shown here through the foramen of Monro, which is enlarged by opening the choroidal fissure.
1.108 Medial transcallosal approach. If the fornices are already markedly elevated and separated by a large third ventricular mass, the interforniceal approach is a reasonable choice. Care should be taken to stay within the midline, to avoid damage to either fornix.

1.109a The transcallosal approach to both foramina of Monro is depicted through an opening in the septum pellucidum.

1.109b A view from above shows both lateral ventricles and both foramina of Monro through a transcallosal approach, with an opening in the septum pellucidum.
1.110a The frontal cortex has been coagulated and is incised with an 11-blade.

1.110b,c The cyst in the septum pellucidum can now be seen through the transventricular exposure. The cyst is opened and the wall resected as far as possible. In order to minimize postoperative hygroma formation, the arachnoid can be closed at the end of the procedure by bipolar coagulation of the arachnoidal edges and by approximating them with 10-0 running suture.
Case 2
Diagnosis: Gangliocytoma in the septum pellucidum
Approach: Transfrontal transventricular

1.111a The lateral ventricle has been exposed through the transfrontal approach. The tumor is visible beneath the choroid plexus.

1.111b Complete visualization of the tumor is achieved by repositioning the retractors interiorly.

1.111c The gangliocytoma has been resected and an opening through the septum pellucidum allows visualization of the contralateral ventricle.
1.112a The trigone of the lateral ventricle has been exposed through a cortical incision in the right angular gyrus. The cyst in the velum interpositum is visible. The foramen of Monro can be seen anteriorly.

1.112b The cyst is exposed.

1.112c The cyst has been partially resected, and the opposite lateral ventricle can be seen through the foramen of Monro.

Case 3
Diagnosis: Cyst in cavum, veli interpositi
Approach: Angular gyrus-transventricular
Case 4

Diagnosis: Glioma (malignant oligodendroglioma) of the lateral ventricles and the septum pellucidum

Approach: Transcallosal

Position: Supine, head turned laterally

1.113a ACT scan through the lateral ventricles reveals a large intraventricular mass extending across the septum pellucidum.

1.113b A lower section demonstrates the mass as it extends interiorly.

1.113c The patient is placed supine, with head turned horizontally and elevated approximately 30 degrees.

1.113d The midline and scalp incision are outlined.
After the scalp incision, the markings on the skull clearly demonstrate the sagittal and coronal sutures. Note that the scalp is retracted additionally with scalp hooks. The incision is approximately two-thirds rostral and one-third caudal to the coronal suture.

The Midas Rex drill is inserted through a small burr hole, and a free bone flap is elevated.

After the bone flap has been removed, the intact dura and sagittal sinus are visible.
1.113h The dura has been reflected toward the sagittal sinus.

1.113i After the hemispheres have been separated, the pale corpus callosum is identified.

1.113j After the corpus callosum has been incised, the choroid plexus and thalamostriate vein are clearly visible. The distorted septum pellucidum and the tumor can be seen superiorly.
1.113k If the microscope is angled further posteriorly, the large tumor extending into the thalamus below the choroid plexus can be visualized.

1.113l A large cavity appears in the thalamus, lateral to the choroid plexus, after extensive tumor resection.

1.113m An anterior view demonstrates the foramen of Monro and the fornix.
1.113n A high-powered view through the foramen of Monro demonstrates the hypothalamic and optic recesses.

1.113o After the tumor has been resected, the large tumor cavity can be appreciated.

1.113p A postoperative MR image demonstrates the area of the corpus callosum resection and the large cavity where the tumor had been located.
Case 5

Diagnosis: Glioma (Pilocytic astrocytoma) of the lateral ventricle

Approach: Right transfrontal transcortical transventricular

Position: Supine

1.114a A CT scan shows a large intraventricular pilocytic astrocytoma.

1.114d A postoperative CT scan demonstrates that the tumor has been removed.
1.114b A view through the frontal lobe into the right lateral ventricle exposes the tumor, thalamostriate vein, choroid plexus, and foramen of Monro.

1.114c A higher magnification of the foramen of Monro, looking into the third ventricle. The tumor is subsequently removed.
Case 6
Diagnosis: Glioma (pilocytic astrocytoma) of the lateral and third ventricles
Approach: Right transfrental transcortical transventricular
Position: Supine

1.115a A CT scan and CT three-dimensional reconstruction of a large pilocytic astrocytoma in the third and lateral ventricles.

1.115b A postoperative CT scan demonstrates excellent tumor removal.

1.115c A sagittal MR image through the midline shows the extent of the tumor in the third ventricle.

1.115d A transfrontal transventricular opening exposes the tumor in the right lateral ventricle.
Before it is removed, the tumor is retracted with the sucker to locate the foramen of Monro.

After a large portion of the tumor has been removed, the foramen of Monro becomes visible. The third ventricle is filled with bloody cerebrospinal fluid.

This view shows the third ventricle through the foramen of Monro at higher magnification after the tumor has been removed.
The interhemispheric fissure has been exposed. The falx and right hemisphere are slightly retracted. The arachnoid of the pericallosal cistern is visible below the edge of the falx.

Following resection of the arachnoid, both pericallosal arteries are exposed. Deeper exposure shows the thinned white corpus callosum.
Case 7
Diagnosis: Intraventricular meningioma
Approach: Transcallosal

1.116d After opening the thinned corpus callosum, the large intraventricular meningioma is exposed. Higher magnification reveals the vascularity of the meningioma.

1.116e Most of the tumor has been resected. The residual tumor is visualized.

1.116f With a view of the trigone of the lateral ventricle, a portion of residual meningioma still remains attached to the choroid plexus.
Case 8
Diagnosis: Neurocytoma of the right lateral ventricle and the third ventricle
Approach: Midline interhemispheric transcallosal transseptal biventricular

1.117a A midline sagittal MR image demonstrates a neurocytoma in the third and right lateral ventricles.

1.117b A horizontal CT section through the lateral ventricles demonstrates a neurocytoma within the right lateral and third ventricles.

1.117c A postoperative MR image shows excellent tumor removal in the third and lateral ventricles, and residual blood in the right frontal horn.
The corpus callosum is exposed through an interhemispheric approach.

The corpus callosum is opened between the two anterior cerebral arteries, exposing a portion of the ventricle and tumor.

After a large portion of the tumor has been removed, a view into the right and left ventricles on either side of the septum pellucidum is possible.

After more tumor has been removed, both foramina of Monro are seen on either side of the septum pellucidum.
Tumors of the Third Ventricle

Clinical Material

Case 1

Diagnosis: Glioma of the third ventricle
Approach: Right transfrontal transventricular

1.118a The lateral ventricle has been exposed through a right frontal cortical incision. The foramen of Monro is visible.

1.118b A third ventricular glioma is identified through the foramen of Monro.
Case 2
Diagnosis: Colloid cyst of the third ventricle
Approach: Midline Interhemispheric transcallosal transventricular

1.119a A CT scan shows a classic colloid cyst, located in the third ventricle.

1.119b Using right frontal cortical incision, the lateral ventricle and foramen of Monro have been exposed. It should be remembered that the septal vein or the choroid plexus can be used as a guide to locate the foramen of Monro if it is not immediately visible.

1.119c The colloid cyst has been punctured, and the thick milky material can be seen as it exudes from the cyst.
1.119d The colloid cyst has been resected.

1.119e A postoperative CT scan after the colloid cyst has been removed.
Case 3
Diagnosis: Colloid cyst of the third ventricle
Approach: Midline interhemispheric transcallosal transventricular

1.120a The lateral ventricle has been opened by resecting a part of the corpus callosum. The cystic structure is visible through the foramen of Monro.

1.120b Higher magnification of the ependymal cyst.

1.120c View of the floor of the third ventricle after complete excision of the cyst wall.

1.120d A preoperative CT scan shows a colloid cyst of the third ventricle.
Case 4
Diagnosis: Echinococcal cyst of the foramen of Monro
Approach: Left transfrontal transcortical transventricular

1.121a A CT scan demonstrates an echinococcal cyst at the foramen of Monro.

1.121b An echinococcal cyst within the foramen of Monro is visible through a transcortical transfrontal exposure.

1.121c After the echinococcal cyst has been removed, the third ventricle can be visualized through the foramen of Monro.

1.121d A postoperative CT scan demonstrates cyst removal.
Case 5

Diagnosis: Cystic craniopharyngioma of the third ventricle

Approach: Transcallosal

1.122a The corpus callosum has been opened, exposing a view of the lateral ventricle with a cystic tumor emerging through the foramen of Monro.

1.122b The tumor is being evacuated, and the cyst wall is resected through the foramen of Monro.

1.122c The tumor has been excised.

1.122d High magnification following removal of the craniopharyngioma allows visualization of the floor of the third ventricle. The flecks of cholesterol crystals from within the cyst are still visible on the floor of the third ventricle.
Case 6
Diagnosis: Choroid plexus papilloma of the third ventricle
Approach: Midline interhemispheric transcannular transventricular
Position: Supine

1.123a A coronal ultrasound of the lateral ventricle and a choroid plexus papilloma in an infant.

1.123b A lateral ultrasound of the enlarged lateral ventricle and the choroid plexus papilloma of the third ventricle.

1.123c A distended and thinned septum pellucidum is visible through a transcannular exposure of the lateral ventricle.

1.123d A slightly more lateral view demonstrates the choroid plexus papilloma.
1.123e The choroid plexus papilloma is seen as it courses through the foramen of Monro.

1.123f After the choroid plexus papilloma has been removed, the third ventricle can be observed.
Case 7
Diagnosis: Astrocytoma of the third ventricle
Approach: Transcallosal

1.124a The right cerebral hemisphere has been retracted away from the falx, exposing its inferior edge.

1.124b The falx is retracted medially and the right hemisphere ipsilaterally to expose the white corpus callosum.

1.124c The midline of the corpus callosum has been incised.

1.124d The right lateral ventricle is exposed. The body of the fornix is stretched over the third ventricle.
1.124e The microscope is focused within the lateral ventricle on the body of the fornix with the rim of the foramen of Monro visualized most superiorly.

1.124f The third ventricle is opened between the bodies of the stretched out fornix.

1.124g The hemorrhagic astrocytoma is exposed within the third ventricle.
Case 8
Diagnosis: Ependymoma of the third ventricle
Approach: Midline Interhemispheric transcicallosal transventricular transseptal biforaminial
Position: Supine

1.125a A CT scan demonstrates an ependymoma in the third ventricle.

1.125b The right lateral ventricle is opened through an Interhemispheric transcicallosal approach. The septum pellucidum and the tumor that extends through the foramen of Monro are visible.

1.125c The septum pellucidum is opened.
1.125d The tumor is visible contralaterally, seen through the open septum pellucidum.

1.125e Using higher magnification, a view through the septum pellucidum shows the tumor bulging through the contralateral foramen of Monro. This exposure of both foramina of Monro allows safe tumor removal.
Combined Approaches to the Third Ventricle

Combined Frontolateral Lamina Terminalis Approach

1.126a Scalp incision and craniotomy for the combined frontolateral approach to the lamina terminalis.

1.126b The arrows show the subfrontal and pterional approach to the third ventricle.

Combined Pterional and Subtemporal Approach

1.127a Scalp incision and craniotomy for the combined pterional and subtemporal approach.

1.127b The arrows indicate the pterional and subtemporal approach to the third ventricle.
Combined Transcortical Transventricular and Frontolateral Approach

1.128a  Scalp incision and craniotomy for a combined transcortical transventricular and frontolateral approach to the third ventricle.

1.128b  The arrows show the transventricular transforaminal approach to the third ventricle, and the frontolateral subfrontal trans-laminaterminalis approach to the third ventricle.

Combined Transcallosal and Pterional Approach

1.129a  The scalp incision and two craniotomies for the combined transcallosal and pterional approach to the third ventricle. The frontolateral and transcallosal approach can also be used.

1.129b  The arrows indicate the transcallosal transforaminal and pterional trans-lamina terminalis approaches to the third ventricle.
Clinical Material
Case 1
Diagnosis: Solid craniopharyngioma in the suprasellar and parasellar region, extending into the anterior third ventricle
Approach: Combined right unilateral subfrontal and lamina terminalis

1.130a A coronal MR image demonstrates a solid craniopharyngioma in the third ventricle.

1.130b A midline sagittal MR image demonstrates the craniopharyngioma and its extension throughout the third ventricle and below the optic chiasm.

1.130c The anterior cerebral, internal carotid, and middle cerebral arteries are seen through a right unilateral subfrontal approach. The Sylvian fissure has obviously been split widely. Between the two optic nerves, the craniopharyngioma can be identified.
1.130d  The tumor can be seen between the optic tract and the middle cerebral artery. This portion of the tumor was then removed.

1.130e  A tumor specimen is removed between the two optic nerves and the tuberculum sella.

1.130f  After the tumor has been removed, the two optic nerves and both the internal carotid artery and anterior cerebral artery are visible. The infundibulum is between the two optic nerves.
1.130g After the lamina terminalis has been opened, the remainder of the tumor within the third ventricle is removed. The opening through the lamina terminalis is shown, as well as the infundibulum between the two optic nerves.

1.130h A postoperative coronal MR image demonstrates the empty third ventricle.
Case 2
Diagnosis: Cystic craniopharyngiomas in the suprasellar region and within the anterior third ventricle
Approach: Combined unilateral subfrontal and transcallosal
Stage 1: Unilateral subfrontal

1.131a The bilobate craniopharyngioma within the third ventricle and frontal fossa.
1.131b A large suprasellar extension of the craniopharyngioma is exposed using a unilateral subfrontal approach.
1.131c The tumor has been opened, exposing its cystic component.
After removal of the cystic portion of the tumor, the tumor capsule is carefully mobilized.

Further dissection and mobilization of the capsule.

By pulling the capsule anteriorly, the limits of the capsule become apparent. The capsule is separated from its attachment and then removed.
Case 2 (cont.)

Diagnosis: Cystic craniopharyngiomas in the suprasellar region and within the anterior third ventricle

Approach: Combined unilateral subfrontal and transcallosal

Stage 2: Midline interhemispheric transcallosal transventricular transforaminal

1.131g The foramen of Monro is exposed through a transfrontal transventricular incision. The complete intraventricular craniopharyngioma is visualized through the foramen of Monro.

1.131h The partially cystic craniopharyngioma is opened and the tumor partially resected.

1.131i The remaining portion of the tumor and cyst wall is visualized through the foramen of Monro.

1.131j A highly magnified view of the floor of the intact third ventricle after complete excision of the craniopharyngioma.
1.132a A coronal MR image demonstrates a large solid craniopharyngioma within the third ventricle.

1.132b A sagittal MR image demonstrates the extent of the craniopharyngioma, in the sellar region as well as the third ventricle.

1.132c The Sylvian fissure has been opened and the optic chiasm exposed through a pterional approach. The internal carotid and anterior cerebral arteries are visible.

Case 3
Diagnosis: Solid craniopharyngioma of the third ventricle
Approach: Combined pterional-lamina terminalis and transcallosal
Stage 1: Right pterional-lamina terminalis
1.132d After the arachnoidal plane has been opened further, the bilateral internal carotid and anterior cerebral arteries are visible.

1.132e The lamina terminalis has been opened, and the craniopharyngioma has been exposed.

1.132f The craniopharyngioma is removed piece-meal through the lamina terminalis.
1.132g The most inferior portion of the craniopharyngioma within the sella is removed between the tuberculum sella and the optic nerves.

1.132h After all the tumor within the sella and most of the tumor within the anterior third ventricle have been removed, the infundibulum and third ventricle are visible. A small amount of tumor, which was later removed successfully, remains adjacent to the optic chiasm and optic tract.
Case 3
Diagnosis: Solid craniopharyngioma of the third ventricle
Approach: Combined pterional-lamina terminalis and transcallosal
Stage 2: Midline interhemispheric transcallosal transventricular transforaminal

1.132i In the second stage of the procedure, the corpus callosum and two anterior cerebral arteries are exposed through an interhemispheric approach.

1.132j The corpus callosum is split.

1.132k The foramen of Monro and the craniopharyngioma are visible through the right lateral ventricle.
1.32l The craniopharyngioma is removed.

1.32n A CT scan through the third ventricle demonstrates excellent tumor removal.

1.32m A lower magnification of the lateral ventricle demonstrates the previously placed ventricular shunt.

1.32o A higher CT scan demonstrates that the craniopharyngioma and ventricular catheter have been removed.
Tumors of the Pineal Region, Posterior Third Ventricle, and Midbrain

Microanatomy

1.133 Midsagittal section through the third ventricle, pineal gland, and vermis.
1.134 Median section through the pineal gland and vein of Galen.

1.135 Posterior portion of third ventricle as seen from above and in front, through the split corpus callosum.
1.136 Quadrigeminal plate viewed from above.

1.137 Ambient cistern, viewed from the side after the tentorium has been pulled back.
1.138 Detailed view of the ambient cistern following resection of the tentorium.
1.139  Right lateral view of the midbrain and superior lateral view of the region of the vein of Galen.

1.140  Superior lateral view of the vein of Galen.
1.141 The dura has been removed from the occipital lobe and cerebellum, leaving the transverse and sagittal sinuses intact.

1.142 The right occipital lobe and the right cerebellar hemisphere are viewed from the side. The dura has been removed from both, the occipital lobe and the cerebellum, leaving the transverse and sigmoid sinus intact.
1.143 The occipital lobe has been elevated, exposing the tentorium and the falk. The deep venous channels, draining into the vein of Galen and into the straight sinus, are readily visible.
1.144 The various approaches to the pineal region, posterior third ventricle, and midbrain. These five approaches include the transcallosal approach through the splenium, the transcortical transventricular approach, the suboccipital transventricular approach, the infratentorial supracerebellar approach, and finally, the subtemporal approach. Each approach is detailed in the following pages.

### Transcallosal Approach

1.145a The craniotomy and scalp incision are used for the approach to the splenium of the corpus callosum. Particular care must be taken to separate this critical portion of the sagittal sinus from any adherence to overlying bone when performing the craniotomy.

1.145b Relationship between the craniotomy, ventricular system, and pineal region.
1.46a The approach along the falx exposes the corpus callosum. The falx and hemisphere have been retracted, exposing the splenium of the corpus callosum.

1.46b The falx and tentorial junction have been opened, exposing the pineal region with its arachnoid membranes.

1.46c An incision into the splenium of the corpus callosum anteriorly allows sharp delineation of the pineal gland between the two internal cerebral veins as they coalesce with the vein of Rosenthal and medial occipital veins to form the vein of Galen.
Transcortical Transventricular Approach

1.147 For this approach, now rarely performed, the patient is positioned supine on the operating table, with the right shoulder elevated. The head is positioned along the horizontal axis.

1.148a The scalp incision and craniotomy are outlined. 1.148b The relationship between the craniotomy, cerebral hemispheres, ventricular system, and pineal region are depicted. A curved cortical incision in the area of the angular gyrus is made to approach the lateral ventricle.
1.149a Following the cortical incision, the trigone of the lateral ventricle is identified.

1.149b The lateral wall of the trigone is resected, exposing the lateral pineal region. The venous structures, with the confluence of the internal cerebral veins, the vein of Rosenthal, and the precentral cerebellar vein, emphasize the awkwardness of this approach, unless a large mass has displaced these structures to allow free access to the pineal region.
With the patient in the sitting position, or in the prone position, the skin incision and craniotomy are schematically outlined.

Relationship between the craniotomy, hemispheres, ventricular system, and pineal region.

This anatomical preparation is included here to demonstrate the exposure of the occipital lobe as seen by the surgeon.
The splenium of the corpus callosum is visualized following the retraction of the occipital lobe.

After the tentorium has been opened, the tip of the vermis and the arachnoidal membrane of the pineal region are exposed.

After the arachnoidal planes have been opened, the pineal gland, precentral cerebellar vein, vein of Galen and both veins of Rosenthal are clearly visible. This approach – as opposed to the previous one – allows good exposure of the pineal area even with small lesions. The precentral cerebellar vein can be sacrificed for the exposure if necessary.
1. The patient is placed in the semi-sitting position with the head maximally flexed.

1.54a The bone removal must extend up to the confluent sinus (torcular) and above the transverse sinus.

1.54b Relationship between the craniotomy and the cerebral and cerebellar hemispheres.

1.54c This is a schematic presentation of the approach. Notice the retractor elevating the confluent sinus (torcular) and transverse sinus.
1.155a The BNI modification of the Concord position is used, and the patient is placed prone with the head flexed and turned toward the contralateral shoulder. This position allows the surgeon to stand behind the ipsilateral shoulder. This approach is useful for the pineal region, as well as for tumors of the cerebellum or occipital lobes. The appropriate degree of head flexion and head rotation depends on the location of the tumor.

1.155b A comfortable sitting position for the surgeon can be maintained by tilting the operating table toward the surgeon.

1.156 Anatomical specimen of the vasculature encountered through the infratentorial supracerebellar approach.
The cerebellar hemispheres and vermis are gently retracted or more commonly will fall away sufficiently to allow access to the pineal region. The arachnoidal membranes cover the underlying pineal region.

Following dissection of the arachnoid, the anatomy of the pineal region becomes apparent. The pale white structure is the splenium of the corpus callosum with the vein of Galen and its tributaries in the midline.

Further inferior dissection reveals the pineal gland and its surrounding vasculature. Most inferiorly the superior colliculi are visible, projecting from the quadrigeminal plate.
Subtemporal Approach (Anterior Subtemporal Approach)

1.158 The patient is placed supine, and the head is turned horizontally and tilted slightly toward the floor.

1.159a The incision begins at the zygomatic arch and extends superiorly along the hairline, to allow a craniotomy of the anterior middle fossa.

1.159b This anterior temporal craniotomy avoids traction of the vein of Labbe. The approach to the midbrain is indicated.
1.160a Midbrain from the right, temporal lobe lifted up. Exposure of the ambient cistern with the basilar artery bifurcating into the posterior cerebral arteries on each side. The superior cerebellar artery is seen coursing in the ambient cistern below the third nerve. Notice the fourth nerve as it emerges next to the superior cerebellar artery and disappears under the tentorium.

1.160b This is a similar view (as above) of the ambient cistern. The greater retraction exposes the course of the third nerve. The midbrain is exposed, and the quadrigeminal plate is (barely) visible.
1.160 c After the base of the temporal lobe has been elevated further, the midbrain and quadrigeminal plate are clearly visible.
1.161a The bridging veins between the tentorium and cerebellar hemispheres are visualized.

1.161b A highly magnified view following coagulation and sectioning of the bridging veins.

1.161c The microscope has been focused more deeply following minimal retraction of the cerebellar hemisphere, exposing the arachnoid adhesions and the vein of Galen.

1.161d Higher magnification demonstrates the arachnoidal connections surrounding the vein of Galen.
1.161e Following the arachnoidal dissection, the tumor becomes apparent lateral to the vein of Galen.

1.161f The precentral cerebellar vein, kept intact throughout the procedure, and the tumor are visualized.

1.161g Resection of the teratoma is initiated.
1.161h Different tissue types are encountered during removal of the teratoma.

1.161i Another tissue type is exposed.

1.161j The empty tumor cavity allows a view into the posterior third ventricle.
Case 2
Diagnosis: Teratoma of the pineal region
Approach: Infratentorial supracerebellar

1.162a A coronal MR image shows a large teratoma in the pineal region.

1.162b A sagittal midline MR image demonstrates a large teratoma of the pineal region.

1.162c The cerebellar hemisphere and vermis are lightly retracted to expose the bridging veins to the tentorium. These veins are sacrificed, and the tumor is visible over the edge of the vermis.
1.162d Several well-formed hairs are seen after the tumor has been opened.

1.162e The tumor is mobilized posteriorly to expose the venous structures.

1.162f By mobilizing the tumor superiorly, the quadrigeminal plate and its vascularity become visible.
The tumor contents are freed and evacuated.

A large portion of the teratoma is lifted over the cerebellar hemispheres.

A postoperative CT scan verifies the removal of the tumor.
1.163a Following the sectioning of the bridging veins and gentle retraction of the cerebellum, the arachnoidal membranes covering the pineal region become visible. These arachnoid membranes are so tenacious that, as with all other microsurgical exposures, sharp dissection is mandatory.

1.163b Following resection of the arachnoidal adhesions, the vein of Galen, precentral cerebellar vein, and underlying tumor are visible.

1.163c Resection of the tumor has started.
1.163d Following tumor resection, Surgicel has been placed in the tumor cavity, with the choroid plexus visible within the third ventricle.

1.163e Higher magnification and refocusing allows good visualization of the roof of the third ventricle (tela chorioidea) and its choroid plexus.

1.163f By changing the microscope position to look a little more interiorly into the third ventricle, a remarkable view of the anterior commissure and the two columns of the fornix is possible.

1.163g CT scan and CT reconstruction of a pineal-region tumor that was identified as a pinealblastoma at surgery.
Following exposure of the pineal region, the vein of Galen, the precentral cerebellar vein, both veins of Rosenthal, and tumor are visible. A tumor cyst extends to the right of the precentral cerebellar vein.

Following resection of the tumor, some Surgicel has been placed in the tumor cavity. The superior colliculi are visible projecting from the quadrigeminal plate. Notice the preservation of the precentral cerebellar vein. It should be emphasized that, should it obstruct tumor dissection, it can readily be sacrificed.
Case 5
Diagnosis: Glioma of the pineal region
Approach: Infratentorial supracerebellar
Position: Concord

1.165a The MR image reveals a large tumor in the pineal region extending into the third ventricle.

1.165b A sagittal midline cut reveals the extent of the tumor as it bulges into the posterior third ventricle.

1.165c The BNI – modified Concord position is used, and the view is toward the top of the head. The posterior fossa muscular attachment has been separated from the nuchal ligaments, but left intact. Above the inion, the occipital bone is covered with periosteum.
1.165d Through a small burr hole in the posterior fossa, the Midas Rex drill is used to create a craniotomy flap that crosses the sagittal, lateral, and occipital sinuses. Emissary veins from the occipital bone to the torcular require coagulation.

1.165e After the bone flap has been removed, the sagittal, both lateral, and the occipital sinuses are visible. The dura has been tacked in numerous locations around the periphery of the craniotomy site.

1.165f The dura has been opened toward the lateral sinuses to expose the cerebellar hemispheres. Because a large amount of bone above the lateral sinuses has been removed, the entire posterior portion of the tentorium can be raised with dural tension sutures.
1.165g Through this angled exposure, the tentorial notch is exposed along with the typical thick arachnoid layers in the pineal region.

1.165h With slightly more retraction, the tumor mass becomes readily visible.
1.165i The medial tip of the temporal lobe is seen as it hangs herniated through the tentorial notch along the side of the tumor. This herniation is obviously secondary to the obstructive hydrocephalus.

1.165j The anterior commissure and both fomices can be visualized by looking through the removed tumor cavity into the third ventricle.

1.165k If the microscope is angled slightly superiorly, the foramen of Monro can be seen adjacent to both fomices. The choroidal plexus from the lateral ventricle passes through the foramen of Monro to the roof of the third ventricle.
1.165m, n Postoperative CT scans demonstrate the absence of the tumor and the collapsed ventricles, with a small amount of residual air.

1.165l After the craniotomy site has been closed, the posterior musculature is attached to the remnants of the nuchal ligaments, attached to the bone flap. The closure of the two muscle groups is then sutured vertically.
1.166a A CT scan demonstrates a large tumor of the pineal region.

1.166b,c Two sagittal T2-weighted MR images demonstrate the tumor and its extension toward the left.

1.166d A postoperative CT scan demonstrates the tumor has been removed.
The left occipital lobe has been retracted from the falx and tentorium to expose the large pinealoma. This particular exposure was used because the tumor extended toward the left side.

The left tentorium is being cut below the straight sinus.

The left occipital vein, the laterally placed vein of Rosenthal, and the posterior pericallosal vein are visible as they join and enter the great vein of Galen.
1.166h The tumor has been incised and is being debulked.

1.166i Most of the tumor has been resected, leaving the tumor capsule in place.

1.166j The tumor has been removed. Notice the intact venous system, particularly the occipital vein and the vein of Rosenthal medially. The cerebellar hemisphere is visible below the cut edge of the tentorium.
Tumors of the Midbrain

Clinical Material

Case 1
Diagnosis: Hematoma within the quadrigeminal plate
Approach: Infratentorial supracerebellar

1.167a The dura has been opened. The transverse sinus and torcular are elevated, and the bridging veins and arachnoidal adhesions are visible.

1.167b Dense arachnoidal membranes around the quadrigeminal plate are exposed.

1.167c The precentral cerebellar vein and surrounding venous vasculature are seen.
1.167d Following dessection between the vermis and tip of the right cerebral hemisphere, the surface of the midbrain just below the inferior colliculi is visible. An area of necrosis and encephalomalacia is apparent.

1.167e A hematoma is identified following minimal resection of the necrosed surface of the midbrain.

1.167f Higher magnification allows clear delineation between midbrain and hematoma.
1.167g The hematoma has been evacuated.

1.167h Following removal of the retractors, the pineal region and quadrigeminal plate above the operative dissection are shown for orientation.
1.168a The pineal region is exposed in this woman, who was diagnosed as having had multiple sclerosis for the previous 15 years because of fluctuating double vision and cerebellar dysfunction. The approach will now concentrate on the right side of the midline.

1.168b With a view over the right cerebellar hemisphere, the arachnoidal adhesions of the ambient cistern have been opened.

1.168c Following splitting of the superior surface of the cerebellar hemisphere, the dissection is carried laterally from the ambient cistern to the quadrigeminal plate. The abnormally colored tissue from the hamartoma is visible below the edge of the right inferior colliculus.

Case 2
Diagnosis: Hamartoma of the midbrain
Approach: Infratentorial supracerebellar
1.168d Following the removal of the solid part of the tumor, a portion of hamartoma presumably responsible for the multiple clinical episodes is visible.

Case 3

Diagnosis: Cystic astrocytoma of the right cerebellar peduncle

Approach: Infratentorial supracerebellar

1.169 With the approach identical to that in the previous case, the cerebellum has been split to allow visualization of the cerebral peduncle. The cystic astrocytoma has been partially resected allowing visualization of the tumor cyst.
Case 4
Diagnosis: Partially cystic Metastatic adenocarcinoma of the midbrain
Approach: Infratentorial supracerebellar
Position: Semi-sitting

1.170a A CT scan with sagittal reconstruction shows a cystic lesion in the quadrigeminal region.

1.170b A coronal MR image demonstrates a cystic lesion in the quadrigeminal plate.

1.170c A CT scan through the same level as the preoperative CT scan demonstrates that the lesion has been removed from the quadrigeminal plate.
1.170d The quadrigeminal plate is exposed by a supracerebellar infratentorial approach over the vermis. A portion of the quadrigeminal plate adjacent to a branch of the cerebellar artery is distended.

1.170e The tumor cavity is opened and sharply circumscribed adenocarcinoma is removed.

1.170f The empty tumor cavity is visualized.
Case 5
Diagnosis: Cystic metastatic tumor in the midbrain
Approach: Right subtemporal

1.171a  A CT scan of a cystic lesion deep within the midbrain. Notice the relationship of the tentorium and the basilar artery to the lesion.

1.171b  The tentorium and base of the temporal lobe are visible using a right subtemporal approach.

1.171c  The midbrain has been opened to expose a metastatic bronchogenic carcinoma between the tentorium and the superior cerebellar artery.

1.171d  After the tumor has been removed, the tumor cavity is visible.

1.171e  A postoperative CT scan shows the cavity from which the metastatic tumor has been removed.
2 Tumors of the Base of the Skull
Introduction

The specific route for a specific pathology depends on both the type and the extent of the pathological process. We typically prefer to approach extradural clival lesions through one of the extracranial routes, whereas intradural clival lesions tend to be best approached through transcranial exposures. The collaborative efforts of a skull base team that includes a neurosurgeon, an experienced skull base neuro-otologist, a plastic surgeon, and an otolaryngological surgeon maximize the chances of treating these lesions successfully.

The diagram (Fig. 2.1) illustrates the chapters of this section. The anterior cranial fossa represents the visible part of the anterior skull base, and is shown in orange. The middle cranial fossa (middle skull base) is presented in green, and the posterior cranial fossa (posterior skull base) in blue. These regions overlap considerably, particularly in the area of the clivus (marked by stripes). For example, the midportion of the clivus can be exposed through a transfacial, subtemporal, combined, or inferior frontolateral approach.
Tumors of the Anterior Skull Base
(Anterior Cranial Fossa)

Tumors of the Anterior Skull Base, Maxillofacial Region, and Anterior Approaches to the Clivus

Microanatomy

2.2 A sagittal section through the brain and skull base vividly demonstrates the importance of the sphenoid sinus, frontal fossa, and nasal pharynx as routes to the clivus.
2.3 A superior view, with half the dura stripped away to expose the clivus and cranial nerves, emphasizes the significant width of the clivus that can be removed before encountering the cranial nerves laterally.

2.4 Paramedian sagittal section through the prepontine cistern (Medial view).
2.5a A horizontal section through the sphenoid sinus and clivus shows the exposed basilar artery and pons (from below). This nicely correlates the anatomy that can be exposed through a trans-sphenoidal or transfacial approach to the clivus.
2.5b A more inferior cross-section cuts through the clivus, internal carotid arteries, and Meckel’s caves bilaterally (from below).
2.6 A horizontal section through the lower clivus (from below).
2.7 Paramedian sagittal section through the sphenoid sinus. Notice the marked difference in details of sphenoid sinus.

2.8 The pituitary region and cavernous sinus from below. The cavernous portion of internal carotid arteries is exposed (notice extreme short distance between carotid arteries). Cisterns are injected yellow.
2.9 Midsagittal section through the pituitary and hypothalamic region.
Anterior Midline Approaches to the Anterior Skull Base (Anterior Cranial Fossa) and the Clivus

Extracranial approaches
- Transsphenoidal
  - Transnasal transseptal transsphenoidal
  - Transoral (sublabial) transseptal transsphenoidal
- Transfacial
- Transmaxillary
- Transoral
- Combined approaches
  - Transfrontal transfacial
  - Transoral transmaxillary
  - Transpalatal transsphenoidal
  - Transoral transpalatal

Intracranial approaches
- Transfrontal (or subfrontal or trans-anterior fossa)
  - Transfrontal extradural
  - Transfrontal intradural

Combined extracranial and intracranial approaches
- Intracranial intradural transfrontal plus extracranial transfacial

2.10 Five common approaches to the sella turcica region and the clivus: a transsphenoidal, b transfacial, c transmaxillary, d transoral, and e transfrontal (trans-anterior fossa). These approaches provide various angles and degrees of access along the skull base to the clivus.
Extracranial Approaches

Transoral Transseptal Transsphenoidal Approach

2.11a The patient is placed to allow the most direct approach to the pituitary region, with the surgeon positioned next to the chest.

2.11b Alternatively, the head is maintained in the neutral position and the surgeon stands directly in front of the head.

2.12a The upper lip is retracted superiorly and a sublabial incision is made.

2.12b The mucosa is gently elevated from the floor of the nose and from the nasal septum.

2.13 After insertion of the nasal speculum the floor of the sphenoid sinus is exposed. The sphenoid sinus is perforated and the mucosa extirpated, exposing the floor of the pituitary fossa.
2.14a The nose, and the incision within the nose along the septum. The ala is protected during the incision by an alar elevator. The incision is made behind the free border of the septal cartilage.

2.14b The mucosa and perichondrium are stripped off the septal cartilage.

2.14c The mucosa is separated bilaterally from the septum, carefully avoiding mucosal tears. The lower dissected part of the cartilaginous septum is luxated out of its osseous groove in the premaxilla with an elevator. Its posterior attachment to the perpendicular lamina of the ethmoid is broken.

2.14d The posterior band of the septal bone which obstructs access to the sphenoid rostrum is resected.

2.14e A self-retaining speculum is introduced between the two separated layers of the septal mucosa and pushed firmly against the floor of the sphenoid sinus.

2.14f Sagittal section through the head with the pituitary speculum in position. An imaginary line along the upper edge points to the tuberculum sellae. The sphenoid sinus is opened.
2.14g The floor of the sphenoid sinus is opened along the broken line. The opening reaches on both sides the foramen of the sphenoid sinus.

2.14h The floor of the sella is exposed in the opened sphenoid sinus. The sphenoid septum is resected, and the mucosa of the sinus is removed. Note the carotid prominences that may be visible.

2.14i After the floor of the sella has been resected, the dura is incised in a door-like fashion. Special care is taken to avoid injury to the cavernous and intercavernous sinuses.

2.15 Lateral diagram of sellar closure.

Combined Subfrontal and Transfacial Approach

2.16 A bicoronal skin incision and one transfacial incision are shown in this diagram of a combined subfrontal (transanterior fossa) and transfacial exposure. The line of the bicoronal craniotomy is indicated and the transfacial removal of the nasal bones is shown.

2.17 Using the extended combined approach, the floor of the anterior cranial fossa and the medial orbital walls are exposed.
2.18 The skin incision used with the transmaxillary approach. Variations are possible; the lip and facial tissues may be elevated enough to minimize the incision through the lips. The bone removal includes mobilization of the midface between the two orbits.

2.19 The removal of the maxilla and the nasal bone structures opens an excellent view to the anterior skull base from below and makes the exposure of the sphenoid bone, the clivus, and both pterygopalatine fossae possible.

2.20 Variation of the transfacial transmaxillary approach. The dental and the palatal part of the maxilla are kept in place. The midface is removed for a midline approach to the clivus.
2.21 Variation of the transoral transfacial transmaxillary approach. Removal of the midface with splitting of the maxilla laterally; using this technique, either a unilateral or a bilateral exposure is practicable. This approach gives an excellent view of the entire clivus, and also of the retroclival region, particularly in cases of intradural tumor extension.

2.22 Combined transfrontal transfacial transmaxillary approach. A combination of the transcranial and transfacial approaches can be varied in many ways. The choice of the exposure depends on the individual location and the extent of the tumor. The illustration shows a combination of a bifrontal craniotomy with an extended maxillotomy. This provides a spectacular view along the entire surface of the clivus.

Combined Transoral Transmaxillary Approach

2.23 The midline structures that can be approached through a combined transoral and transmaxillary exposure. The advantage of the transoral approach with mobile lips is that it provides a vast opening that can be enhanced by mobilizing the maxilla. Splitting the mandible and the tongue has not been necessary to gain adequate access to any region of the midline of the skull base.
2.24 The patient is positioned supine on the operating table, with the head extended. The amount of extension depends on which portion of the clivus is to be approached. A tracheostomy is unnecessary, as the retractor includes a groove for the endotracheal tube and is capable of retracting it and the tongue adequately.

2.25 The posterior pharyngeal wall is incised in a longitudinal fashion, overlying the portion of the clivus to be resected. For the most inferior portion of the clivus or for the foramen magnum, the soft palate need only be retracted into the nasal pharynx by passing a red rubber catheter through the nose and by suturing its end to the uvula. Then tension is put on the red rubber catheter as it exits from the nose. This maneuver pulls the soft palate and uvula into the nasal pharynx.

If the mid-or upper portion of the clivus is to be approached, the soft palate is incised in the midline and retracted to each side. The hard palate can be partially resected if necessary. The desired portion of the clivus is removed with an airdrill until the dura is visible. Bipolar coagulation of the dura will obliterate the common basilar venous sinuses prior to opening the dura.

2.26a The odontoid process as it compresses the cervicomedullary junction.

2.26b The intention in the transoral approach after resection of the odontoid is to leave the base of C2 intact.
Intracranial Approaches

Transfrontal or Subfrontal or Trans-Anterior Fossa Approaches

Transfrontal Extradural and Intradural Approach

2.27 The coronal skin incision gives excellent exposure of the entire frontal region, and makes a wide variety of approaches possible. During this scalp incision, and following craniotomy, all material for the final wound closure, such as galeal and pericranial flaps, a temporal muscle flap, a dural flap, and – if desired – split cranial bone flaps (tabula interna or externa), may be prepared and preserved. The shape of the bifrontal craniotomy can be adapted to the special situation of the case, so that all variations between an extended bifrontal approach (continuous line) and a rather limited midfrontobasal approach (dotted line) are possible.
Clinical Material
Transseptal Transsphenoidal Approach
Case
Diagnosis: Intrasellar adenoma
Approach: Transsphenoidal

2.28a The nasal speculum has been inserted between the two leaves of the mobilized nasal mucosa, exposing the nasal septum.

2.28b The nasal septum has been resected, exposing the anterior wall of the sphenoid sinus.

2.28c The sphenoid sinus has been opened.

2.28d The floor of the sella is visualized.
2.28e After resection of the sellar floor, the dura, expanded by tumor, is seen.

2.28f The cystic tumor protrudes through the dural opening.

2.28g After removal of the tumor, the empty sella is seen.

2.28h After the fat tissue has been introduced into the empty sella, the sellar floor is reconstructed with a piece of nasal septum. A drop of fibrin glue is being applied to obtain watertight closure.
2.29a MR image of a large chordoma that has already been operated on and undergone radiation therapy.

2.29b The procedure has already been completed, but the figure shows the patient's position and emphasizes that a posteriorly placed coronal incision is needed to harvest sufficient periosteum and galea for separate vascularized flaps.

2.29c The incision for the transfacial approach is shown.
2.29d The skin along the nose has been opened, and the bone has been skeletonized.

2.29e After a bilateral coronal scalp incision has been made, care is taken to preserve the periosteum over the lateral frontal cranium. The periosteal flap is marked so that it can be hinged toward the right.

2.29f The periosteum is mobilized with its pedicle on the right.
2.29g The coronal scalp flap is further mobilized and stretched below the nasal bones.

2.29h The intended galeal flap has been outlined. Notice that a small remnant of galea has been preserved along the incision, so that it can be used to achieve a solid scalp closure.
2.29i The long galeal flap has been completely mobilized.

2.29j After a classical bifrontal craniotomy has been performed, the orbital roofs, nasal skeleton, and floor of the frontal fossa are removed in one piece.

2.29k A lateral view of the removed portion of the bone.
2.29l A view between the orbits exposes the sphenoid sinus. This extradural exposure allows visualization of the pituitary fossa and of the entire clival region.

2.29m After the tumor has been resected, the dura of the clivus is visible.

2.29n After the tumor has been removed, the nasal skeleton and rim of the orbits are replaced and fixed to the lateral skull with miniplates.
2.29o  Interiorly, the nose is also fixed to the facial skeleton with miniplates.

2.29p  After the scalp has been moved back toward the orbital rims, the galea is pulled through one of the orbital openings that has been laid over the entire extent of the clivus resection. This maneuver gives an excellent layer of vascularized soft tissue that extends from the frontal fossa all the way to the foramen magnum.
2.29q A split-thickness bone graft, harvested from the inner table of the frontal craniotomy, has been sculptured to replace the floor of the frontal fossa, and is placed over the galeal pedicle.

2.29r The laterally hinged pericraea is now placed over the bone graft, and envelops the bone graft between two vascularized pedicles that consist of the galea underneath and the pericraea above.

2.29s After the far bicoronal scalp incision has been closed, the nasal incision is ready to be closed. This combined approach allows excellent exposure of the entire length of the clival dura, and is particularly suitable for extradural tumors such as chordoma.
Case 2
Diagnosis: Chordoma of the clivus
Approach: Transfacial transmaxillary and transoral

2.30a A CT scan demonstrates the extent of a chordoma that has been treated by previous surgery and radiotherapy.

2.30b A coronal MR image demonstrates the extent of the lesion.

2.30c,d Two sagittal MR images show the marked distortion of the brain stem by the chordoma.
2.30e The patient is positioned on the operating table, and a coronal incision is placed far posteriorly to allow the long galeal and osteal血管 flaps to be harvested.

2.30f The incision for the transfacial exposure to perform the maxillectomies.

2.30g The face is retracted to expose the maxilla.

2.30h Further bilateral retraction and elevation of the nose allows a midline incision of the maxilla, and allows the maxilla to be detached from the skull while being hinged on a vascular and neural pedicle, so that the freed halves of the maxilla can be retracted laterally on each side.
2.30i The hypopharynx becomes visible after lateral displacement of both mobilized maxillae.

2.30j After most of the chordoma, which had eroded through a good portion of the dura, has been dissected, a dramatic view of the basilar artery, superior cerebellar arteries, and posterior cerebral arteries is seen. As in the previous case, a long vascularized galeal flap is placed over the open dura and supported by a fat graft. The hypopharynx is closed, and gently packed with vaseline gauze. A lumbar spinal drain is used for five to six days. If there is further cerebrospinal fluid leakage, a lumboventricular shunt is inserted.
2.30k The patient several months after surgery.

2.30l, m Two MR images demonstrate the amount of tumor resected and the placement of the flaps and fat graft. Diagnosis: large clivus chordoma in a 60-year-old.
Case 3
Diagnosis: Chordoma of the clivus
Approach: Transoral transfacial transmaxillary

2.31a A coronal MR image depicts a giant chordoma that has eroded the entire clivus in a 6-year old.

2.31b A sagittal MR image shows the mid-line portion of the clival chordoma.

2.31c Surgical set-up seen from above. Several retractors are used to obtain a transoral and transmaxillary exposure of the clivus.
2.31d A higher magnification of the hypopharynx.

2.31e An even higher magnification of the hypopharynx and tumor.

2.31f After the tumor has been removed, the hypopharynx has been closed, the maxilla has been replaced, and the soft and hard palates have been closed, the short facial skin incision is also sutured. The nasogastric feeding tube is inserted while microscopic visualization of the hypopharynx is still possible. Diagnosis: large chordoma in a 6-year-old female; approach: transoral with removal of the hard palate.
Transoral Approach
Case 1
Diagnosis: Chordoma of the clivus
Approach: Transoral, with removal of the hard palate (transoral transpalatal)

2.32a A transverse MR image demonstrates the extensive chordoma.

2.32b A midline sagittal MR image demonstrates the replacement of the entire clivus by the chordoma.

2.32c The soft palate is cut via the transoral approach, and the incision is extended in the midline over the hard palate. The mucosa is retracted over the hard palate to allow excision of the hard palate in one piece.
2.32d A higher magnification after the hard palate has been resected and the hypopharynx exposed.

2.32e The hard palate after it has been removed. At the end of the procedure, the hard palate is replaced and the mucosa closed over it.

2.32f The tumor is visible through the distended hypopharynx.
2.32g The typical appearance of the chordoma is visible next to the exposed dura.

2.32h The hard palate has been replaced and fastened with miniplates.
Case 2

Diagnosis: Epidermoid of the upper clivus
Approach: Transoral

2.33a CT scan with paramedian sagittal reconstruction, demonstrating a large midline epidermoid.

2.33b Vertebral angiogram, lateral projection, demonstrating elevation and displacement of basilar artery by the epidermoid.
2.33c An epidermoid tumor has inserted itself between the basilar artery and the pons and midbrain. Because of previous inability to remove the center of the epidermoid extending into the pons and midbrain, a midline transoral transclival approach was used. The soft palate has been cut in the midline through its entire length. The retractor holding the tongue and endotracheal tube is at the superior edge of the picture. The nasal pharynx is being incised.

2.33d The clivus has been largely resected with a high-speed air drill.

2.33e Lateral skull film with metrizamide placed in the defect where the clivus has been resected.
The dural opening has been started. The dura has been opened throughout its bony exposure, and the ependymal tumor visualized lateral to the basilar artery. The basilar artery is easily mobilized to the right and to the left for extensive tumor removal. At the end of the procedure, the entire ventral surface of the pons and midbrain was visible.

Following removal of the ependymal tumor, the basilar artery is seen. An ependymal tumor is ideal for this approach because of its lack of vascularity. Hemostasis from a highly vascular lesion would encounter some difficulty because of the very limited exposure. Closure of the dura is achieved by placing a piece of fascia lata on the inside of the dural opening and gluing it in place. Several further layers are then inserted within the bony opening and again glued appropriately. The nasal pharynx is closed in one or, if possible, in two layers. Continuous lumbar drainage for the first three days allows healing of the dural defect. The internalization of the lumbar drain into a lumboperitoneal shunt will
Case 3  
Diagnosis: Chordoma of the lower clivus  
Approach: Transoral

2.34a The patient has been positioned for a transoral approach to the clivus. The head is fixed in a pinion headrest and a retractor is inserted to open the jaw and hold the endotracheal tube inferiorly. Brain stem-evoked potential monitoring is routine, and the necessary equipment has been inserted into the ears. The electrodes for sensory evoked potential monitoring are barely visible. A red rubber catheter, which has been sewn to the uvula on each side after having been inserted through the nose, has been tied firmly to the retractor. This puts tension on the uvula and soft palate, retracting them posteriorly into the nasopharynx, providing excellent exposure of the oral mucosa overlying the lower clivus.

2.34b Notice the retracted portion of the soft palate interiorly. The remainder of the uvula and soft palate are now in the nasopharynx, having been retracted there with the red rubber catheters as previously described.

2.34c The endotracheal tube is held out of the way with the MacGarver retractor. The oral mucosa overlying the clivus has been incised. The chordoma has been largely resected following the removal of the lower clivus with the drill. The oral mucosa and muscle layer have been mobilized laterally with a self-retaining retractor.
2.34d  Following extensive removal of the tumor, the dura and its vasculature are visible. No gross tumor remains. The dura was not opened. Following extensive antibiotic irrigation, the posterior wall of the pharynx was closed in two layers.
Case 4
Diagnosis: Brain stem compression from basilar invagination and retropulsed odontoid due to rheumatoid arthritis
Approach: Transoral

2.35a A preoperative sagittal MR image demonstrates marked compression of the brain stem. Basilar invagination and downward migration of the medulla is obvious.

2.35b The postoperative MR image is included for comparison next to the preoperative MR image. The tip of the odontoid process as well as the inferior portion of the clivus and soft tissue mass have been resected. The brain stem is relaxed and well decompressed.

2.35c The position for the transoral approach is shown with the retractor in place. The red rubber catheters have been passed through each nostril into the hypopharynx, where they have been sutured to the base of the uvula. Traction on the red rubber catheters then pulls the uvula and soft palate behind the hard palate. Notice the endotracheal tube held in place with the retractor.
2.35d This transoral view visualizes the tongue, the retracted uvula and soft palate, and the hypopharynx.

2.35e After a midline incision and lateral retraction of the soft tissues of the hypopharynx, the base of C2 is identified. A portion of C1 is visible.

2.35f The base of C2 has been drilled, and a pseudoarticulation between the odontoid process and the body of C2 is apparent.
2.35g  A typical specimen of the odontoid tip is shown. The largest part of the inferior portion of the odontoid and top of C2 is resected with the drill, and therefore is not part of the specimen.

2.35h  A typical pannus from a patient with rheumatoid arthritis demonstrates why good nonoperative reduction is often impossible in these patients. The pannus is located between the odontoid process and the anterior rim of C1.
Case 5

Diagnosis: Carcinoma of C3 compressing the spinal cord
Approach: Transoral

2.36a A preoperative MR image demonstrates a tumor that has eroded the body of C3 and compressed the spinal cord anteriorly to cause myelopathy. A metastatic workup was negative.

2.36b A postoperative MR image shows good decompression of the spinal cord. This case illustrates well the inferior extent that can be obtained through the transoral route.

2.36c Through a transoral exposure, the bottom portion of the body of C2 has been drilled away to expose the dura. The entire body of C3 was infiltrated with soft metastatic tumor.
2.36d. An intraoperative X-ray after complete tumor extirpation shows the cavity outlined with Pantopaque. The upper body of C4 and the inferior body of C2 was drilled away, leaving a significant bone defect.

2.36f. A lateral X-ray after bone fusion demonstrates excellent alignment and placement of the graft.

2.36e. A bone graft has been inserted into the tumor cavity, bridging the gap between C2 and C4.
Tumors of the Middle Skull Base (Middle Cranial Fossa)

Tumors of the Parasellar Region, Cavernous Sinus, Upper clivus, and Petrous Apex

Microanatomy

2.37a Microanatomy of the cavernous sinus (viewed from behind). This coronal section demonstrates the proximity of the internal carotid artery within the subarachnoid space to its proximal intracavernous position. With a section straight through the infundibulum, the anatomical arrangement of the nerves and the intracavernous portion of the internal carotid artery can be visualized.
Higher magnification demonstrates the relationship of the internal carotid artery between the subarachnoid and intracavernous portions.
2.38a A high-magnification CT scan through the infundibulum demonstrates the carotid artery and nerves within the cavernous sinus.

2.38b Anterior coronal section through the anterior clivus and curve of the internal carotid artery as it exits the cavernous sinus and enters the subarachnoid space. The cranial nerves within the cavernous sinus and the sphenoid sinus medially can be readily appreciated.
2.38c A high magnification coronal section slightly further posterior through the cavernous sinus at the level of the pituitary gland. The proximity of the internal carotid artery and pituitary gland is apparent.

2.39 A view further posterior adjacent to the third nerve (from behind) demonstrates the relationship of the carotid artery to the trigeminal nerve.
2.40 This specimen of the cavernous sinus, viewed through the middle fossa, demonstrates the posterior portion of the cavernous sinus and Meckel's cave. Notice the entrance of the internal carotid artery and the relationship of the foramen spinosum to the foramen ovale. All structures are intimately related to the internal carotid artery, and are landmarks for exposing the internal carotid artery in its intranetrous course.

2.41 With further unroofing of Meckel's cave, the subarachnoid space (blue) can be recognized as well as the three branches of the trigeminal nerve. The entire course of the trigeminal nerve, from the brain stem into Meckel's cave, is visualized. These relationships are further defined in the microanatomy section dealing with the combined approach.
2.42 An oblique view of the cavernous sinus demonstrates the relationship between the internal carotid artery, basilar artery, and the third and fourth cranial nerves. The lateral wall of the cavernous sinus and the posterior clinoid have been removed. The blue depicts the area of Parkinson’s triangle.
The cavernous sinus has been dissected further, and the third and fourth cranial nerves and first division of the trigeminal nerve have been reflected interiorly. The entire intracavernous course of the internal carotid artery can be appreciated. The sixth cranial nerve is seen throughout its entire intracavernous course. Notice the relationship of the subarachnoid internal carotid artery, the optic nerve, the anterior clinoid process, and the intracavernous portion of the internal carotid artery.
The cavernous sinus has been dissected still further, and the anterior clinoid process has been removed. The relationship of the subarachnoid intracavernous portion of the internal carotid artery is visible. The fibrous ring surrounding the internal carotid artery at its junction with the cavernous sinus is clearly demonstrated.
In this view of the cavernous sinus, the internal carotid artery is pulled down, allowing excellent visualization of the intracavernous branches of the internal carotid artery.
By opening the lateral wall of the pituitary fossa, the relationship of the pituitary gland and intracavernous portion of the internal carotid artery can be appreciated. Note the vascular supply of the internal carotid artery to the pituitary gland, and the relationship of the fibrous ring at the junction of the subarachnoid and the intracavernous portion of the internal carotid artery.
2.47 This diagram illustrates the various triangles that can be used to enter the cavernous sinus. The relationship of the cranial nerves and the internal carotid artery can be appreciated. The entry into the cavernous sinus is determined by the pathological process and its particular distortion of the cranial nerves. Often, a large space, which cannot be appreciated in the normal anatomy, is created by an expanding mass such as between the third and fourth cranial nerves. Particular attention should be paid to the relationship of the foramina ovale and spinosum to the internal carotid artery. Nomenclature of the cavernous sinus triangles (running clockwise): 1 triangle of Parkinson, 2 oculomotor triangle, 3 paramedial triangle, 4 anteromedial triangle, 5 anterolateral triangle, 6 lateral triangle, 7 posterolateral triangle of Glasscock, 8 posteromedial triangle of Kawase.

2.48a The lateral wall of the right cavernous sinus is visualized by the pterional approach. Parkinson's triangle can be identified.
2.48b The incision of the lateral sinus wall is carried out in flaplike shape. Only the inner layer of the lateral wall is cut.

2.48c After retraction of the dural flap the superficial layer of the lateral wall can be studied. The fibers of the ophthalmic and maxillary nerves can be seen and also Parkinson's triangle has been opened.
2.48d By higher magnification one can observe through the Parkinson’s triangle the ascending portion of the intracavernous internal carotid artery.

2.48e Exploration of the lateral sinus wall with preservation of the nerves.
2.48f  Wide opening of Parkinson's triangle leads to good visualization of the intracavernous portion of the internal carotid artery.

2.48g  The superior aspect of the cavernous sinus is prepared by the transsylvian approach. The anterior clinoid process is drilled off and the optic canal has been decompressed. The dural sheath of the oculomotor and trochlear nerves has been opened. By this dissection the cavernous sinus can be prepared from above.
### Choice of Approach

The arrows indicate the various approaches that are available to the surgeon for exposure of the sellar and parasellar region. The specific area of interest obviously plays an important role in the choice of approach.

### Approaches to the Middle Skull Base (Middle Cranial Fossa)

#### Anterior approaches

- Extracranial extradural
  - Transsphenoidal
  - Transoral transseptal transsphenoidal
  - Transnasal transseptal transsphenoidal
  - Transmaxillary transethmoidosphenoidal
  - Fronto-orbital external transethmoidal

- Transcranial intradural
  - Subfrontal (unilateral and bilateral)
  - Subfrontal transsphenoidal
  - Subfrontal pre-, sub-, and retrochiasmatic
  - Unilateral subfrontal, between the optic nerve and carotid artery
  - Frontolateral subfrontal, between the carotid artery and oculomotor nerve

#### Lateral approaches

- Extracranial lateral (temporal and infratemporal fossae: anterior part of the middle skull base)
- Extracranial posteroinferior (carotid canal, jugular foramen: posterior part of the middle skull base)
- Intracranial extradural
- Intracranial intradural
  - Fronto-temporal
  - Pterional
  - Orbitopterional
  - Subtemporal
    - Anterior subtemporal
    - Posterior subtemporal
  - Subtemporal transtentorial posterior fossa or combined supratentorial and infratentorial

Similarly, head positioning depends not only on the approach selected, but also on the specific area of interest. This diagram illustrates how the surgeon would position the patient's head so that the vision through the microscope is in the vertical axis in relationship to the exposure. With a 45-degree rotation off the vertical axis, a frontolateral or pterional approach would give excellent visualization of the sellar region. However, if the surgeon were interested in a region lateral to the sella, such as the sphenoid wing, less rotation would be desired. Alternatively, if the area of interest were the tuberculum sellae, more rotation would be required.
2.51a,b  These diagrams show the many routes that can be used to approach the parasellar region. The specific topography of the lesion to be visualized plays a significant role in selecting which approach is most suitable, e.g., a lesion located between the optic nerves in the plane of the optic nerves and chiasm is best approached through an exposure as close to the vertical axis as possible, in order to allow visualization between the optic nerves without requiring any retraction. Yet, this approach would be undesirable if a lesion located only a centimeter below the optic nerve and the internal carotid artery were to be exposed. In this lesion, a lateral pterional approach allowing visualization below the optic nerve and internal carotid artery would be the exposure of choice. It is the ability to determine the location of the lesion preoperatively, combined with the experience of what each approach affords, that is the critical factor in the decision-making process leading to the proper exposure in any individual case.

Pterional Approach

2.52a  The scalp incision and craniotomy for the standard pterional approach to the parasellar region are shown here. Extensive drilling of the sphenoid wing and the anterior clinoid process can be performed extradurally.

2.52b  Relationship between the craniotomy and the underlying Sylvian fissure, pituitary gland, and ventricular system.
Orbitopterional Approach

2.53 The scalp incision and craniotomy of the orbitopterional approach are depicted.

2.54 A skull specimen demonstrates the saw cuts for the orbitopterional craniotomy.
2.55a The orbitopterional craniotomy is outlined in black on this skull.

2.55b The perisellar and sellar region are visualized after an orbitopterional craniotomy.

2.55c The extent of the removal of the orbital wall can best be appreciated from this anterior view.
Clinical Material

Case 1
Diagnosis: Meningioma of the lateral wall of the cavernous sinus
Approach: Right pterional

2.56a A coronal CT scan of the sellar region demonstrates a meningioma of the lateral wall of the cavernous sinus.

2.56b The lateral wall of the cavernous sinus, with its typical meningioma vascularity, is visualized through an extensive right pterional approach.

2.56c After the anterior clinoid and the lateral wall of the cavernous sinus along with the meningioma, the intracavernous cranial nerves and carotid artery are exposed.
Case 2
Diagnosis: Suprasellar, parasellar, and intrasellar pituitary adenoma
Approach: Right pterional

2.57c Following a right pterional craniotomy the tumor is visualized behind the optic nerve and the internal carotid artery. The tumor extends above the sella.

2.57d Decompression of the optic nerve by partial removal of the roof of the optic canal. The ophthalmic artery is pressed by the underlying tumor against the optic nerve and causes a red-discolored bulging of the nerve.

2.57a, b Coronal CT sections demonstrate a large intrasellar tumor extending into the suprasellar and parasellar regions. The tumor is growing around the intracavernous portion of the internal carotid arteries.
2.57e After mobilization of the oculomotor nerve, the suprasellar portion of the tumor is resected.

2.57f The cavernous sinus is opened for further tumor removal.

2.57g With the microscope angled, the basilar artery can be seen in the depth of the operative field, between the internal carotid artery and the third cranial nerve.
2.57h When the lateral wall of the cavernous sinus is opened, the tumor is visible.

2.57i After the intracavernous portion of the pituitary tumor has been resected, hemostasis is achieved with packing.
Case 3
Diagnosis: Carcinoma of the cavernous sinus with extension into the hypopharynx
Approach: Transorbital pterional and cervical

2.58a A coronal MR image demonstrates a diffuse tumor in the right cavernous sinus, extending into the hypopharynx and intermittently involved with the internal carotid artery.

2.58b A slightly anterior section shows how the tumor is strangling the intracavernous and intrapetrous portions of the internal carotid artery.

2.58c A selective internal carotid artery arteriogram demonstrates a marked constriction of the internal carotid artery in the cavernous sinus and petrous bone.
2.58d A bone flap involving the frontal and middle fossa has been turned.

2.58e The Midas Rex drill has been used to obtain an exposure that is flush with the floor of the frontal fossa. The small bony protuberances on the floor are also drilled off to obtain a completely flat approach.

2.58f The exposure of the middle fossa, including the removal of the base of the zygomatic arch, is demonstrated. This exposure will allow a lateral approach to the cavernous sinus, if needed.
2.58g The lateral rim of the middle fossa is resected with a drill until it is flush with the tip of the temporal lobe. Notice that the zygomatic process has been drilled off considerably.

2.58h The dura has been opened after the pterion has been drilled down to the anterior clinoid. Notice that there is no bony protuberance on the floor of the frontal fossa.

2.58i The common and external and internal carotid arteries are exposed through a cervical incision. Notice the marked retraction in the anterior direction of the temporalis muscle and the scalp.
2.58j The middle fossa is exposed, with mild retraction of the temporal lobe and minimal elevation of the frontal lobe.

2.58k A saphenous vein graft is passed from the cranial to the cervical incision after a direct internal carotid artery-to-saphenous vein anastomosis was performed.

2.58l The plastic trocar, which has been cut longitudinally to ease the placement of the saphenous graft, is shown. The plastic trocar is then pulled out through the cervical incision, leaving the saphenous vein graft properly oriented in its track.
2.58m After both anastomoses have been completed, the saphenous vein graft is shown as it comes through the cervical incision to its anastomosis to the internal carotid artery. The tumor itself can be appreciated in the middle fossa.

2.58n The orbital roof and zygomatic process are removed in one piece, because the exposure of the tumor in the cavernous sinus was inadequate.

2.58o The entire orbital roof and orbital rim are being removed.
2.58p The tumor is vaporized by a microneedle attached to a coagulation unit.

2.58q The middle fossa is shown with only bone remaining, and with a hole through the middle fossa into the hypopharynx, which is illustrated with the dissector.

2.58r A galeal flap is prepared from the frontal scalp.
The large galeal flap has been freed from the scalp based on a vascular pedicle in the temporal region.

The galea has been used to cover the large middle fossa opening, and fills the opening into the hypopharynx through the cavernous sinus.

The orbital roof has been replaced and the dura closed.
2.58v The bone flap has been replaced.

2.58w A postoperative CT scan reveals air in the hypopharynx and the degree of bone resected to achieve tumor-free margins.

2.58x A higher cut demonstrates the entire resection of the sphenoid wing and anterior clinoid.
Case 4
Diagnosis: Cavernous malformation of the cavernous sinus
Approach: Anterior subtemporal

2.59a The angiogram demonstrates a significant vascular blush in the middle fossa, originating in the cavernous sinus.

2.59b An anterior view demonstrates that the tumor mass has markedly compromised the internal carotid and middle cerebral arteries.

2.59c A CT scan demonstrates a large tumor extending into the middle fossa and encroaching on the sphenoid ridge.

2.59d A lower section shows the tumor within the cavernous sinus, extending into the pituitary fossa.
The tumor is visible through an anterior-subtemporal approach. Previous attempts at tumor resection resulted in severe hemorrhage. The tumor was treated with proton-beam radiation. However, the ophthalmoplegia was progressive.

The entire tumor mass has been mobilized from Meckel's cave, and portions of the third and fifth cranial nerves can be identified. This uncommon tumor is very vascular, compared to cavernous malformations within the brain.

The cavernous malformation has been largely removed, and the extension into the pituitary fossa has been resected. The internal carotid artery was dissected free from the tumor margin and preserved.
2.59h The tumor remnants around the carotid artery are removed by laser.

2.59i The tumor bed, with partial preservation of N. V/3, is shown.

2.59j A medial view shows the extent of the course of the carotid artery with the third cranial nerve coursing just above it.
2.59k The carotid artery is surrounded with radiopaque sutures to assure complete tumor eradication.

2.59l The middle fossa defect is covered with a fascia lata autograft.
2.59m  The seeds attached to the radiopaque sutures are visible in this anteroposterior projection.

2.59n  A lateral view demonstrates the radioactive seeds.

2.59o  The CT scan demonstrates the extent of bone resection and the medial extent of the lesion.

2.59p  A lower view demonstrates the margin of the tumor adjacent to the sphenoid sinus.
Case 5
Diagnosis: Recurrent meningioma of the left sphenoid ridge infiltrating the orbit and paranasal sinuses
Approach: Left pterional and transfacial

2.60a A CT scan through the orbit and lower sphenoid ridge demonstrates a large tumor.

2.60b A higher section demonstrates the tumor as it compresses the left temporal and frontal lobes.

2.60c The temporal and frontal lobes are retracted through an extensive left pterional exposure. The large intradural portion of the tumor is being removed with the ultrasonic aspirator.

2.60d The intradural tumor is removed, and the sphenoid sinus is exposed. The tumor had eroded and entered the sinus. The middle cerebral and internal carotid arteries are visible. The ophthalmic artery has been clipped, and the intracavernous portion of the internal carotid artery has been exposed.
2.60e The tumor has been mobilized anteriorly and the orbit opened widely. The stump of the oculomotor nerve is visible. The middle cerebral and anterior cerebral carotid arteries and bifurcation are seen.

2.60f The entire orbital contents are removed through a transfacial incision.

2.60g There is a tail of tumor deep in the orbit.
2.60h A large opening is created by resecting the bone posteriorly along the base of the middle fossa until all biopsies are negative. The dural defect is bridged with a large fascia lata autograft.

2.60i A vascularized free graft is harvested from the back and prepared for anastomosis to the superficial temporal artery and vein. After the free vascularized graft is inserted into the space created by the bone resection and tumor removal, the scalp is closed.

2.60j View of the patient after completing the skin sutures. The skin portion of the free vascularized graft is incorporated into the suture line to check for adequate vascularization of the free graft. The facial incision is closed.
2.60k A CT bone reconstruction demonstrates the large amount of the skull base that has been resected.

2.60l Several weeks later, the anterior bony vault is reconstructed with methylmethacrylate and titanium mesh.

2.60m After the cranial vault is reconstructed, a normal cranial contour is achieved.
Subtemporal Approach

Microanatomy

2.61a In this anatomical specimen, the temporal lobe has been elevated slightly out of the temporal fossa. Notice the fourth cranial nerve as it traverses from the ambient cistern and recedes beneath the edge of the tentorium to enter the cavernous sinus. The third cranial nerve is visualized as it leaves the brain stem and enters the cavernous sinus.
After the arachnoid has been opened, the relationship of the third cranial nerve to the brainstem, superior cerebellar artery, edge of the tentorium, and internal carotid artery can be appreciated. Notice the hump of the posterior clinoid, which can be removed carefully with the diamond burr when further exposure is required. Remember that the posterior communicating artery lies just medial to the posterior clinoid, and may groove it extensively before the posterior clinoid process is removed aggressively.
2.61c A slightly more anterior orientation in the posterior fossa nicely demonstrates the relationship among the internal carotid artery, optic nerve, posterior cerebral artery, and third cranial nerve.
This preparation demonstrates the relationships between the third cranial nerve, a voluminous posterior communicating artery, and the posterior cerebral and superior cerebellar arteries.
2.62a Subtemporal approach to the tentorial hiatus. In this series of microsurgical dissections, the brain stem is exposed progressively with removal of the medial tip of the cavernous sinus and exposure of the trigeminal nerve. The relationships between the third cranial nerve, the tentorium, and the posterior cerebral and superior cerebellar arteries should be noted.
The third and fourth cranial nerves have been exposed, with removal of the lateral wall of the cavernous sinus and partial resection of the tentorium.
2.62c Meckel's cave has been opened extensively, demonstrating the relationships between the first five cranial nerves.
With the opening of the tentorium and resection of the medial portion of the petrous ridge, the internal carotid artery and the seventh and eighth cranial nerves are exposed as they exit from the brain stem and traverse to the internal auditory canal.
2.62e Section through the portion of the internal carotid artery which runs through the pars petrosa of the petrous bone. The ascending pars petrosa of the carotid canal is followed by the petrosal curvature and the pars transversalis. Then the carotid artery ascends into the cavernous sinus (ascending cavernosal part).
This view, further posterior, demonstrates the degree of cerebellar exposure that can be achieved by an extended subtemporal transtentorial approach and apexectomy.
Overview of Approaches

2.63 The various approaches to the tentorial notch, clivus, and basilar artery. These approaches include the pterional approach (1), the subtemporal (transtentorial) approach (2), the combined lateral supratentorial and infratentorial approach (3), the dorsolateral posterior fossa (retromastoid) approach (4), the dorsolateral suboccipital approach (5), the transoral (transclival) approach (6), the infratentorial supracerellar approach (7), and the occipital supratentorial approach (8).

Anterior Subtemporal Approach

2.64a The patient is placed in the supine position, with the appropriate shoulder elevated and the head in the horizontal position and slightly extended.

2.64b The scalp incision and craniotomy. It is essential to extend the craniotomy interiorly until it is flush with the floor of the middle fossa.

2.64c The relationship between the craniotomy and the temporal lobe and midbrain.
2.65a The patient is positioned supine on the operating table with the right shoulder elevated. The head is slightly extended and the face is moderately turned toward the table.

2.65b The scalp incision and craniotomy. It is essential to extend the craniotomy interiorly until it is flush with the floor of the middle fossa. This may require the opening of the mastoid air cells which should be sealed with bone wax or methylmethacrylate.

2.65c The relationship between the craniotomy and the temporal lobe and midbrain. Particular attention should be given to preserving the vein of Labbe.
Subtemporal Transtentorial Posterior Fossa Approach, or Combined Supratentorial and Infratentorial Approach

2.66a The patient is positioned supine on the operating table with the right shoulder elevated. The head is slightly extended and the face is moderately turned toward the table.

2.66b The patient is placed in a modified park bench position with the head flexed and rotated 120 degrees off the vertical axis.

2.66c A schematic drawing of the scalp incision and the craniotomy. The posterior rim of the incision extends down beyond the tip of the mastoid process.

2.66d Schematic representation of the craniotomy and its relationship to the temporal lobe, the tentorium, and the contents of the posterior cranial fossa.
Clinical Material
Case 1
Diagnosis: Meningioma of the posterior part of the cavernous sinus and upper clivus
Position: Left subtemporal transtentorial
Position: Semi-sitting

2.67a A CT scan with sagittal reconstruction demonstrates a meningioma within the posterior cavernous sinus, the petrous tip, and the upper clivus.

2.67b A coronal MR image demonstrates the meningioma.

2.67c The edge of the tentorium and tumor are visible through a left subtemporal craniotomy.

2.67d After further mobilization of the temporal lobe, the extent of the tumor can be appreciated.
After the tumor has been resected partially, the relationship of the brain stem to the third cranial nerve becomes clear.

The tentorium has been opened above the third and fourth cranial nerves to allow further tumor removal.

The third and fourth cranial nerves are seen with minimal residual tumor visible on the upper clivus. The remainder of this tumor was readily removed between the fourth and fifth cranial nerves.

A postoperative CT scan demonstrates the meningioma removal.
Case 2
Diagnosis: Chordoma of the sphenoid sinus and the upper clivus
Approach: Transsphenoidal and transtemporal

2.68a A sagittal midline MR image reveals a large tumor protruding above the upper clivus and extending into the sphenoid sinus.

2.68b Another sagittal section demonstrates the marked distortion of the brain stem by the tumor.

2.68c A selective vertebral artery injection demonstrates the marked distortion of the basilar artery by the tumor.
2.68d An intraoperative X-ray demonstrates the removal of the tumor through a trans-sphenoid approach.

2.68e After transsphenoidal surgery, the MR image reveals a significant amount of residual tumor below the brain stem, but complete tumor removal in the sphenoid sinus.

2.68f A transverse MR image demonstrates tumor and distorted midbrain.
2.68g Through a right subtemporal approach, the tentorium has been cut and the 3rd and 4th nerves, brain stem, and temporal lobe identified.

2.68h The anatomy becomes clear as the tumor is progressively removed. The posterior cerebral arteries on both sides become visible, and the opposite posterior communicating artery can be clearly seen.

2.68i A different angle shows residual tumor in the upper clivus, and also better demarcates the vascularity. The contralateral posterior cerebral artery and the ipsilateral posterior cerebral and superior cerebellar arteries are visible.
2.68j With the tumor now dissected from the basilar artery, the residual tumor remains attached to the clivus. The basilar artery bifurcation and the superior cerebellar artery are clearly visible.

2.68k The basilar artery is followed caudally until the inferior portion of the tumor is clearly identified.

2.68l The residual tumor is being evacuated and lifted out just below the 4th nerve. The high position of the 4th nerve makes it particularly susceptible to trauma because it is often out of the focus of the microscope while working on the deepest portion of the tumor.
2.68m The tumor is lifted around the fourth nerve.

2.68n After the tumor has been removed, the entire basilar artery and bifurcation are clearly visible. The contralateral third nerve can be seen originating between the contralateral posterior cerebral and superior cerebellar arteries. The ipsilateral posterior cerebral and superior cerebellar arteries are also visible.

2.68o When the basilar artery is retracted slightly, the contralateral sixth nerve can be visualized as it arises from the brain stem and enters Duretto's canal.
An overview of the operative site after tumor extirpation shows the intact fourth nerve, the tentorium, and the basilar artery.

Under higher magnification, the basilar artery and its bifurcation can be appreciated.

A postoperative lateral X-ray demonstrates the craniotomy site.

A postoperative CT scan reveals tumor excision.

A lower CT section also verifies complete tumor excision. This patient had no new demonstrable cranial nerve deficit and left the hospital within five days of the craniotomy.
Case 3
Diagnosis: Meningioma of the upper clivus
Approach: Subtemporal

2.69a A midline sagittal MR image demonstrates a large tumor on the clivus, compressing the brain stem.

2.69b A CT scan demonstrates that the tumor extends to the right.

2.69c An internal carotid artery angiogram demonstrates the tumor stain.

2.69d An anteroposterior internal carotid artery angiogram outlines the tumor.
2.69e Through a right anterior subtemporal approach, the tentorium and tumor protrusion can be appreciated. Because the preoperative studies revealed that the tumor was mostly in the upper portion of the clivus, a subtemporal approach was used. The tumor, however, is almost large enough to necessitate a combined approach. If a tumor cannot be removed completely through a subtemporal approach, then a staged operation with either a posterior fossa approach or combined approach can be substituted.

2.69f The vascularity of the tumor is apparent, and the edge of the tentorium is retracted with forceps.

2.69g At a higher magnification, the fourth cranial nerve and the tumor, as it compresses the brain stem, can be seen.
2.69h The tumor has been dissected free from the brain stem and removed from the clivus. The base of the brain and its vascular and cranial nerve anatomy are visible. Both posterior communicating arteries are clearly visible, and anteriorly the vascular pituitary stalk can be readily identified.

2.69i The pituitary stalk and the vascular anatomy are seen at higher magnification.

2.69j An overview demonstrates the continuity of the third and fourth cranial nerves and the exposure that can be obtained through an anterior subtemporal approach.
Tumors of the Tentorium, Petroclival Region, and Middle Clivus

Combined Supratentorial and Infra-tentorial Approaches

Microanatomy

2.70a View of the cerebellopontine angle from above. The tentorium is reflected from the side of the ambient cistern. Notice the acoustic, trigeminal, and trochlear nerves.
2.70b View of the tentorial notch with the tentorium reflected laterally and with the cerebellum retracted, exposing the nerve root entry zone of the trigeminal nerve.

2.70c Partial resection of the cerebellum allows visualization of the trigeminal nerve and the loop of the superior cerebellar artery (viewed from the right and from above).
2.71a View of the tentorial notch from the right and above. With the tentorium reflected laterally, the cerebellopontine angle is visualized between the trigeminal nerve and the vagal nerve group.

2.71b After resection of the tentorium, the cerebellopontine angle is viewed from above and lateral.
In this dorsal view of right petrous bone, the petrosal sinus is demarcated as it enters the sigmoid sinus. Notice the cranial nerves from the fifth (top) through the twelfth.
2.73 Lateral view of the right cerebellar hemisphere, with sinuses. The transverse and sigmoid sinuses are intact, but the right side of the tentorium and the dura have been excised. This illustration shows the transtentorial view of the pineal region and cerebellar hemisphere.
2.74 Anatomical view, with the dura opened in front of and behind the sigmoid sinus. The relationship of the tentorium to the superior petrosal sinus is well appreciated.
2.75a After a complete petrosectomy has been performed, the relationship between the fourth, fifth, sixth, and seventh cranial nerves and the ninth, tenth, and eleventh cranial nerves is appreciated. Notice the relationship of the internal carotid artery to the fifth, seventh, and eighth cranial nerve complex.
After further dissection of the fifth cranial nerve, Meckel's cave and the cavernous sinus are opened.
2.75c Downward retraction of the trigeminal nerve and the Gloss- 
serian ganglion reveals the course of the carotid artery within the 
petrous pyramid.

2.76 An overview of the clivus, brainstem, cerebellum, and cranial 
nerves as seen surgically through the combined supratentorial and 
infatentorial approach.
Combined supratentorial and infratentorial Approach

2.77 Stepwise demonstration of a typical combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-sinus petrosus transtentorial approach on the right side (fresh cadaver dissection). The specimen is positioned as for an operation in a semi-sitting position, a. The bone flap is outlined, and the location of the transverse and sigmoid sinuses is marked.

2.77b The bone flap is cut in one piece, using a Midas Rex drill, and removed. The dura covering the temporal lobe and the cerebellum is exposed.
2.77c,d The lateral parts of the petrous bone have already been removed. The dura of the posterior cranial fossa is seen fixed to the posterior surface of the petrous bone in the region of the superior petrosal sinus, at the entrance point of the endolymphatic sac, and at the location of the jugular bulb.

2.77e The craniotomy reaches down to the base of the posterior cranial fossa. The atlantal part of the vertebral artery is exposed.
2.77f The temporobasal dura has been incised, the dura of the posterior fossa has then been opened presigmoidally, and the superior petrosal sinus is about to be divided.

2.77g With the temporal retractor slightly elevating the temporal lobe the tentorium is exposed, and is cut parallel to the petrous ridge from lateral to medial as far as the tentorial notch. The temporal retractor may be placed beneath the tentorium to protect the temporal lobe.

2.77h Before the tentorial notch is reached with the microscissor, the trochlear nerve requires special attention. The nerve is situated behind, or slightly above, the dural margin, and is woven into the arachnoid in the region of the ambient cistern. The nerve enters the dura at the posterior petroclinoid fold.
2.77i View into the supratentorial space in an anterior direction. The midbrain, trochlear nerve and superior cerebellar artery can be appreciated.

2.77j More anteriorly, we can see the oculomotor nerve and the right and left optic tracts, and between these structures the infundibulum. The trochlear nerve enters the dura at the posterior petroclinoid fold.

2.77k In a side view in a fairly upwards direction, the mamillary body becomes visible.
2.77l A horizontal view provides an overview of the optic system flanking the infundibulum.

2.77m More anteriorly, the internal carotid artery becomes apparent.

2.77n A slightly downwards view gives a good view of the internal carotid artery and oculomotor nerve, which enters the cavernous sinus. In the lower left corner, the trochlear nerve is visible, entering the dura.
Tumors of the Middle Skull Base

2.77o View into the infratentorial space. Minimized retraction on the cerebellum exposes the cerebellopontine angle and the prepontine space. The trigeminal nerve and the seventh and eighth nerve group can be appreciated.

2.77p The presigmoidal approach gives an excellent overview of the structures in the cerebellopontine angle. It should be borne in mind that the jugular bulb forms the caudal limit of the approach.

2.77q Pointing the microscope in a more caudal direction, the group with the ninth, tenth, and eleventh nerves becomes visible. Below these nerves, the vertebral artery and the hypoglossal nerve fibers can be seen. The posterior inferior cerebellar artery originates from the vertebral artery.
2.77r,s The caudal cranial nerves, among them the ninth, tenth, eleventh, and twelfth, are exposed. The vertebral artery, posterior inferior cerebellar artery, and medulla oblongata can be visualized. The jugular bulb limits the caudal extension of this presigmoidal approach.

2.77t Overview of the supratentorial and infratentorial space exposed by the transtentorial and presigmoidal approach. The fourth to twelfth cranial nerves are visualized, and the superior cerebellar artery, posterior inferior cerebellar artery, and vertebral artery are seen.
Introduction and Technique

The combined supratentorial and infratentorial approach is recommended for any tumor that is situated above and below the tentorium along the petrous ridge, the clivus, or both. The relationship between the vascular and neural structures is so important that the surgeon who is unfamiliar with this region is urged to dissect several cadavers before attempting surgery. A team approach including a neurosurgeon and a neuro-otologist is highly advantageous.

The incision begins in front of the ear below the zygomatic arch, above and behind the frontalis branch of the facial nerve. The incision curves over the ear to end behind and below the tip of the auditory meatus. Variations on this incision depend on the particular exposure desired.

The scalp and underlying muscle is mobilized in two directions. The first is retraction of the scalp and temporalis muscle anteriorly, to expose a significant portion of the zygomatic process and a portion of the middle fossa. This is best accomplished with scalp hooks attached to rubber bands and fixed by a Leyla bar. The other direction of retraction runs inferiorly, exposing the rim of the external auditory canal and the entire auditory meatus. Again, scalp hooks, rubber bands, and a Leyla bar are advantageous.

The petrous bone is drilled initially, exposing the dura and sigmoid sinus. This opening is used to perform a craniotomy. The extent of petrous bone resection depends on the desired exposure. The resection, and therefore the exposure, can be extensive even if hearing needs to be preserved. If, however, the entire inner ear can be sacrificed, the petrous bone resection can be maximized after mobilizing the seventh cranial nerve, thereby gaining a generous view of the base of the skull. When this approach is combined with the subtemporal and posterior fossa approach, the entire extent of the base of the skull can be visualized from the foramen magnum to the tip of the temporal fossa.

The important vascular relationship to be borne in mind after the craniotomy is that of the dural sinuses and the inferior anastomotic vein of Labbe. The vein of Labbé enters the transverse sinus proximal to the junction of the sigmoid and superior petrosal sinuses. Recognizing this relationship is important, because it allows the entire
width of the tentorium to be split below this junction, sacrificing the superior petrosal sinus while preserving the important drainage of the vein of Labbé into the lateral sinus. After ensuring that bilateral sigmoid sinus drainage is present, or that the venous drainage is primarily through the contralateral sigmoid sinus, the ipsilateral sigmoid sinus can be sacrificed. This maneuver allows almost unlimited retraction of the incised tentorium, along with the lateral sinus, the vein of Labbé, and the base of the temporal lobe. The need for this retraction is, however, considerably reduced, as the petrous bone resection provides considerable exposure. If the facial nerve is completely drilled out of its canal, facial paresis that can persist for 6–12 months must be anticipated. If slightly less exposure is adequate, the seventh cranial nerve can be protected with a rim of bone and left in its normal anatomical course, to avoid facial palsy. The petrous portion of the internal carotid artery can be readily exposed; if direct exposure is not required, a bony rim can be left to protect it. The technique of presigmoidal incision of the dura of the posterior cranial fossa is an alternative to the supratentorial and infratentorial approach described above, which involves transection of the sigmoid sinus. The advantage of this technique is the preservation of the sigmoid sinus. The jugular bulb forms the caudal limit of this approach.

The combined approach has been divided into three variations. The first is the retrolabyrinthine exposure, which maintains the labyrinth intact during the drilling of the petrous ridge, thus preserving hearing. The second is the translabyrinthine exposure, in which the labyrinth is removed and ipsilateral hearing is thereby sacrificed. The third, and most extensive, approach is the transcochlear, in which the entire cochlea and the remainder of the petrous pyramid are sacrificed. The seventh cranial nerve is severed from its superficial petrosal branch and transposed from its canal.

2.79a
The venous phase of the arteriogram demonstrates the normal bilateral drainage of the supratentorial contents through the transverse sinuses. With bilateral venous drainage assured, it is safe to sacrifice one sigmoid sinus. A normal venous drainage pattern must be established before sacrificing a sigmoid sinus.

2.79b An example of an abnormal drainage system. A portion of the left transverse sinus is missing completely.
2.80a The venous vasculature is again emphasized here. Because the vein of Labbe drains into the transverse sinus above the junction of the superior petrosal sinus and sigmoid sinus, the sigmoid sinus and superior petrosal sinus can be sacrificed. The vein of Labbe will then drain into the transverse sinus and empty through the contralateral side (Fig. 2.89f).

2.80b Knowledge of the anatomy of the cochlea within the petrous bone is extremely important if hearing is to be preserved. Obviously, if hearing can be sacrificed and the seventh nerve mobilized, a much greater degree of petrous bone can be resected to gain further exposure (transcochlear exposure).

2.81a The scalp incision usually extends below the zygomatic arch in front of the ear between the frontalis branch of the facial nerve and the tragus of the ear. The posterior rim of the incision extends down to the mastoid tip or beyond, and depending on the extent, the mastoid and petrous bone are resected.

2.81b The craniotomy and its relationship to the skull base.
2.82 These illustrations have been deliberately placed upright to emphasize the anatomical relationship when the sitting position is used. A petrous resection that spares the labyrinth. A translabyrinthine petrous resection would include the blue shading; the transcochlear approach would additionally include the green shading.

2.83a,b The retrolabyrinthine petrosal resection.

2.83c The extended retrolabyrinthine approach, with skeletonized posterior and superior semicircular canals and mastoidectomy.

2.82b A lateral diagram summarizes the three approaches: the supra-infratentorial retrolabyrinthine approach (yellow), the translabyrinthine approach (blue), and the transcochlear approach (green).
2.84a, b  The translabyrinthine petrosal resection.

2.85a,b  The transcochlear petrosal resection.
2.86a  A postoperative three-dimensional CT reconstruction of a retrolabyrinthine approach demonstrates significant preservation of the petrous ridge to preserve hearing.

2.86b  In contrast, the entire petrous ridge has been drilled away in this transcochlear CT reconstruction.

2.87a  The same CT reconstruction as in Fig. 2.86a, seen from the side, demonstrates the preserved labyrinth.

2.87b  The same patient as in Fig. 2.86b, showing removal of the entire petrous ridge, viewed from the side.

2.88a  An oblique view of a three-dimensional CT reconstruction of the skull base after a retrolabyrinthine approach, demonstrating the extent of petrous bone resection.

2.88b  An oblique view of a CT reconstruction after a transcochlear approach. These CT reconstructions dramatically illustrate the degree of petrous ridge resection that is possible, depending on the approach used.
2.89 This series of illustrations has deliberately been placed upright to emphasize the anatomical relationship when the sitting position is used. a The scalp incision.

2.89b Extension of supratentorial and infratentorial craniotomy across the transverse sinus. The dural incision is outlined according to a retrolabyrinthine presigmoidal supra-transverse sinus subtemporal trans-petrosal sinus approach.

2.89c Approach as in Fig. 2.89b, showing the direction of the transtentorial incision.

2.89d Outline of the dural incision for a retrolabyrinthine presigmoidal retrosigmoidal supra-transverse sinus subtemporal trans-petrosal sinus approach. This approach provides more extensive access to the posterior cranial fossa in the direction of the foramen magnum.

2.89e Dural incision with a retrolabyrinthine subtemporal trans-petrosal sinus trans-sigmoid sinus posterior fossa approach. With this approach, the sigmoid sinus is sacrificed.

2.89f The venous drainage system. If the sigmoid sinus is sacrificed, the ipsilateral great anastomotic vein (vein of Labbé) will drain contralaterally, as it enters the lateral sinus above the junction of the superior petrosal and sigmoid sinuses.

2.89g Retrolabyrinthine presigmoidal subtemporal trans-petrosal sinus approach. Because of the position of the great anastomotic vein (Labbé), the subtemporal incision is not carried posteriorly above the transverse sinus.
2.90a Anatomical relationships when the patient is positioned supine on the operating table with the head turned parallel to the floor, inclined slightly downward. The illustrations are presented in the upside-down position.

2.90b Extent of the bone resection in an extended combined supratentorial and infratentorial approach. The larger exposure in the subtemporal region shows the two angles of exposure to the petrous tip and the clivus.

2.90c This dural incision is presigmoid, and crosses the superior petrosal sinus to join the dural incision over the temporal lobe.

2.90d The craniotomy, with an orange line indicating the presigmoidal dural incision with preservation of the sigmoid sinus, and clips across the superior petrosal sinus. The labyrinthine segment of the facial nerve is exposed after removing the roof of its bony canal.

2.90e Two separate dural incisions, in front of and behind the sigmoid sinus, preserve the integrity of the sigmoid sinus.

2.90f The dural incision crosses the superior petrosal sinus as well as the sigmoid sinus, and extends in a retrosigmoid fashion for a maximal dural opening. The sigmoid sinus can only be sacrificed after bilateral patency of the transverse sinuses has been established.
2.90g  Extended retrolabyrinthine approach, with exposure of the labyrinthine segment of the facial nerve and the dural incision crossing both the superior petrosal and sigmoid sinuses.

2.90h  The temporal dural incision crosses the superior petrosal sinus to join with a dural incision in front of the sigmoid sinus. For better exposure in the direction of the foramen magnum, the sigmoid sinus is sectioned between clips, and a retrosigmoid dural incision allows access in front of and behind the sinus.

2.90i  The temporal lobe and the incised tentorium, protected by a retractor. The base of the temporal lobe, along with the incised tentorium is elevated without stretching the great anastomotic vein (Labbé). The ipsilateral petrous region, the entire clivus, and the cranial nerves are exposed.
Clinical Material  Case 1

Diagnosis: Right hemangioblastoma with supratentorial and infratentorial extension

Approach: Combined supratentorial, and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrosal sinus transtentorial

Position: Semi-sitting

2.91a A CT scan with coronal reconstruction demonstrates a hemangioblastoma at the apex of the petrosal pyramid, associated with a large cyst.

2.91b A CT scan with a sagittal reconstruction demonstrates the location of the hemangioblastoma at the medial tip of the petrous ridge.

2.91c The patient is in the semi-sitting position, and the craniotomy exposes the sigmoid sinus. This is a retrolabyrinthine approach with a presigmoid dural incision.

2.91d The dura has been incised above and below the superior petrosal sinus to expose the base of the temporal lobe and the arachnoid of the posterior fossa.

Transverse sinus

Superior petrosal sinus

Sigmoid sinus

Superior petrosal sinus

Petros bone

Presigmoid dural incision
2.91c After the tentorium has been cut along the petrous ridge, the hemangioblastoma is exposed.

2.91f In a slightly inferior view, the sixth, seventh, and eighth cranial nerves are visible inferior to the tumor. A small segment of the basilar artery is visible just medial to the sixth cranial nerve.

2.91g The hemangioblastoma is mobilized and separated from its blood supply in one piece.
After the hemangioblastoma is excised, the fifth cranial nerve can be seen as it is distended superiorly, and as the sixth, seventh, and eighth cranial-nerve complex is distended inferiorly by the tumor. The basilar artery is visible in the depth of the opening.
Case 2
Diagnosis: Right supratentorial and infratentorial craniopharyngioma (subtemporal and tentorial hiatus)
Approach: Right combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrosal sinus transtentorial
Position: Semi-sitting

2.92a,b Horizontal CT scans demonstrate a partial cystic craniopharyngioma which extends deeply into the midbrain and pons from the right side.

2.92c,d CT scans with a sagittal reconstruction give an impression of the supratentorial and infratentorial location of the tumor. The corpus callosum shows a defect resulting from a transcallosal total extirpation of a cystic craniopharyngioma from the third ventricle fifteen years before.
After the supra-infratentorial craniotomy and drilling of the lateral parts of the petrous bone, the transverse, sigmoid, and superior petrosal sinuses are exposed.

The temporobasal and presigmoidal dura has been incised.

The superior petrosal sinus is occluded with two clips.
2.92h The superior petrosal sinus is divided, and the tentorium is visualized.

2.92i By gently lifting the temporal lobe, the tentorium can be surveyed, and it is now transected as far as the tentorial notch.

2.92j Exposure of the tumor.
2.92k Evacuation of a supratentorial tumor cyst; piecemeal removal of the solid tumor.

2.92l The solid part of the craniopharyngioma is grossly resected. In a slightly anterior view, a thoroughly calcified section of the tumor located in the parasellar region can be seen. This tumor is adherent to the internal carotid artery.

2.92m The space between the tentorial notch and the brain stem is freed from tumor tissue. The trochlear and oculomotor nerves, superior cerebellar artery, and other vascular structures can be visualized.
A large cystic part of the craniopharyngioma located within the midbrain and the pons is evacuated, and the lateral cyst wall is removed.

In a slightly inferior view, the fifth, seventh, and eighth nerves are exposed, the petrous vein can be seen. A caudal part of the tumor, fixed to the trigeminal nerve, is removed.

The situation after closure of the subtemporal and presigmoidal dural incision.

A postoperative CT scan confirms the extirpation of the large tumor compromising the brain stem. The suprasellar calcified tumor remains untouched.
Case 3  
Diagnosis: Meningioma of the right petrous pyramid  
Approach: Right combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrosal sinus transtentorial  
Position: Sitting

2.93a An MR image demonstrates a petrous ridge meningioma.  
2.93b A coronal section of the MR image demonstrates the medial extent of the small meningioma.  
2.93c The patient is in the sitting position.  
2.93d A close-up of the sitting position, where the incision will be placed behind the ear.
2.93e After the craniotomy and drilling of the petrous ridge, the dura and sigmoid sinus are visible.

2.93f A presigmoid dural incision exposes the cerebellum below the superior petrosal sinus, and the temporal lobe above the superior petrosal sinus.

2.93g After the base of the temporal lobe has been elevated, the superior petrosal sinus and the tentorium are transected.
2.93h After the tentorium has been resected, the fourth cranial nerve is visible overlying the tumor.

2.93i After much of the tumor has been removed, the fourth cranial nerve can be seen as it courses through the ambient cistern.

2.93j The fifth cranial nerve and petrosal vein become visible more interiorly.
After the tumor has been completely removed, a superior view demonstrates the fourth cranial nerve.

A slightly lower view demonstrates the fifth cranial nerve and the petrosal vein as it enters the superior petrosal sinus.

An even lower view demonstrates the petrosal vein, the fifth cranial nerve, and the sixth cranial nerve below the fifth cranial nerve.
When the microscope is tilted even lower, the seventh and eighth cranial nerves come into focus.

Postoperative CT scan demonstrates the resection of the petrous bone and the removal of the meningioma.
Case 4
Diagnosis: Meningioma of the left petrous pyramid
Approach: Left combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrous sinus transtentorial
Position: Semi-sitting

2.94a A sagittal MR image demonstrates a large meningioma originating from the petrous pyramid mainly into the posterior cranial fossa.

2.94b A transverse scan reveals the tumor markedly compressing the brain stem and distorting the fourth ventricle.

2.94c A coronal MR image shows the supratentorial and infratentorial extension of the meningioma. The midbrain and pons are heavily compressed.

2.94d The patient is placed in a semi-sitting position, with the head turned about 30 degrees to the left. The skin incision, mastoid, and localization of the transverse and sigmoid sinuses are marked.
2.94e  The scalp flap is reflected.

2.94f  Using a Midas Rex drill, a supratentorial temporal bone flap is completed. An infratentorial suboccipital bone flap has already been removed.

2.94g  After drilling the petrous ridge, the transverse, sigmoid, and superior petrosal sinuses are visible.
2.94h The supratentorial dural incision is carried out along the temporobasal dura.

2.94i The sinuses are identified.

2.94j The dura of the posterior fossa has been opened presigmoidally, and the superior petrosal sinus is interrupted with clips.
2.94k The superior petrosal sinus has been divided. Gentle lifting of the temporal lobe exposes the anterior inferior bridging veins draining blood to the upper knee of the sigmoid sinus.

2.94l By lifting the temporal lobe, the tentorial notch is visualized. The midbrain, trochlear nerve, and superior cerebellar artery can be appreciated.

2.94m After complete transection of the tentorium, the supratentorial and infratentorial extension of the tumor can be recognized.
2.94n A slightly inferior view into the cerebello-pontine angle shows the seventh and eighth cranial nerves as a complex bundle, and below these, we can recognize the abducent nerve and the vertebral artery.

2.94o From the level of the transected tentorium downwards, we can see the trigeminal nerve, the seventh and eighth nerves, and, above the tentorial level, the midbrain and superior cerebellar artery.

2.94p The supratentorial space is now free of tumor; we can recognize the trigeminal nerve, the midbrain, and the superior cerebellar artery.
Case 5
Diagnosis: Petroclival meningioma
Approach: Right combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrosal sinus transtentorial
Position: Semi-sitting

2.95a–c CT scans with sagittal reconstructions showing a large meningioma extending above and below the tentorium, and severely compressing the brain stem.
2.95d A craniotomy flap has been performed, overlying the middle cranial fossa.

2.95e Drilling of the lateral portion of the petrous ridge exposes the superior petrosal sinus.

2.95f The transverse sinus, superior petrosal sinus, and sigmoid sinus can be visualized after the bone has been removed.
2.95g A supratentorial dural incision is carried out along the temporobasal dura, parallel to the superior petrosal sinus, and continues along the transverse sinus (until the vein of Labbé is identified).

2.95h The dura of the posterior fossa is incised presigmoidally.

2.95i A suture is placed through the tentorium around the superior petrosal sinus.
2.95j After transection of the superior petrosal sinus, the tentorium is incised from lateral to medial.

2.95k The tumor capsule is being mobilized.

2.95l Most of the tumor has been removed, and only a distal portion of the capsule is visible.
After the entire tumor has been removed, the fourth cranial nerve and the brain stem are visible.
Case 6
Diagnosis: Neurinoma of the trigeminal nerve
Approach: Left combined supratentorial and infratentorial subtemporal trans-petrosal sinus trans-sigmoid sinus retrolabyrinthine retrosigmoidal (posterior fossa) transtentorial
Position: Supine

2.96a An MR image depicts a tumor within Meckel's cave and the posterior fossa.

2.96b Another section through the tumor demonstrates the compression of the brain stem.

2.96c An MR image demonstrates the trigeminal neuroma.

2.96d This section demonstrates the entrance into Meckel's cave.
2.96e Petrous bone is resected in the initial stage.

2.96f An overview of the petrous bone resection and its relationship to the external auditory meatus.

2.96g A close-up of the petrous resection delineates the sigmoid sinus and the location of the superior petrosal sinus. The petrous ridge has been resected, but the inner ear has been preserved to protect hearing.
2.96h The bone flap is elevated. Notice the marked temporal craniotomy and the relatively limited posterior fossa craniotomy.

2.96i After the dura has been incised over the base of the temporal lobe and cerebellum, the sigmoid sinus is obliterated with silver clips.

2.96j The tentorium is incised after obliterating the superior petrosal sinus. Only a small portion of the tentorium remains. The large efferent vein of Labbé is visualized where the tentorium is cut.
2.96k The third and fourth cranial nerves are identified after complete transection of the tentorium. The markedly enlarged Meckel's cave is distended with tumor.

2.96l After a large portion of the trigeminal neuroma in the posterior fossa has been resected, the fifth cranial nerve becomes visible.

2.96m The fifth cranial nerve is followed into Meckel's cave, and the tumor is removed completely. The entire fifth cranial nerve remains intact, except for a few fascicles from which the tumor arose. Postoperatively, the patient had diminished, but good, sensation on the side of the tumor.
2.96n A postoperative CT scan demonstrates the bone resection and the preservation of much of the petrous ridge, which protected the patient's hearing.

2.96o A higher CT section demonstrates that the tumor has been removed and that fat has been placed in the cavity of the resected petrous ridge.
Case 7
Diagnosis: Cavernous malformation of the midbrain
Approach: Right combined supratentorial and infratentorial subtemporal retrolabyrinthine presigmoidal trans-petrosal sinus transtentorial
Position: Supine

2.97a A sagittal MR image demonstrates a large cavernous malformation in the midbrain.

2.97b A coronal MR image shows the asymmetric location of the tumor next to the third ventricle.

2.97c A transverse section demonstrates the cavernous malformation and its relationship to the brain stem.
2.97d The patient is positioned supine, and the head is turned to expose the right side. The previous incision from two earlier craniotomies that attempted to remove the tumor, which had bled several times, is incorporated into the combined incision.

2.97e The previous craniectomy is visualized, and the new craniotomy incorporating this previous craniectomy is begun.

2.97f After the craniotomy, the petrous ridge is exposed.
2.97g The petrous ridge and the floor of the middle fossa are drilled away, but the inner ear and hearing are preserved.

2.97h After the petrous bone has been resected, the sigmoid sinus and superior petrosal sinus become visible.

2.97i In this case, only the superior petrosal sinus is incised; the sigmoid sinus is kept intact. This approach is used when a combined approach is necessary but the ipsilateral sigmoid sinus is the major draining sinus from the two hemispheres. Although the intact sigmoid sinus slightly restricts the ability to retract the base of temporal lobe, the petrosectomy provides excellent exposure. Paddies have been placed over the cerebellum anterior to the sigmoid sinus and in the temporal fossa, outlining the superior petrosal sinus and tentorium.
2.97j The superior petrosal sinus is obliterated with a clip.

2.97k The tentorium has been cut, exposing the midbrain. Previous hemorrhage and surgical intervention are responsible for the adhesions and scar tissue. The tumor cavity is opened.

2.97l The cavernous malformation is mobilized within the small opening in the midbrain.
2.97 m After piecemeal resection of the large cavernous malformation, the typically hemosiderin-stained tumor cavity is visible.

2.97 n A view through the brain stem into the fourth ventricle via the tumor cavity.

2.97 o,p Postoperative CT scans demonstrate removal of the cavernous malformation.
Case 8
Diagnosis: Meningioma of the tentorium and the clivus
Approach: Right combined supratentorial infratentorial subtemporal trans-petrosal sinus trans-sigmoid sinus retrolabyrinthine retrosigmoidal (posterior fossa) transtentorial
Position: Supine

2.98a  A CT scan reveals a large meningioma extending above and below the tentorium.

2.98b  A lower CT scan demonstrates the extent of tumor within the posterior fossa.

2.98c  An MR image demarcates the tumor and the compression of the brain stem.

2.98d  A sagittal MR image demonstrates the base of the tumor on the clivus and significant brain-stem compression.
2.98e The patient is placed supine, with the head turned completely horizontal and slightly angled toward the floor.

2.98f The position is viewed as it appears to the surgeon, from the top of the head.
2.98g The scalp has been incised. The scalp and temporals muscle are retracted anteriorly, and the edge the scalp incision over the external auditory meatus is retracted interiorly. This maneuver exposes the rim of the zygomatic arch and the external auditory meatus, which is covered with a paddy, and the mastoid tip.

2.98h After the petrosectomy, which preserved the inner ear structures, the amount of exposure of the superior petrosal and sigmoid sinuses can be readily appreciated.

2.98i After the dura of the temporal and posterior fossae has been opened, the sigmoid sinus is occluded. Gelfoam has been placed over the temporal lobe and cerebellum for protection.
2.98j An overview demonstrates the exposure. Retractors are placed on the cerebellum and the base of the temporal lobe.

2.98k By focusing along the cut portion of the tentorium, the ambient cistern can be identified.

2.98l A slightly inferior view demonstrates the large tumor.
2.98m  After extensive tumor resection, the cranial nerves are visualized.

2.98n  Tumor resection continues below the fifth cranial nerve.

2.98o  As the tumor is resected from the clivus, the midbasilar artery becomes visible. The ipsilateral sixth cranial nerve is visible.
After the entire tumor has been mobilized and is ready for delivery, the fourth cranial nerve and the vasculature in the ambient cistern are readily visible.

A postoperative CT scan demonstrates tumor removal.

A lateral skull X-ray shows the extent of the craniotomy and the clips for the sigmoid sinus and superior petrosal sinus.
Case 9:
Diagnosis: Petroclival meningioma
Approach: Left combined supratentorial and infratentorial subtemporal trans-petrosal sinus trans-sigmoid sinus retrolabyrinthine retrosigmoidal (posterior fossa) transtentorial
Position: Supine

2.99a A coronal MR image demonstrates a petroclival meningioma.

2.99b A horizontal MR image demonstrates distortion of the brain stem by the petroclival meningioma.

2.99c A sagittal MR image demonstrates distortion of the brain stem by the meningioma.
2.99d The patient is placed in the supine position, with the head turned horizontally.

2.99e The petrous bone, including the labyrinth, has been drilled. The cochlea, however, has been preserved to protect the seventh cranial nerve.

2.99f The craniotomy, which crosses the transverse sinus, is elevated.
2.99g  Further drilling is performed along the floor of the temporal fossa and the zygomatic arch.

2.99h  The dura of the posterior fossa, the sigmoid sinus, superior petrosal sinus, and middle fossa are exposed.

2.99i  When bilateral drainage of the sigmoid sinus is ascertained, the sinus is exposed and a 27-gauge needle is inserted into it. The pressure in the sigmoid sinus is recorded, and its outflow is temporarily occluded. If the pressure in the sigmoid sinus remains stable, or increases only by a few mm torr, the sinus can be sacrificed. If, however, pressure in the sigmoid sinus increases markedly, the sinus is left intact.
2.99j After the sigmoid sinus has been clipped proximally and distally, it is transected.

2.99k After the dura has been opened and partially sectioned, the cerebellum and the base of the temporal lobe are exposed.

2.99l A small remnant of the tentorium persists, under which the arachnoid-covered fourth cranial nerve is visualized.
2.99m The tentorium is split completely to expose the fourth cranial nerve and the tumor.

2.99n The meningioma is removed in the usual fashion, allowing exposure of the cranial nerves. The fifth, seventh, and eighth cranial nerves are visible in the posterior fossa.

2.99o A vascularized temporalis muscle fascia pedicle is harvested.
2.99p The vascularized temporalis pedicle is elevated and left attached at its base.

2.99q After the vascularized temporalis pedicle has been placed in the cavity formed by the petrous bone resection, the bone flap is replaced.

2.99r Several days after surgery, the patient shows good residual function of the seventh cranial nerve.
2.99s The appearance of the scalp incision several days after surgery.

2.99t,u Sequential horizontal MR images show the petrous bone resection, the tumor cavity, and the temporalis flap in the drilled petrous cavity.
Case 10
Diagnosis: Meningioma of the clivus and tentorium
Approach: Right combined supratentorial and infratentorial subtemporal
trans-petrosal sinus trans-sigmoid sinus retrolabyrinthine
retrosigmoidal (posterior fossa) transtentorial
Position: Supine

2.100a An MR image shows tumor markedly compressing the brain stem and partly encasing the basilar artery.
2.100b An MR image delineates the tumor compressing the brain stem and distorting the fourth ventricle.
2.100c A CT scan shows the tumor and its relationship to the tentorium.
2.100d Through a right-sided combined approach, the temporal and occipital bone have been exposed.

2.100e The posterior fossa dura has been opened, and the sigmoid sinus has been obliterated with a large tantal clip.

2.100f The temporal lobe has been elevated. The temporal lobe and cerebellum have been retracted from the superior petrosal sinus, which has been clipped on both sides. The tentorium along the base of the temporal lobe is visible.
2.100g After the tentorium has been completely cut, the tumor is visible as it elevates the fifth cranial nerve.

2.100h After the tumor has been resected extensively, the course of the fourth cranial nerve is visible. Although retractors are on the cerebellum and the base of the temporal lobe, the amount of retraction is slight, because the petrosectomy provides an excellent view of the base of the skull.

2.100i After complete tumor resection, the base of the brain stem, the blood vessels, and the third, fourth, and fifth cranial nerves are clearly visible. The seventh and eighth cranial nerve complex can just be glimpsed on the upper edge of the photograph.
2.100j In this anterior view, the dissector has opened the arachnoid that covers the pituitary stalk. The fourth cranial nerve is visible in the foreground.

2.100k Viewed rostrally along the brain stem, the basilar artery is clearly visible.

2.100l From a view above the fifth cranial nerve, the sixth cranial nerve can be seen arising from the brain stem and entering Dorello’s canal.
2.100m A postoperative CT scan demonstrates the extent of bone resection.

2.100o A view of the soft tissue shows the resection of the tumor. The fourth ventricle is not shifted.

2.100n A higher view.

2.100p A higher CT scan demonstrates the absence of swelling or ventricular distortion.
Case 11
Diagnosis: Meningioma of the middle and lower clivus
Approach: Left combined supratentorial and infratentorial subtemporal trans-petrosal sinus trans-sigmoid sinus translabyrinthine retrosigmoidal (posterior fossa) transtentorial
Position: Supine

2.101a A sagittal MR image shows a large posterior fossa tumor originating from the clivus and distorting the brain stem.

2.101b A coronal section demonstrates the tumor extending toward the left.

2.101c A more posterior coronal MR image shows the tumor extending through the foramen magnum.

2.101d An anteroposterior selective internal carotid artery angiogram, showing extensive tumor stain.

2.101e A lateral selective internal carotid artery arteriogram also shows the tumor stain, which is partially obscured by the petrous ridge.
2.101f  The patient's head is turned completely horizontal, and the ipsilateral shoulder is elevated.

2.101g  The incision is seen from above, from the surgeon's view.

2.101h  The scalp pedicle is retracted interiorly. The translabyrinthine petrosectomy and craniotomy are shown. The bone flap is still in place. Notice that the scalp is retracted by scalp hooks, which are then attached to the Leyla bar to provide retraction in any direction desired.
2.101i The petrosectomy has been completed, and the facial nerve has been exposed, but left within its osseous canal. This permits an extensive translabyrinthine petrosectomy with sacrifice of the inner ear, yet protects the seventh cranial nerve with bone. This prevents the temporary facial paresis that always occurs when the seventh cranial nerve is completely drilled out of its bony canal and transposed. The exposure, although not as extensive as when the bony canal is removed from the facial nerve (transcochlear), is adequate in most cases.

2.101j The temporal lobe and cerebellum have been exposed. The sigmoid sinus has been bisected, and the dura has been cut toward the petrosal sinus.
2.101k Except for a small remnant, the tentorium has been incised to expose the arachnoid over the ambient cistern.

2.101l After the tentorium has been completely incised, the seventh cranial nerve is visualized. The fifth cranial nerve is distorted by the tumor.

2.101m A laser and microdissection were used to free the tumor entirely from the clivus. The basilar artery and the charred clivus are visible. Petrosectomy and incising the tentorium provide the advantage of allowing tumor resection from many angles, thereby making dissection between the cranial nerves considerably easier and safer.
After removing the tumor that extended into the cervical canal, the cisterna magna is visible. A loop of the posterior inferior cerebellar artery is visible, and the entire cervicomedullary junction can be appreciated. The eleventh cranial nerve, which was distorted by tumor, is now completely free.

A slightly different view, below the brain stem, is shown. The basilar artery and both vertebral arteries can be appreciated. The twelfth cranial nerve courses into the hypoglossal canal.

A view toward the middle portion of the basilar artery shows the seventh cranial nerve superficially, the ipsilateral sixth cranial nerve slightly deeper, and the exposed clivus where the tumor was attached.
By angling the microscope and lifting the basilar artery slightly, the contralateral sixth cranial nerve can be visualized.

A postoperative CT scan verifies tumor removal and demonstrates the fat placed in the petrous cavity.
Case 12
Diagnosis: Recurrent neurinoma of the trigeminal nerve
Approach: Right supratentorial and infratentorial transcochlear
Position: Supine

2.102a  A CT scan shows a large tumor in the posterior fossa, extending into Meckel's cave.

2.102b  A higher section demonstrates the portion of the tumor within the middle fossa.

2.102c  An external carotid arteriogram shows the tumor blush. A significant portion of the tumor extends along the clivus.

2.102d  The tumor blush diminishes after embolization.
2.102e After an extensive transcocchlear petrosectomy, the craniotomy exposes the temporal and posterior fossae. An earlier dural incision was higher, and a new incision has been made toward the base of the temporal lobe.

2.102f A close-up of the petrosectomy demonstrates complete removal of the petrous bone and inner ear. The petrous course of the internal carotid artery, covered with a rim of bone, is visible. The seventh cranial nerve has been drilled out of its entire canal and transposed. Tumor was encountered around the internal carotid artery.

2.102g The sigmoid sinus is clipped and is being transected with scissors to open the posterior fossa dura toward the superior petrosal sinus.
2.102h The dura along the base of the temporal lobe is also being opened toward the superior petrosal sinus.

2.102i The seventh cranial nerve in its extradural course, showing its relationship to the internal carotid artery.
2.102j With retractors on the temporal lobe and the cerebellum, the large tumor is readily identified. The fourth cranial nerve is seen as it courses around the brain stem. Notice the complete absence of the petrous ridge provided by the complete transcochlear approach, compared to the previous cases, in which the retrolabyrinthine or translabyrinthine approach was used.

2.102k There is evidence of previous surgery, with extensive adhesions along the brain stem. The portion of the tumor hanging into the posterior fossa is readily removed.

2.102l Residual tumor remains only within Meckel's cave. The brain stem has been decompressed.
2.102m  Meckel's cave has been opened, and the entire tumor contents have been removed. The fourth cranial nerve is visible as it courses from the brain stem to the tentorium towards the cavernous sinus. The third cranial nerve is visible arising between the posterior cerebral and superior cerebellar arteries. The posterior communicating artery, as it branches from the internal carotid artery, can also be seen. The basilar artery and opposite cerebral and posterior communicating arteries are clearly visible.

2.102n  An overview demonstrates the empty Meckel's cave and the vascular structures, including the basilar artery and its bifurcation.

2.102o  Higher magnification and a upward angle shows the hypothalamus as it forms the pituitary stalk.
Higher magnification demonstrates the pituitary stalk, the third and fourth cranial nerves, and the basilar artery bifurcation.

Again, the hypothalamus is seen at a higher magnification converging toward the pituitary stalk.

The patient's profile several days after surgery.

A frontal view of the patient. She had no extraocular palsy. Her obvious facial weakness was anticipated because of the extradural removal of the osseous roof of the seventh cranial nerve. With this complete petrosectomy, it was not possible to preserve hearing.
Case 13
Diagnosis: Petroclival meningioma
Approach: Right combined supratentorial and infratentorial transcochlear subtemporal trans-petrosal sinus trans-sigmoid sinus transtentorial posterior fossa
Position: Supine

2.103a A coronal MR image shows a large petroclival meningioma.
2.103b A posterior coronal MR image demonstrates brain stem distortion by the petroclival meningioma.

2.103c A sagittal MR image shows the petrous portion of the petroclival meningioma.
2.103d A common carotid angiogram demonstrates the tumor blush.
2.103e The entire course of the transposed seventh cranial nerve is visible after a transcochlear petrosectomy. The jugular bulb, sigmoid sinus, and superior petrosal sinus can be appreciated. The additional petrous bone resection gained by the transcochlear approach can be appreciated in comparison with the retrolabyrinthine approach (Figs. 2.93g, 2.94i).

2.103f The craniotomy crosses the transverse sinus.

2.103g The sigmoid sinus is tested with distal temporary occlusion to assure that venous outflow is unobstructed. A previous angiogram verified bilateral transverse sinus drainage from the sagittal sinus.
2.103h The temporal lobe has been gently retracted to provide an overview of the operative field.

2.103i The exposure after the tentorium has been resected. The four clips are placed at each end of the sigmoid and superior petrosal sinuses.

2.103j After the tumor has been resected, the third, fourth, fifth, and seventh and eighth cranial nerves can be seen coursing between the skull base and the brain stem. The flatness of the approach to the brain stem and the clivus offered by the transcochlear exposure can be seen.
Looking more posteriorly demonstrates the fifth, sixth, seventh and eighth, and the ninth, tenth, and eleventh cranial nerves in front of the basilar artery.

Looking even further posteriorly, the lower cranial nerves can be visualized.

After the dura has been reapproximated, fat is placed in the cavity created by drilling the petrous bone.
2.103n  A lateral skull film demonstrates the clips on the sigmoid and petrosal sinuses, as well as the outline of the craniotomy.

2.103o  A postoperative CT scan demonstrates that the tumor has been removed.

2.103p  A postoperative CT scan adjusted for imaging bone allows good visualization of the petrous bone resection.
Tumors of the Posterior Skull Base (Posterior Cranial Fossa) and Craniocervical Junction

Microanatomy

2.104 A transverse section through the foramen magnum.
2.105 A transverse section through the atlas demonstrates the relationship between the odontoïd process (dens of axis), transverse ligament, atlas, dura and spinal cord (viewed from above).
A sagittal midline section through the cranio cervical junction and the brain stem. Note the relationship of the odontoid to the cervicomedullary junction.
2.107 A transverse section through the lateral aspect of the cranio cervical junction demonstrates the odontoid, the process of the axis, brain stem, and cervical nerve roots.

2.108 A sagittal section through the brain stem and clivus exposes the entire clival region and provides a medial view of the cerebellopontine angle. The pons is retracted dorsally.
2.109 A dorsal view of the cerebellum, vermis, tonsils, brain stem, and fourth ventricle.

2.110 A dorsal view of the cerebellum and spinal cord, with the vertebral arteries dissected extradurally.
2.111 A dorsolateral view of the posterior inferior cerebellar artery and lower cranial nerves.

2.112 A dorsolateral view of the vertebral artery, with the extradural loop of the vertebral artery dissected free.
2.113 The intradural vertebral artery and loop of the posterior inferior cerebellar artery are visible here, seen from behind.
2.114 After the brain stem has been resected, the course of the vertebral and basilar arteries can be seen in relation to the exits of the cranial nerves. The entire clivus is visible.
2.115 A lateral view of the clivus demonstrates the course of the cranial nerves, from the brain stem to their respective foramina.

2.116 A lateral view of the lower cranial nerves and their relationship to the intradural and extradural portions of the vertebral artery.
2.117 Extradural exposure of the sigmoid sinus, vertebral artery, and internal jugular vein.

2.118 Lateral view of the foramen magnum from behind, with dissection of the vertebral artery and the surrounding vertebral venous plexus. The cerebellum is displaced to the left.
2.119 Further dissection shows the extradural and intradural portions of the vertebral artery.

2.120 Lateral view of the opened jugular foramen shows the relationship between the cranial nerves and arteries.
2.121 Dissection of the first and second cervical nerves (seen from the front).

2.122 The vertebral arteries and basilar artery and its branches from basal.
2.123 Craniocervical junction, basal view. The origin of the posterior inferior cerebellar artery from the vertebral arteries at the foramen magnum is shown. This anatomy is particularly relevant for the transoral transclival approach.

2.124 A basal view of the vertebrobasilar junction and its relationship to the brain stem.
2.125 The circle of Willis viewed from above, with its relationship to the cranial nerves and skull base.
2.126 The brain stem has been retracted, stretching the various cranial nerves and exposing the vertebral arteries and basilar artery (seen from rostral).
Tumors of the Foramen Magnum and Lower Clivus

Approaches to the Posterior Skull Base (Posterior Cranial Fossa)

Lateral Intradural Approaches

- Combined Infratentorial and Supratentorial
  Retrolabyrinthic presigmoidal supra-transverse sinus subtemporal transpetrosal transtentorial
  Retrolabyrinthic presigmoidal and retrosigmoidal supra-transverse sinus and infra-transverse sinus subtemporal transpetrosal transtentorial
  Retrolabyrinthic retrosigmoidal transsigmoidal subtemporal transpetrosal transtentorial
  Retrolabyrinthic presigmoidal (retrosigmoidal infra-transverse sinus) subtemporal transpetrosal transtentorial. Due to the location of the inferior anastomotic vein of Labbé, the subtemporal dural incisions is not carried out posteriorly above the transverse sinus
  Transmastoid extended translabyrinthine
  Transmastoid extended transcochlear
- Combined infratentorial and supratentorial and extended transcochlear and far lateral suboccipital
- Combined infratentorial and supratentorial and far lateral transcondylar ("combined-combined")

Position and Approach

Far Lateral Posterior Fossa Approach Position

2.127 A semi-sitting position, with the head turned for the far lateral suboccipital approach.

2.128 A modified park-bench position, for the far lateral suboccipital approach.

2.129 A modified park-bench position, with the ipsilateral shoulder taped down and the patient taped securely to the operating table. This position allows use of the full range of the operating table's lateral rotation.
Lateral Suboccipital or Posterior Fossa Approach

2.130a The scalp incision for the far lateral suboccipital approach.

2.130b The underlying cervical musculature can be appreciated in this schematic drawing.

2.130c The proposed craniotomy overlies the lower border of the transverse sinus and courses along the sigmoid sinus.
Dorsolateral Posterior Fossa Approach

2.131a An alternative proposed skin incision for the far lateral suboccipital (suboccipitocervical) approach.

2.131b The underlying cervical musculature.

2.131c The craniotomy and a C1-C2 laminectomy (including partial resection of the occipital and C1 condyles).

2.131d Extension of suboccipital bone removal.
Technique
The patient is placed in a modified park-bench position. The head is rotated downward (away from the lesion), positioning the inferior clivus perpendicular to the floor, and maximally opening the posterior cervical-to-suboccipital angle. An inverted hockey-stick incision starts at the mastoid prominence and proceeds under the superior nuchal line to the midline (Figs. 2.132a, 2.133a). The muscle mass is freed from along the nuchal line, leaving a one-centimeter edge of nuchal fascia and muscle for closure (Fig. 2.132b). During closure, the neck is extended, to help reapproximate the cervical musculature to the nuchal fascia. The incision continues caudally in the midline down to the C6 spinous process. The paraspinosus muscles are split until the spinous processes of C1 and C2 are exposed. The muscle flap is dissected from the suboccipital bone and the laminae of C1 and C2. The muscle flap is retracted inferiorly and laterally with fish hooks attached to a Leyla bar. The midline flap can be retracted contralaterally with fish hooks from a second Leyla bar.

The lateral mass of C1 and the vertebral artery from C1 to its dural entry are exposed. A C1 laminotomy is performed with a Midas Rex drill. The contralateral lamina is cut across the midline, and the ipsilateral lamina is cut at the sulcus for the vertebral artery (Figs. 2.132c, 2.133b). The lamina is saved and replaced at closure.
A suboccipital craniotomy performed with the same drill is begun at the foramen magnum in young patients, or with a small keyhole in older patients. The craniotomy extends contralaterally across the midline, and ipsilaterally as far laterally as possible. The craniotomy proceeds back to the foramen magnum, and exits medially to the entry of the vertebral artery. The ipsilateral rim of the foramen magnum is removed to the lateral mass of C1 and the occipital condyle (Figs. 2.132c, 2.133c). The important aspect of this modified approach is the removal of the posterior condyle and the lateral mass of C1. With the high-speed drill, the posterior occipital condyle and the superior lateral mass and facet of C1 are removed. Drilling away the inner portion of the condyle until only a thin shell of cortical bone remains will protect the surrounding structures in this restricted space. The shell is then removed with microcurettes. Since the hypoglossal canal is situated in the anterior medial third of the occipital condyle, it is never threatened by removal of the posterior lateral third of the condyle. The extradural vertebral artery should be protected with a small dissector while the condyle is drilled. The bone is removed to create a one-centimeter gap between the dural entry of the vertebral artery and the resected occipital condyle. The dura is opened in a curvilinear fashion, hinged laterally, and tented up with sutures. The extensive removal of the condyle and lateral mass of C1 eliminates the last osseous shelf obstructing direct vision to the clivus and anterior brain stem, and allows lateral movement of the extradural vertebral artery when the dura is tented. The extensive bone removal, and the ability to move the artery, combined with lateral and inferior retraction of the muscle mass with fish hooks, significantly enhance the direct exposure of the lower clivus, the anterior foramen magnum, anterior brain stem, and upper cervical spinal cord. Minimal elevation of the cerebellar tonsil and hemisphere also improves the exposure.
Clinical Material

2.134 The localization of meningiomas of the foramen magnum and lower clivus.

Case 1
Diagnosis: Meningioma of the right lateral lower clivus and the anterior lateral circumference of the foramen magnum
Approach: Right far lateral suboccipital (posterior fossa)
Position: Semi-sitting

2.135a An axial CT scan, showing a large meningioma extending from the foramen magnum into the lower cerebellopontine angle, and anteriorly into the premedullary space.

2.135 b A postoperative CT scan with mid-sagittal reconstruction. The tumor has been removed, and the foramen magnum is completely decompressed.
2.135c The lateral aspect of the foramen magnum has been exposed. Most superiorly is the dura of the posterior fossa as it passes into the foramen magnum. Underneath is the floor of the posterior fossa and the edge of the foramen magnum. Below the bone is the vertebral artery as it enters the dura. Inferiorly, the C1 and C2 nerve roots are exposed.

2.135d With the dura of the posterior fossa elevated, the airdrill is used to resect the foramen magnum and the floor of the posterior fossa.

2.135e The foramen magnum has been resected to the jugular tubercle. Adjacent to the retractor, the end of the sigmoid sinus (as it courses down to become the internal jugular vein) is seen. On the left side of the foramen magnum is the junction between the spinal and the posterior fossa dura.
2.135f The posterior fossa dura has now been opened, exposing the meningioma and the inferior portion of the cerebellar hemisphere.

2.135g Further retraction and exposure after the arachnoid has been opened reveals the eleventh cranial nerve as it courses over the tumor with multiple rootlets from the medulla. At the tip of the meningioma, the twelfth nerve is visible.

2.135h With further mobilization, the tumor can be lifted off the vertebral artery. The eleventh nerve, coursing over the tumor, and the twelfth nerve, coursing over the vertebral artery, are visible. Notice the accessibility along the floor of the foramen magnum following the extensive bone resection, without the need to rotate the brain stem.
Following resection of approximately half of the tumor, the eleventh nerve is now considerably relaxed, and the twelfth nerve is no longer tense. The bifurcation of the posterior inferior cerebellar artery and the vertebral artery is clearly visible.

Following complete tumor excision, the opposite vertebral artery and the origin of the posterior inferior cerebellar artery are visible. The entire clivus at the level of the foramen magnum is exposed.

By moving the microscope more toward the right, the right vertebral and posterior inferior cerebellar artery are visualized. The eleventh nerve has been retracted superiorly, demonstrating the tumor-free clivus.
Case 2
Diagnosis: Meningioma of the right lateral lower clivus, the anterior lateral foramen magnum, and the upper cervical canal (craniocervical junction)
Approach: Right far lateral suboccipital and upper cervical
Position: Sitting

2.136a An axial CT scan shows a large meningioma extending to the right anteriorly and laterally into the cerebellopontine angle, and anteriorly between the brain stem and clivus.

2.136b A CT scan with parasagittal reconstruction shows the relation of the tumor to the clivus and atlas, the brain stem, and the upper cervical cord. There is marked compression of the neural structures in the region of the craniocervical junction.

2.136c With the patient placed in a semi-sitting position, a far lateral suboccipital craniotomy and removal of the C1 to C3 laminae on the right side is carried out. The craniocervical meningioma is exposed. The suction tip points to the supraforaminal part of the tumor.
2.136d The tumor is mobilized and retracted from the brain stem and cervical cord.

2.136e The bulk of the tumor is removed. A small part of the tumor is adherent to the sensory roots of C1.

2.136f After section of the C1 root, the tumor can be totally removed.
2.137a A sagittal MR image shows a large meningioma of the lower clivus and anterior foramen magnum.

2.137b A coronal MR image demonstrates the distortion of the brain stem.

2.137c Another coronal section indicates how far the meningioma extends posteriorly.

2.137d The foramen magnum is opened, and the tonsil and brain stem are exposed through a right far lateral suboccipital approach. The patient is in the semi-sitting position.

Case 3
Diagnosis: Meningioma of the lower clivus and the anterior foramen magnum
Approach: Right far lateral suboccipital
Position: Semi-sitting
2.137e Elevating the cerebellar tonsil allows the meningioma, draped by the rootlets of the eleventh cranial nerve, to be visualized.

2.137f After the tumor has been extirpated, the cranial nerves are visible; the verteobasilar junction is in the background.

2.137g At high magnification, the verteobasilar junction is visible after the tumor has been extirpated.
Case 4
Diagnosis: Meningioma of the lower clivus and the anterior foramen magnum
Approach: Right far lateral suboccipital
Position: Modified park-bench

2.138a  A MR image demonstrates extensive compression of the brain stem from a large clival meningioma.

2.138b  A CT scan demonstrates the broad base of the meningioma at the foramen magnum.

2.138c  A sagittal MR image shows a portion of the tumor as it extends from the lower half of the clivus and bridges the foramen magnum.

2.138d  A selective vertebral artery injection demonstrates marked compression of the vertebrobasilar system.
2.138e The patient is placed in a modified park-bench position. The patient is securely taped to the operating table, which can then be tilted safely to its limits. This allows the surgeon to maintain a comfortable operating position while approaching the tumor from various angles.

2.138f Viewed from above, the incision from the midcervical region crosses the inion and extends down to the ipsilateral mastoid tip.

2.138g The C1 and C2 laminae have been removed on the right side. The dura of the posterior fossa craniotomy is exposed. More bone is drilled away along the rim of the foramen until the medial third of the occipital condyle and the C1 condyle are removed. This maneuver significantly exposes the dura beneath the intradural entrance of the vertebral artery.
After the dura has been opened toward the right, the cerebellar hemisphere, herniated tonsil, and brain stem can be visualized beneath the intact arachnoid.

After the arachnoid has been opened and tacked to the dura, the herniated tonsil is clearly visible. The medulla is markedly distorted and elevated by the tumor.

Elevating the cerebellar tonsil slightly enables the large tumor to be appreciated as it bridges the clivus and the cervical canal. Notice the flat approach along the floor of the clivus.
2.138k After the tumor has been almost completely removed, the cranial nerves and basilar artery are visible.

2.138l A view along the clivus demonstrates the junction of the vertebral and the basilar arteries, the bilateral exit of the sixth cranial nerves from the brain stem, and further laterally, the ninth cranial nerve. The eleventh cranial nerve courses out of focus above the vertebral artery, which was dissected free from the tumor.

2.138m A view from below shows the clivus after tumor removal.

2.138n A postoperative MR image demonstrates the complete removal of the tumor.

2.138o A sagittal MR image demonstrates the brain stem resuming a normal position.
Case 5
Diagnosis: Meningioma of the right lateral lower clivus and the anterior lateral circumference of the foramen magnum
Approach: Right far lateral suboccipital
Position: Semi-sitting

2.139a A sagittal MR image reveals a large meningioma in the lower clivus and the anterior foramen magnum.

2.139b After a right far lateral inferior sub-occipital approach, the dura of the posterior fossa, foramen magnum, and spine is visible.

2.139c After the tumor capsule is opened, the tumor proper is clearly visible.
2.139d The tumor capsule is opened.
CUSA = cavitron ultrasonic aspirator

2.139e The tumor is debulked, leaving the capsule behind.

2.139f The capsule is mobilized and retracted from the brain stem.
2.139g After the tumor has been entirely removed, the anterior medullary spinal junction is visible. The tumor bed is filled with bloody cerebrospinal fluid.

2.139h A small remnant of tumor capsule is visible deep in the tumor bed, attached to the opposite vertebral artery.

2.139i After the final tumor capsule has been removed, the contralateral vertebral artery is visible. The eleventh cranial nerve is distorted and pushed up superiorly.

2.139j CT and CT reconstruction scans show the absence of meningioma along the posterior clinoid, and the cerebrospinal fluid space created by the tumor removal.
Case 6
Diagnosis: Clival schwannoma extending into the jugular foramen
Approach: Right combined supratentorial and infratentorial, and extended transcochlear and far lateral suboccipital
Position: Modified park-bench

2.140a An MR image of a large jugular foramen neurinoma extending up to the clivus, into the middle fossa, and down into the cranio cervical junction.

2.140b A sagittal MR image demonstrates part of the tumor.

2.140c The patient is placed in a modified park-bench position, with the ipsilateral shoulder retracted down. The skin incision extends anteriorly from the zygomatic arch to the occipital protuberance, and down the midline to C5 or C6.

2.140d Seen from an anterior view, the patient is firmly taped to the operating table so that it can be rotated to either side.
The scalp is pulled interiorly. The external auditory meatus is sectioned, and the zygomatic arch and tip of the auditory meatus are exposed.

2.140f After a transcochlear petrosal resection in this patient who had previously lost hearing, a bone flap, which begins at the foramen magnum, is raised.
2.140g The elevated bone flap encompasses the posterior and middle fossae and exposes the transverse and sigmoid sinuses.

2.140h The foramen magnum is drilled toward the skull base with a Midas Rex drill.

2.140i The occipital and C1 condyle are drilled out, and the condylar vein is controlled with bone wax.
2.140j The thin osseous remnant of the condyle is removed with a small rongeur.

2.140k The removed lamina of C1 will be replaced at the end of the procedure.

2.140l Overview of the dura of the spine, foramen magnum, and posterior fossa.
2.140m The upper portion of the tumor is apparent through the combined supratentorial and infratentorial approach.

2.140n The inferior extent of the tumor is apparent through the far lateral suboccipital approach.

2.140o After tumor has been removed extensively, the floor of the skull base and the cranial nerves are visible in this overview.
2.140p The tumor capsule is mobilized.

2.140q After the tumor has been removed, both vertebral arteries and the junction to the basilar artery are visible. The two contributions from the vertebral arteries that form the anterior spinal artery are also visible.

2.140r The vertebral artery and the lower cranial nerves are visible. The twelfth cranial nerve and its entrance into the hypoglossal canal are visible.
Two postoperative MR images demonstrate tumor removal and the free fat graft that has been placed in the petrous bone resection. This combination of the supratentorial and infratentorial approach is particularly useful for large lesions that extend from the middle fossa to below the foramen magnum.

The bone has been replaced and sutured securely.
Case 7

Diagnosis: Neurenteric cyst between clivus and brain stem
Approach: Combined supratentorial and infratentorial, combined with far lateral posterior fossa transcondylar
Position: Modified park-bench

2.141a  Sagittal, b coronal, and c axial magnetic resonance images of an neurenteric cyst located in front of the brain stem.
2.141d A modified park-bench position allows a combined supratentorial and infratentorial, combined with far lateral posterior fossa transcondylar approach:

2.141e The incision extends from the midline of the posterior cervical region over the ear to the insertion of the zygomatic arch.

2.141f After a retrolabyrinthine petrous bone resection, a craniotomy is performed, exposing the dura of the spine and the posterior and middle fossae.
Case 7
Diagnosis: Neurenteric cyst between clivus and brain stem
Approach: Combined supratentorial and infratentorial, combined with far lateral posterior fossa transcondylar
Position: Modified park-bench

2.141g The dura is opened, exposing the markedly displaced spinal cord and cerebellum, and the neurenteric cyst.

2.141h Higher magnification shows the distorted spinal cord, the eleventh cranial nerve, the vertebral artery, and its arterial branches.

2.141i After the enteric cyst has been resected, the sixth cranial nerve is visible as it exits the brain stem and enters Dorello's canal.
2.141j A view at lower magnification demonstrates the arterial and neural structures along the brain stem and clivus.

2.141k Looking up underneath the brain stem, the basilar artery with its branches is visualized. This unusual view of the basilar artery is possible because the cyst had separated the brain stem from the basilar artery. We can readily visualize the anterior inferior cerebellar arteries bilaterally, and the perforating brain stem branches.

2.141l After the neurenteric cyst has been resected completely, an overall view shows the neural and vascular structures.
2.141m A sagittal postoperative MR image demonstrates removal of the neurenteric cyst.

2.141n An MR bone window demonstrates the resection of the medial portion of the condyle to allow this very far lateral exposure of the foramen magnum. Notice also the replaced bone flap.

Case 7
Diagnosis: Neurenteric cyst between clivus and brain stem
Approach: Combined supratentorial and infratentorial, combined with far lateral posterior fossa transcondylar
Position: Modified park-bench
Tumors of the Craniocervical Junction

2.142 The craniocervical junction. The arrows indicate the extension of tumors in the craniocervical and cervico-cranial directions.

Midline Suboccipitospinal Approach

2.143a The scalp incision overlies the posterior fossa and cervical spine to approach this group of lesions. The incision needs to be modified depending on the lateral extent of the lesion. Although this picture is represented with the patient in the sitting position, a prone position is equally suitable.

2.143b The dural opening.

2.143c A dorsal view into the craniocervical junction and the upper cervical spinal canal (laminae C1 to C3 have been removed).
Clinical Material
Case 1
Diagnosis: Meningioma of the craniocervical junction, left dorsolateral
Approach: Midline suboccipital-spinal
Position: Sitting

2.144a Axial CT images of the skull base and vertebrae C1 and C2. A dorsolateral meningioma of the craniocervical junction is seen bulging into the foramen magnum and spinal canal.

2.144b Using a posterolateral approach to the foramen magnum, the medulla and the meningioma are visualized.

2.144c Following excision of the meningioma, the rim of the foramen magnum is visualized. The caudal loop of the posterior inferior cerebellar artery is visible at the top of the picture.
Case 2

Diagnosis: Hemangioblastoma of the medulla oblongata and the upper cervical cord

Approach: Midline suboccipital and C1, C2 spinal

Position: Sitting

2.145a An MR image reveals a large lesion consistent with the presence of a cyst in the cervicomedullary junction.

2.145b The open dura reveals a glistening arachnoid, through a midline suboccipital approach, and a laminectomy of C1 and C2. The tumor is visible towards the right.

2.145c Opening the arachnoid membrane and tacking it to the dura reveals the tonsils, dilated medulla, and cervical cord, as well as the blood supply to the hemangioblastoma.
The hemangioblastoma is carefully removed from its vascular blood supply. Because the surgical plane at the edge of the tumor is maintained, no neural tissue is sacrificed. When the tumor is elevated, the large tumor cyst becomes visible. After the tumor has been completely removed, the medulla and cervical cord collapse noticeably.
Case 3
Diagnosis: Exophytic dorsal focal ependymoma of the medulla oblongata and upper cervical cord
Approach: Midline suboccipital and C1, C2 cervical
Position: Sitting

The illustrations in this and the remaining cases in this section are oriented in relation to the semi-sitting position, although a number of these cases were actually operated on in the prone position.

2.146a A sagittal MR image shows an exophytic ependymoma at the craniocervical junction.

2.146b The tumor is exposed through a midline suboccipital approach.

2.146c The tumor is mobilized.
2.146d The tumor is freed from its origin in the floor of the fourth ventricle.

2.146e The tumor bed after removal of the tumor.
Case 4
Diagnosis: Intramedullary, partially cystic, ependymoma of the medulla oblongata and upper cervical cord
Approach: Midline suboccipital and C1, C2 cervical
Position: Sitting

2.147a A coronal MR image through the craniocervical junction shows a multicystic ependymoma.

2.147b A more anterior coronal section through the cervicomedullary junction demonstrates the cystic ependymoma located within medulla oblongata and cervical cord.

2.147c The dorsal cervicomedullary junction is exposed through a midline suboccipital exposure and C1-C2 laminectomy.

2.147d Under high magnification, the median raphe, distorted by the tumor below, can be identified.
2.147f After the ependymoma has been removed from there, the tonsil is retracted higher to expose more tumor. The loop of the posterior inferior cerebellar artery is seen laterally.

2.147g The tumor bed within the upper cervical cord after the ependymoma has been evacuated.

2.147e The raphe is opened to expose the tumor.
Case 5

Diagnosis: Solid exophytic ependymoma of the medulla oblongata, overlapping the dorsal cervical cord
Approach: Midline suboccipital and C1-C3 laminectomy
Position: Sitting

2.148a A sagittal MR image reveals a large, dorsally sited ependymoma with a significant exophytic component.

2.148b The exophytic ependymoma is exposed through a midline suboccipital craniotomy and C1-C3 laminectomy.

2.148c The exophytic portion of the tumor is mobilized above the vertebral artery.

2.148d The tumor bed is visible after complete excision of the ependymoma.
Case 6
Diagnosis: Dermoid cyst (cholesteatoma) reaching from the left cerebellopontine angle down to the upper cervical canal
Approach: Mediolateral suboccipital and C1, C2 laminectomy
Position: Sitting

2.149a, b Consecutive coronal MR images demonstrate a large epidermoid tumor over the craniocervical junction, extending from the spinal region to the posterior fossa laterally.

2.149c A transverse MR image demonstrates the extent of the epidermoid invasion into the cerebellopontine angle.
2.149d A mediolateral suboccipital craniotomy was used in conjunction with a C1-C2 cervical laminectomy, with the patient in the sitting position. The dura has been opened to expose the classic appearance of the epidermoid tumor.

2.149e The tumor is visible along the eleventh cranial nerve.

2.149f After most of the tumor has been removed, the fifth to eleventh cranial nerves are clearly visible.
3 Infratentorial Tumors
3.1 Midsagittal section through the brain stem and vermis.
3.2a Cerebellum and medulla oblongata exposed from the dorsal aspect.
3.2b The cerebellar vermis and medulla oblongata, viewed from a dorsocaudal aspect.
3.2c Median and lateral apertures of the fourth ventricle. The right half of the cerebellum and the vermis have been partially removed (seen from behind).
3.3 Dorsal view of the tentorium, with the temporal lobe above and the cerebellum below.
3.4 Posterior fossa, viewed from above.
3.5 Dorsal view of the right petrous bone, with the dura resected and the bone drilled away to expose a high jugular bulb.
3.6 Right cerebellar hemisphere, from dorsolateral.
3.7 Posterior fossa with dura still intact, demonstrating the transverse and sigmoid sinuses. The dura from the supratentorial compartments has been resected.
3.8 A midsagittal section, cutting through the straight sinus and vein of Galen. The medial side of the occipital lobe is visible supratentorially with a section through the brain stem. The cerebellum has been removed. (A very rare course of the basal vein).
3.9 The right cerebellar hemisphere is viewed from the side.
The dentate nucleus has been exposed in a sagittal section of the vermis.
3.11 A side view of the cerebellum and temporal lobe after the tentorium has been removed.
3.12 Brain stem and fourth ventricle from above, with the cerebellum resected.
3.13a, b The cerebellopontine angle, seen from the right and from above (with a large posterior meningeal artery from the ascending pharyngeal artery).
Position and Approach to the Posterior Fossa

Sitting and Semi-Sitting Position

3.14 The sitting position, with head moderately flexed.

3.15 The neck is flexed maximally in this semi-sitting position, requiring attention to prevent compromise of the endotracheal tube.

3.16 The amount of flexion of the head required depends on the relationship of the tumor to the straight sinus. The straight sinus (blue line) is indicated to illustrate the amount of flexion required so that it is parallel to the floor.
Prone and Semi-Prone Position

3.17–19 These three illustrations show the approach using the prone or semi-prone positions. The amount of head flexion and rotation depends on the area within the posterior fossa that requires exposure.

Park-Bench Position

3.20 This position allows good exposure of the cerebellopontine angle or midline structures. It is important to pull the ipsilateral shoulder interiorly and to extend the head in the opposite direction, rotating the head 15 to 30 degrees and flexing it maximally. This allows clear access above and behind the ipsilateral shoulder.

Lateral Position

3.21 This position is only useful for a cerebellar hemisphere lesion located laterally and near the surface. It is not appropriate for the cerebellopontine exposure.
Approaches to the Posterior Skull Base (Posterior Cranial Fossa)

Posterior (dorsal) intradural approaches
- Midline or medial
- Paramedian or mediolateral
- Combined medial suboccipital and upper cervical (to cranio cervical junction)

Lateral intradural approaches
- Dorsolateral
- Far Lateral
- Retromastoid retrosigmoid
- Transmastoid translabyrinthine (transcochlear)

3.22 Common approaches to the posterior cranial fossa.
- The midline or medial approach (yellow and orange); the orange color represents the supracerebellar infratentorial approach.
- The mediolateral approach (green).
- The unilateral paramedian approach, usually combined with the mediolateral approach.
- The lateral retromastoid approach (blue).
3.23 A skin incision starting several centimeters above the inion and extending down to C2 may be used.

3.24 The nuchal ligament and midline are identified and then cut in a modified T-shaped incision, allowing adequate residual nuchal ligament attached to the bone to permit complete closure of this layer at the end of the procedure. This closure is made possible by extending the flexed neck at the end of the intracranial procedure, following dural closure and prior to muscle closure.

3.25a Midline craniotomy, with removal of the arch of the atlas and a proposed dural opening.

3.25b The relationship between the craniotomy and the underlying neural structures.
3.26a Alternative opening, with the atlas kept intact. Also, the foramen magnum may or may not be resected, depending on the location of the lesion to be exposed.

3.26b This view relates the craniotomy to the underlying neural structures, with the atlas kept intact.

Views from above and from the side demonstrating how to approach the variously located lesions through a midline exposure:

3.27a, b Medial approach to tumors in and near the midline of the cerebellum.
3.28a  Medial approach to a tumor of the upper cerebellar vermis. Notice that the posterior arch of the atlas is kept intact.

3.28b  Medial approach to a tumor of the lower cerebellar vermis. The posterior arch of the atlas has been resected.

3.28c  Medial approach to tumors of the cerebellar vermis. Note the lateral displacement of the dentate nuclei.
3.29a The scalp incision for the mediolateral posterior fossa approach.

3.29b A possible dural incision.

3.29c Exposure of the cerebellum through the mediolateral posterior fossa craniotomy.
Unilateral Paramedian Posterior Fossa Approach

3.30a The scalp incision used with the unilateral paramedian posterior fossa approach.

3.30b The proposed dural incision.

3.30c The cerebellum exposed using the unilateral paramedian posterior fossa approach.
Lateral Approaches

3.31 The semi-sitting position, with the head rotated 30 degrees for a lateral posterior fossa approach. Alternatively, the previously described park-bench position may be used (see Fig. 2.128).

3.32a The prone position is visualized with the head rotated 30 degrees for exposure of a laterally situated cerebellar hemisphere lesion.

3.32b Another position for a convenient approach to the lateral posterior fossa is a modified park-bench position. This position allows use of the full range of the operating table’s lateral rotation.

3.33a The four possible scalp incisions that can be used with the lateral posterior fossa approach.

3.33b The incisions and dissections of the cervical musculature for the lateral approach.
Far Lateral Approaches
Far Lateral Suboccipital Approach

3.34a The scalp incision for the far lateral approach.

3.34b The proposed craniotomy overlies the junction of the transverse sinus and courses along the sigmoid sinus.

Far Lateral Suboccipitocervical Approach

3.35a Two proposed skin incisions for the far lateral suboccipital approach.

3.35b The craniotomy and C1-C2 laminectomy.
3.36 The shaded areas correspond to the bone removal for the lateral approaches to the various illustrated lesions in the cerebellar hemispheres.

3.37 Demonstration of the various directions of displacement of the dentate nucleus caused by the tumor. Of Importance is that the tumor approach does not require sectioning through the dentate nucleus.

3.38 Three proposed craniotomies and routes of exposure for variously located cerebellar mass lesions are shown.

a Midline approach to a tumor in the cerebellar hemisphere which displaces the caudate nucleus dorsally.

b Unilateral paramedian approach.

c Lateral approach.

d Retromastoid Retrosigmoidal Approach

See Figures 3.89a–c, and 3.90a–d
3.39a The cerebellar hemispheres have been exposed using a midline posterior fossa craniotomy. The tumor can be seen emerging through the foramen of Magendie.

3.39b The cerebellar hemispheres are slightly separated, providing a better view of the extent of the tumor.

3.39c The medulloblastoma has been removed, providing a view of the floor of the fourth ventricle.

Tumors of the Fourth Ventricle

Clinical Material

Case 1

Diagnosis: Medulloblastoma of the fourth ventricle
Approach: Midline
Case 2
Diagnosis: Medulloblastoma of the fourth ventricle
Approach: Midline

3.40a The tumor is seen emerging through the foramen of Magendie, filling the cisterna magna and extending below the foramen magnum.

3.40b Following elevation of the tumor, the floor of the fourth ventricle is exposed.

3.40c Following resection of the tumor, the dilated aqueduct of Sylvius with the posterior commissure is visible.
Case 3
Diagnosis: Medulloblastoma of the fourth ventricle
Approach: Midline suboccipital

3.41a A CT scan demonstrates a typical enhancing medulloblastoma.

3.41b Using a midline posterior fossa approach, the cerebellar hemisphere, vermis, and brain stem are visualized. A bulging tumor mass is readily identified.
3.41c The tumor cyst has been opened, and most of the tumor has been evacuated. Notice the markedly distorted vermis.

3.41d After radical tumor removal, the tumor cavity and residual vermis are visualized.

3.41e A postoperative CT scan with enhancement demonstrates a large tumor cavity, with no evidence of residual tumor.
Case 4  
Diagnosis: Ependymoma of the fourth ventricle  
Approach: Midline

3.42a The midline approach, including resection of the arch of the axis, provides a view of the medulla oblongata, tonsils and tumor extruding through the foramen of Magendie.

3.42b Slight retraction of the tumor reveals the extensive vascularization of the tumor base.

3.42c The attachment of the tumor to the floor of the fourth ventricle is visible. Superiorly the aqueduct of Sylvius is seen.
Case 5
Diagnosis: Ependymoma of the fourth ventricle with extension through the foramen of Luschka
Approach: Midline

3.43a A large midline exposure of the posterior fossa reveals an ependymoma protruding between the cerebellar hemispheres.

3.43b By elevating the partially resected tumor, its attachment to the floor of the fourth ventricle is evident. Laterally, the tumor can be seen extending around the cerebellum emerging from the cerebellopontine angle. This tumor is the portion that protruded through the foramen of Luschka.

3.43c Superiorly, the foramen of Luschka with the choroid plexus is visible through which the tumor previously protruded. The tumor has been excised, exposing the side of the brain stem and the posterior inferior cerebellar artery draped with the hypoglossal nerve.
Case 6
Diagnosis: Medulloblastoma of the fourth ventricle, filling the cisterna magna and overlapping the upper cervical cord
Approach: Midline suboccipital

3.44a Sagittal MR image demonstrates a large medulloblastoma.

3.44b Through a midline posterior fossa approach, the area of the foramen of Magendie and the upper cervical cord are exposed. With the arachnoid still intact, the tumor mass can be appreciated as it exits from the foramen of Magendie and occupies the cisterna magna covering the upper cervical cord.

3.44c In a similar view, the arachnoid is opened and tacked to the dura.
3.44d The rostral portion of the tumor has been mobilized and elevated to reveal the cervicomedullary junction below. The entrance of the foramen of Magendie is now visible.

3.44 e The tumor is allowed to fall back after cottonoids have been inserted between the floor of the fourth ventricle and the tumor.

3.44f The tumor is mobilized from the upper end of the fourth ventricle and separated from the vermis. The upper end of the fourth ventricle can be seen between the tumor and the vermis.
After the tumor has been removed and the microscope angled upward along the floor of the fourth ventricle, the enlarged aqueduct of Sylvius is visible.

An overview of the fourth ventricle after excision of the tumor.

Postoperative CT scan demonstrates the tumor excision.
Case 7
Diagnosis: Choroid plexus papilloma of the fourth ventricle
Approach: Midline

3.45a The tonsils of the cerebellar hemispheres are retracted laterally, exposing the tumor located in the fourth ventricle.

3.45b After splitting a small portion of the vermis, the entire tumor can be visualized.

3.45c The tumor has been resected, except for its attachment to the choroid plexus. The floor of the fourth ventricle, the aqueduct of Sylvius, and the posterior commissure are visualized.
3.46a A CT scan with coronal reconstruction shows a large meningioma within the fourth ventricle.

3.46b A CT scan with sagittal reconstruction depicts the location of the large meningioma within the fourth ventricle.

3.46c The tonsils, vermis, and cerebellar hemispheres can be identified through a midline suboccipital exposure, with the patient in the sitting position. The tumor bulges through the foramen of Magendie.

3.46d After the tonsils have been partially mobilized, the lateral extent of the inferior portion of the meningioma can be appreciated.

Case 8
Diagnosis: Meningioma of the fourth ventricle
Approach: Midline suboccipital
Position: Sitting
3.46e After the tumor has been debulked considerably, the upper end of the fourth ventricular meningioma is mobilized from the floor of the fourth ventricle.

3.46f After the tumor has been excised completely, the floor of the fourth ventricle and the opening of the aqueduct with the posterior commissure can be appreciated.

3.46g An overview demonstrates that the meningioma has been removed.
Case 9
Diagnosis: Teratoma of the fourth ventricle
Approach: Midline suboccipital

3.47a A sagittal MR image demonstrates a large mass in the posterior fossa that markedly distorts the brain stem and cerebellum.

3.47b A coronal image demonstrates the marked distortion of the brain stem.

3.47c A horizontal section through the posterior fossa shows the tumor occupying the entire dilated fourth ventricle.

3.47d Through a midline exposure of the posterior fossa, a large cystic mass can be appreciated as it protrudes through the foramen of Magendie.
3.47e The exposed cyst wall is shown at a higher magnification.

3.47f Opening the cyst wall reveals a highly proteinaceous fluid.

3.47g Further opening of the tumor demonstrates thick, gelatinous material and well-formed hair.
3.47h The tumor wall is separated from the vermis and cerebellar hemisphere.

3.47i A view of the floor of the fourth ventricle can be appreciated after the excision of the tumor.

3.47j An overview of the operative site is shown after a complete excision of the tumor.
3.48a A midline approach to the posterior fossa reveals a large cystic lesion emerging through the foramen of Magendie below the vermis between the two cerebellar hemispheres.

3.48b Higher magnification of foramen of Magendie below the vermis shows the cyst partially evacuated.

3.48c Following removal of the cyst, the vermis is split, and further cystic structures within the tumor are identified.
3.48d Following resection of the tumor within the vermis, the floor of the fourth ventricle begins to appear.

3.48e The floor of the fourth ventricle can be seen in its entirety following extensive removal of the vermian tumor.
Case 2
Diagnosis: Cystic cerebellar astrocytoma within the vermis
Approach: Midline

3.49a The arachnoid-covered hemispheres, tonsils, brain stem, tumor-enlarged vermis, and loop of the posterior inferior cerebellar artery are exposed.

3.49b This view is the same as that in the previous figure, after the arachnoid has been opened.

3.49c The vermis has been split and the cystic astrocytoma is exposed.
The tumor has been resected extensively, and the fourth ventricle is exposed.

All visible tumor has been resected, and the fourth ventricle is visualized through the split vermis. The tumor margin in the vermis has been covered with Surgicel.
Case 3
Diagnosis: Solid astrocytoma of the cerebellar vermis
Approach: Midline suboccipital supracerebellar

3.50 a A CT with reconstruction shows a large, globular, solid mass in the vermis.

3.50 b A coronal reconstruction illustrates the outline of the tumor and its relationship to the tentorium.

3.50 c The cerebellar hemispheres and vermis are exposed through a midline high posterior fossa approach.
3.50d When the vermis is depressed, a large solid tumor nodule is encountered.

3.50e The vermis is split to expose the well-demarcated astrocytoma.

3.50f After excision of the tumor, the tentorial notch and deep vasculature are visible.
3.50g  A postoperative sagittal MR image verifies tumor removal.

3.50h, i  A postoperative CT scan after tumor removal.
Case 4
Diagnosis: Metastatic tumor of the vermis
Approach: Midline

3.51a The midline of the posterior fossa has been exposed, revealing the markedly expanded vermis.

3.51b The vermis has been opened, revealing a typical well-circumscribed metastatic lesion.

3.51c The floor of the fourth ventricle is visualized following tumor resection.
Tumors of the Cerebellar Hemispheres

Clinical Material

Case 1
Diagnosis: Cystic juvenile cerebellar astrocytoma
Approach: Paramedian

3.52a A paramedian craniectomy over the right posterior fossa has exposed the dura, through which a cystic lesion can be seen.

3.52b The cystic astrocytoma following dural opening.

3.52c Following removal of the cyst fluid, the tumor is being resected.
3.52d The cystic astrocytoma has been resected, causing the cerebellar hemispheres to collapse, and leaving a large subdural gap between the tentorium and the cerebellar surface.
Case 2
Diagnosis: Solid astrocytoma of the cerebellar hemisphere
Approach: Paramedian

3.53a The right cerebellar hemisphere is exposed using a right paramedian craniectomy and dural incision.

3.53b The cerebellar hemisphere has been incised.

3.53c The infiltrating tumor is isolated and largely resected.
Case 3
Diagnosis: Solid hemangioblastoma of the cerebellar hemisphere
Approach: Paramedian

3.54a The right cerebellar hemisphere has been exposed using a right paramedian craniectomy. The folia are enlarged and flattened.

3.54b The right cerebellar hemisphere has been incised and the surface of the tumor identified.

3.54c Further cerebellar hemisphere resection allows complete delineation of the hemangioblastoma.

3.54d Following resection of the hemangioblastoma, the internal acoustic porus and the tentorium can be seen.
Case 4
Diagnosis: Cystic hemangioblastoma of the cerebellar hemisphere
Approach: Paramedian

3.55a, b Funduscopic examination reveals dilated arterial and venous channels with a retinal hemangioblastoma. The diagnosis of Hippel-Lindau disease is established.
A right paramedian exposure of the cerebellar hemisphere has been performed. Upon reflection of the dura, the flattened gyri of the cerebellar hemisphere are evident. Upon incising the cerebellar hemisphere, a large cyst is encountered. The solid nodule of the hemangioblastoma is located on the superior aspect of the cyst wall. The repositioning of the retractor exposes the hemangioblastoma nodule in its entirety, where it was easily extirpated.
Case 5  
Diagnosis:  Hemangioblastoma with hemorrhage  
Approach:  Midline

3.56a The exposure of the left cerebellar hemisphere reveals a large hemorrhagic cystic lesion.

3.56b The lower extent of the cerebellar hemisphere can be seen. Noteworthy is the downward herniation of both cerebellar tonsils through the foramen magnum.

3.56c The solid hemangioblastoma nodule is visualized upon opening the cyst and removing the hemorrhagic fluid.
3.56d The hemangioblastoma has been resected.
Case 6
Diagnosis: Medulloblastoma of the right cerebellar hemisphere
Approach: Unilateral paramedian

3.57a The distorted cerebellar hemisphere and tumor nodule are visible through a right paramedian exposure of the posterior fossa.

3.57b The tumor nodule is separated from the cerebellar hemisphere.

3.57c After the tumor mass has been excised, a tract to the fourth ventricle is visible.

3.57d Higher magnification reveals the floor of the fourth ventricle and the entrance into the aqueduct of Sylvius.
Tumors of the Cerebellopontine Angle

Microanatomy

3.58 The right cerebellopontine angle, with exposure of the nerves and arteries. The tentorium has been reflected forward, and the cerebellum has been elevated (viewed from the side and behind).

3.59 The right cerebellopontine angle, viewed from the lateral aspect.
3.60 Posterior cranial fossa. Tentorium reflected forwards, cerebellum elevated dorsally. The course of the cranial nerves in the posterior fossa en route to the clivus is shown, including the junction between the middle and posterior fossa. Seen from behind, laterally and above.

3.61 The right cerebellopontine angle, after removal of the cerebellum by dividing the cerebellar peduncle. Seen from the lateral aspect.
3.62 Higher magnification of the course of the cranial nerves within the cerebellopontine angle. Notice also the petrosal vein and the subarcuate artery.

3.63 The cerebellopontine angle and the cranio-cervical junction (from behind and below, right side).
3.64 An anatomical specimen of the cerebellopontine angle indicates the cranial extent of the loop of the posterior inferior cerebellar artery.

3.65 Surgeon's view of the cerebellopontine angle. A prominent flocculus overlies the origin of the seventh and eighth nerves on the brain stem.
3.66 The various vessels that supply the facial nerve through its entire course.

3.67 The various positions of the meatal loop of the anterior inferior cerebellar artery.

3.68 Anatomy of the branches of the anterior inferior cerebellar artery.
3.69 A lateral exposure of the right cerebellopontine angle. The eighth nerve has been retracted with a nerve hook, exposing the underlying seventh nerve.

3.70 This exposure visualizes the nerve root entry zones of the trigeminal nerve on top, the facial nerve (elevated by two pins), the nervus intermedius with an underlying arterial branch, and the vestibular and cochlear parts of the eighth nerve (left side, viewed from anterior).
3.71 The seventh and eighth cranial nerves viewed from above as they enter the internal auditory meatus. A part of the meatal roof has been removed.

3.72 A magnified frontal view of the facial nerve on top, the nervus intermedius next (with the vestibular and cochlear portions of the eighth nerve separated). Notice the degree of pigmentation of pia along the vestibular portion of the eighth nerve as it extends through its intracranial course. Important in this respect is that this pigmentation correlates well with central myelinization of the neurons, and explains in part the eighth nerve’s vulnerability to compression in its intracranial course. The seventh nerve alternatively has central myelin only for a very short distance, following its exit from the brain stem (right side, from anterior).
3.73 A microsection of the vestibulocochlear nerve, demonstrating the central, junctional, and peripheral segments.
A posterolateral exposure of the seventh and eighth nerves as they enter the internal acoustic porus. The internal acoustic meatus has been drilled to expose its contents.

The internal acoustic meatus has been opened completely (seen from above). The superior vestibular nerve has been cut, exposing the inferior vestibular nerve, the transverse crest, and the cochlear nerve. The facial nerve was cut at the brain stem and lifted anteriorly, demonstrating the anastomoses between the facial nerve, the intermediate nerve, and the geniculate ganglion.
3.76 An anatomical specimen shows the exposure of the cerebellopontine angle as if a middle fossa approach has been used (seen from above).

3.77 Slightly more dissection reveals the geniculate ganglion of the seventh cranial nerve. This view is similar to the operative view through the middle fossa to the cerebellopontine angle.
3.78 The cochlear and vestibular nerves, seen from the left side after cutting and displacing the facial nerve, depicts the anatomy of the eighth nerve complex.
3.79 With the facial nerve cut and displaced, the transverse crest is visualized. In this view, again through the middle fossa approach, the vestibular portion has also been cut, leaving the cochlear nerve in place.
3.80 The bone has been drilled further to demonstrate the proximity of the transverse crest to the cochlea. Notice also the delicate labyrinthine artery.

3.81 The internal acoustic meatus from the ventral aspect.
3.82 The fundus of the right internal acoustic meatus with the posterior meatal lip resected.

3.83 A transverse section through the right temporal bone at the level of the internal and external acoustic meatus and its contents (viewed from below).
3.84 Dimensions of the internal acoustic meatus in millimeters, important for defining the limitations of surgical exposure.

3.85 In this specimen, an enlarged internal auditory meatus is present, expanded by an incidentally discovered acoustic neurinoma. Notice the flaring of the meatus and the extension of the tumor to the cochlea.
3.86 The left internal acoustic meatus, section in a frontal plane near the anterior wall. Exposure of the seventh and eighth nerves. Viewed from the front.

3.87 Neural structures of the internal acoustic meatus and the adjacent petrous bone. Right side, viewed from the frontal aspect.
3.88 Exposure of the jugular foramen, with the lateral wall opened, demonstrates the course of the ninth, tenth, and eleventh cranial nerves.

Position and Approach

Retromastoid Retrosigmoidal Approach

3.89a–c The three most common positions used to approach the cerebellopontine angle. The supine position, with the head turned and flexed, is particularly useful for the translabyrinthine approach. The modified park-bench or semi-sitting position is best for the retromastoid approach.
3.90a  A paramedian incision is made from the level of C2 overlying the mastoid to extend above the nuchal line with a slight curve anteriorly.

3.90b  The underlying musculature.

3.90c  The craniotomy. Care must be taken to expose the sigmoid sinus which may require resection of mastoid air cells. These should be sealed appropriately.

3.90d  The craniotomy and its relationship to the cerebellum and brain stem.
Arachnoiditis of the Cerebellopontine Angle

Clinical Material

Case 1
Diagnosis: Arachnoiditis of the cerebellopontine angle
Approach: Retromastoid

3.91a Severe arachnoidal adhesions are visible.

3.91b The glossopharyngeal and vagal nerve complex can be appreciated following resection of some of the arachnoidal adhesions.

3.91c Progressive dissection of the arachnoidal adhesions frees the cranial nerves.
3.91d  A final dissection exposes the glossopharyngeal and vagus nerves.

3.91e  With the facial nerve slightly elevated to expose it from behind the eighth nerve, the obvious hypervascularity, which occurred following the nerve compression due to the arachnoidal adhesions, becomes visible.

3.91f  Higher magnification of the eighth cranial nerve reveals the hypervascularity of the distal portion of the nerve secondary to compression. Of interest is the return of eighth nerve function following resection of these arachnoidal adhesions.
Neurinoma of the Statoacoustic Nerve

Tumor Grading by Size

Origin and Growth Pattern of Acoustic Neurinomas

3.92 The grading system for these important tumors is included here because the approach and results vary markedly between different tumor sizes.

Grade 1: Intracanalicular tumor with a longitudinal diameter of 1–10 mm.

Grade 2: Intracanalicular and intracisternal tumor with a longitudinal diameter up to 20 mm.

Grade 3: Intrameatal and intracisternal tumor with a longitudinal diameter up to 30 mm (reaching the brain stem).

Grade 4: Intrameatal intracisternal tumor with a longitudinal diameter more than 30 mm (indenting and displacing the brain stem).

3.94a The origin of acoustic neurinomas. At the fundus of the internal auditory meatus, the inferior vestibular nerve is consumed by tumor in more than 70% of cases, the superior vestibular nerve in 30%, and the cochlear nerve in more than 20% of cases. This proves that in the majority of cases, "acoustic neurinomas" originate from the vestibular portion of the eighth nerve during its intrameatal course, but may also involve other components of the eighth nerve. All of these tumors originate in the neurilemmal segment of the nerve, lateral to the glial-neurilemmal junction.

3.94b Growth pattern of acoustic neurinomas in relation to tumor grades.
3.93 Neuroimaging of acoustic neurinomas of grades 2 to 4. a–d Grade 2 acoustic neurinomas.

3.93e, f Grade 3 acoustic neurinomas.

3.93g–j Grade 4 acoustic neurinomas.
Operative Techniques for Removing
Acoustic Neurinomas in Correlation with the
Size and Extension of the Tumor

3.95 The four tumor grades and the surgical approach suggested.

Grade 1: Where hearing is preserved, either an extradural subtemporal approach or a suboccipital transmeatal approach is preferred. Only in cases where hearing is absent can the translabyrinthic approach be recommended.

Grade 2: The same approaches can be utilized, although the suboccipital approach with its full visualization of the intracranial course of the nerves is preferred.

Grades 3 and 4: Visualization of the brainstem and cranial nerves makes the suboccipital transmeatal approach the procedure of choice.
Clinical Material

Grade 1 Acoustic Neurinomas

Case

Diagnosis: Grade 1 acoustic neurinoma

Approach: Retromastoid transmeatal

3.96a Intracanalicular right-sided acoustic neurinoma grade 1. Axial post contrast CT section at the level of the internal acoustic canal. Note the globular contour of the small neurinoma which does not extend to the fundus of the meatus.

3.96b The right cerebellopontine angle is exposed performing a standard suboccipital retro-mastoid approach. The upper lip of the internal acoustic porus is overlapped by a bony protrusion. No tumor is seen protruding out of the internal meatus.

3.96c The dura overlying the posterior wall of the internal acoustic meatus is coagulated and incised with an 11-knife blade; the small dural flap is separated from the bone and pushed to the posterior lip of the internal acoustic porus.
3.96d The posterior wall of the internal acoustic meatus is removed with a high-speed Midas-Rex diamond drill. The cul-de-sac-like dura of the internal meatus is exposed.

3.96e After resection of the dura the intrameatal nervous structures are exposed. The VIII and VII nerves are displaced posteriorly by the neurinoma which is located in front of the nerves.

3.96f A blunt hook separates the nerves VIII and VII.
3.96g  By spreading the bundles of the seventh and eighth nerve the nodule of the neurinoma is brought into view.

3.96h  Downward displacement of the facial nerve exposes the tumor lying in front.

3.96i  The attachment of the acoustic neurinoma can be visualized.
3.96j The tumor is separated from the VIIIth nerve; the connection between neurinoma and nerve has been cut.

3.96k The seventh and eighth nerve bundle can be seen within the enlarged internal acoustic meatus.

3.96l The margins of the posterior meatal wall is sealed with fibrin glue and small plates of gelloam (or pieces of muscle). The preoperative hearing is preserved.
Grade 2 Neurinomas

Case 1

(Courtesy of Prof. Dr. F. Oppel, Bielefeld, Germany)

Diagnosis: Grade 2 acoustic neurinoma
Approach: Cisternoscopic

3.97 The right cerebellopontine angle is visualized through a cisternoscope, revealing a grade 2 acoustic neurinoma as it protrudes from the meatus. Notice the inferior vestibular nerve entering directly into the tumor, whereas the superior vestibular, cochlear, and facial nerves are displaced rostrally.
Case 2
Diagnosis: Grade 2 acoustic neurinoma
Approach: Retromastoid

3.98a The cerebellopontine angle is visualized following a standard suboccipital retromastoid approach to the meatus.

3.98b Higher magnification and additional arachnoid dissection reveal the neurinoma protruding out of the meatus.

3.98c Following complete arachnoid dissection, the eighth nerve and the labyrinthine artery are clearly identified as well as the neurinoma and its draining vein.
3.98d Higher magnification of the meatal region demonstrates the eighth nerve compressed by the tumor and the efferent vein from the neurinoma.

3.98e The dura overlying the posterior wall of the acoustic meatus is coagulated.

3.98f The dura is incised with an 11-blade.
3.98g The dura is mobilized interiorly and superiorly with a sharp curette.

3.98h The posterior wall of the acoustic meatus is removed with a diamond drill.

3.98i The intrameatal dura is separated from the bone with a blunt hook.
3.98j Bony removal has been completed, exposing the dura covering the tumor within the meatus.

3.98k The dura is elevated to expose the intrameatal portion of the tumor.

3.98l The entire tumor is visualized with resection of its arachnoidal covering.
3.98m The tumor is separated and elevated from the eighth nerve.

3.98n The obvious connection to the inferior vestibular part of the eighth nerve is apparent.

3.98o The inferior vestibular nerve is sectioned by means of microscissors.

3.98p The neurinoma is separated from the remaining eighth nerve.
3.98q  Completion of the tumor removal, with preservation of continuity of the eighth nerve and the superior vestibular part. The seventh nerve, lying in front, required no manipulation at all. Hearing was preserved.
Case 3
Diagnosis: Grade 2 acoustic neurinoma
Approach: Retromastoid

3.99a Following the usual exposure of the meatal region, the eighth nerve, its blood supply, and the tumor emerging from the internal acoustic porus are visualized.

3.99b The dura over the meatus has been opened, and the bone removed with a diamond drill.

3.99c The tumor is carefully mobilized and sharply separated from its attachment to the inferior vestibular nerve.
3.99d Using a sharp hook, a cleavage plane between the intrameatal portion of the tumor and the eighth nerve is developed.

3.99e The distal attachment of the neurinoma to the inferior vestibular portion of the eighth nerve is visualized prior to being cut.

3.99f Inspection of the internal acoustic meatus using an angled mirror reveals a residual piece of tumor near the fundus.
3.99g The continuity of the eighth nerve is seen following complete tumor removal. Hearing was preserved.
Case 4
Diagnosis: Grade 2 acoustic neurinoma
Approach: Retromastoid

3.100a Using a retromastoid approach, the right eighth nerve complex is exposed, revealing a small tumor within the subarachnoid space as it enters the internal auditory meatus.

3.100b After the internal auditory meatus has been drilled, a better view of the size of the tumor is available.

3.100c The tumor capsule is opened, and the tumor contents are evacuated. Note the continued preservation of the fine vascular network of the eighth nerve interiorly. The vestibular portion courses over the tumor.
3.100d The tumor origin arises from the superior vestibular nerve, which is being sectioned.

3.100e After the superior vestibular nerve has been sectioned, the tumor capsule is mobilized toward the internal auditory meatus, and the seventh nerve can be seen emerging behind the eighth nerve. Again, note the careful preservation of the auditory artery and its fine vascular supply.

3.100f After the tumor has been completely excised, the remainder of the inferior vestibular nerve and the cochlear nerve are visible. The seventh nerve is elevated with a small dissector. Hearing was preserved.
3.100g  A postoperative axial CT proves total tumor removal.

Intracranial Extrameatal or „Medial” Acoustic Neurinomas

3.101  Purely intracranial extrameatal acoustic neurinomas growing in the cerebellopontine angle compromise less than 8% of all cases of acoustic neurinomas. They occur more commonly with von Recklinghausen’s disease, and are a good example of tumors growing medially to the apparent myelin-Schwann cell junction of the eighth nerve.
Case 1
Diagnosis: Acoustic neurinoma grade 2, intracranial extrameatal
Approach: Retromastoid

3.102a The eighth nerve and its surrounding arachnoid are visualized using a standard exposure of the cerebellopontine angle.

3.102b After further exposure, the arachnoid-covered eighth nerve and neurinoma are visible.

3.102c On removal of the arachnoid, the tumor and the remainder of the eighth nerve fascicles are clearly visualized.
3.102d The medial attachment of the acoustic neurinoma has been cut, and the tumor is mobilized laterally. The completely uninvolved seventh nerve appears in the background.

3.102e Following complete excision of the tumor, the eighth nerve and underlying seventh nerve are visible. The anterior inferior cerebellar artery can be seen crossing medially and interiorly. Preoperative hearing was preserved.
Case 2
Diagnosis: Grade 3 acoustic neurinoma, intracranial extrameatal
Approach: Retromastoid

3.103a A horizontal CT demonstrates a grade III acoustic neurinoma within the cerebellopontine angle.

3.103b Using a right retromastoid exposure, the neurinoma becomes visible.

3.103c When the arachnoid and dura have been dissected at the internal auditory meatus, the tumor origin can be identified as extrameatal. Sometimes, eighth nerve function is partially intact, and can be preserved despite the large size of the tumor.

3.103d A postoperative horizontal CT confirms total tumor removal.
Grade 3 and 4 Acoustic Neurinomas (Facial Nerve)
Because of the importance of preserving the facial nerve when encountering large acoustic neurinomas, the course, shape, and anatomical displacement found with these large tumors is indicated here in detail.

3.104 This case illustrates that even grade 4 acoustic neurinomas may occur completely outside of the meatus. The eighth nerve can be seen exiting the tumor, with the seventh nerve coursing rostrally and superiorly.

3.105 The common anatomical locations that the facial nerve takes in the presence of grade 3 or 4 acoustic neurinomas. The anterior displacement is most common, and is found in about 70% of cases (A). Course B, representing the superior displacement of the facial nerve, may be observed in 10% of cases. Course C, where the facial nerve takes a posterior course around the tumor, and thus is clearly visualized by the suboccipital retromastoid approach, is found very infrequently, in only 7% of cases. Course D, where the facial nerve takes an inferior course, occurs in about 13% of cases.

Two distinct patterns of facial nerve distortion are recognizable. The first is where the nerve maintains a clearly recognizable shape in the form of a thin bundle, and the second where the nerve is splayed out into multiple finger-like projection closely adherent to the capsule. In approximately two-third cases in non–von Recklinghausen’s acoustic neurinoma, the facial nerve remains in a recognizable bundle. In the other third, it is splayed out. These percentages are virtually reversed in the neurinomas found in von Recklinghausen’s disease. Examples follow.
3.106 a An example of type A facial nerve displacement in a grade 3-4 acoustic neurinoma. Obviously, the facial nerve is in front of the tumor, exposed through a retromastoid approach.

3.106 b After removal of the tumor, one can see the intact (previously rostrally displaced) facial nerve.
Case 2
Diagnosis: Acoustic neurinoma grade 4 – type B facial nerve
Approach: Retromastoid

3.107 An example of type B. The facial nerve courses superiorly over the tumor.

Case 3
Diagnosis: Acoustic neurinoma grade 3 – type C facial nerve
Approach: Retromastoid

3.108 The much more uncommon, but surgically preferred, facial nerve location (type C). It is advantageous for the surgeon, as it is readily visible on initial tumor exposure.
Case 4
Diagnosis: Acoustic neurinoma grade 4 – type C facial nerve, splayed
Approach: Retromastoid

3.109 The same type C location of the facial nerve as in the previous case, except that here, the facial nerve is splayed out in a finger-like pattern. Nevertheless, this facial nerve function can be preserved by maintaining continuity of the individual fibers. At times, part of the adherent capsule will need to be left behind. This does not appear to result in tumor recurrence.
Case 5
Diagnosis: Acoustic neurinoma grade 4 – type D facial nerve
Approach: Retromastoid
Case 6
Diagnosis: Acoustic neurinoma grade 3 – type D facial nerve
Approach: Retromastoid

3.111a A coronal MR image demonstrates a grade III acoustic neuroma.

3.111b A postoperative CT demonstrates complete tumor removal.

3.111c Using a right retromastoid approach, a large acoustic neuroma becomes visible. Note the ninth, tenth, and eleventh nerve complex below the tumor.

3.111d The tumor is opened and debulked.
3.111e After debulking, the tumor is mobilized laterally, exposing the eighth nerve and the origin of the seventh nerve. It is already apparent that the seventh nerve follows an unusual course along the inferior surface of the tumor.

3.111f With the tumor almost completely debulked, the seventh nerve can be seen throughout its subarachnoid course.

3.111g After the tumor has been completely removed, the seventh nerve is visualized, and its inferior course can be fully appreciated.
Although hearing is lost in the great majority (90%) of patients with grade 3 and 4 acoustic neurinoma, there is a small but significant number of patients (10%) who, despite harboring these large masses, have preserved useful hearing. In this small number of patients, every attempt should be made to preserve eighth nerve function, despite the presence of these large tumors.

**Type I:** The most common anatomy of the eighth nerve (50%) in acoustic neurinomas. The eighth nerve, after exiting from the brainstem, becomes intimately involved in the tumor, making any separation between nerve and tumor impossible.

**Type II:** In this second pattern (found in 40% of patients), the eighth nerve, although beginning as a bundle, becomes splayed as it is displaced by the acoustic tumor, and becomes so intimately adherent and part of the capsular structure of the tumor as to make functional preservation impossible.

**Type III:** In this type, the uninvolved portion of the eighth nerve maintains its anatomical integrity, and is displaced by the tumor as a separate bundle, allowing anatomical preservation as well as preservation of acoustic function of the nerve, despite removal of the tumor. Although this pattern occurs in only 10% of patients, the clinical presentation of preserved hearing in the presence of a large tumor should alert the surgeon to the possibility of saving eighth nerve function. In these cases, the CT or MR scan occasionally reveals a large tumor without extension into the meatus.
Case 1
Diagnosis: Acoustic neurinoma grade 3 – type I, type A facial nerve
Approach: Retromastoid

3.115a A grade 3 acoustic neurinoma. The eighth nerve is identified along the brain stem through a retromastoid approach.

3.115b The eighth nerve can be visualized just above the seventh nerve as it exits the brain stem and then diverges to enter the tumor. This is an example of the first type of eighth nerve tumor involvement; the entire nerve needs to be sacrificed for complete tumor removal.
Case 2
Diagnosis: Acoustic neurinoma grade 3 – type I, type A facial nerve
Approach: Retromastoid

3.116a Using a right retromastoid exposure, the grade III acoustic neuroma is identified.

3.116b Looking medially, the facial nerve is seen below the eighth nerve. The entire eighth nerve appears to splay into the tumor mass.

3.116c The internal auditory meatus is opened, and the portion of the tumor entering the meatus is visualized.

3.116d After complete tumor excision, the brain stem stump of the eighth nerve is seen. The seventh nerve is intact as it enters the meatus.
Case 3
Diagnosis: Acoustic neurinoma grade 3 -
   type II, type A facial nerve
Approach: Retromastoid

3.117a Another grade 3 acoustic neurinoma is
   being mobilized to gain visualization of the eighth
   nerve at the brain stem.

3.117b A glimpse of the eighth nerve is seen as
   the large tumor is being mobilized laterally.

3.117c The second type of eighth nerve pattern
   is seen as the eighth nerve splays out widely into a
   thin band and becomes intimately involved in the
   tumor capsule. Again, hearing cannot be pre-
   served.
Case 4

Diagnosis: Acoustic neurinoma grade 4 – type III, facial nerve type A

Approach: Retromastoid

3.118a A grade 4 acoustic neurinoma is exposed through a standard suboccipital retromastoid craniectomy.

3.118b Prior to tumor removal, one can see the eighth nerve displaced inferiorly, but remaining intact. In this patient, useful hearing (despite the size of the tumor) was preserved.
Case 5
Diagnosis: Acoustic neurinoma grade 3 – type III, facial nerve type A
Approach: Retromastoid

3.119a Using a standard suboccipital retromastoid craniectomy, the cerebellopontine angle is exposed, and a grade 3 acoustic neurinoma becomes visible.

3.119b The eighth nerve and the seventh nerve are visible following removal of the tumor. The displaced seventh and eighth nerve bundle emerges from the brain stem and enters the meatus. The large trigeminal nerve is seen in the background.

3.119c Using a mirror, the internal meatus can be checked to verify that it is free of any residual tumor.
Case 6
Diagnosis: Acoustic neurinoma grade 4 – type III; facial nerve type D
Approach: Retromastoid

3.120a A grade 4 tumor has been exposed in the cerebellopontine angle.

3.120b The tumor has been greatly debulked and the capsule has been separated from the seventh and eighth nerves adjacent to the brain stem.

3.120c The tumor has been entirely removed. The basilar artery is seen deep within the operative exposure, with the abduc-cent nerve coursing over it.

3.120d The microscope has been focused on the seventh and eighth nerve complex, from the brain stem to the meatus. Despite the size of this tumor, useful hearing was preserved.
Case 7
Diagnosis: Acoustic neurinoma grade 4 –
type III, facial nerve type A
Approach: Retromastoid

3.121a Using a right retromastoid
approach, a large acoustic neuroma, covered
with arachnoid, is encountered.

3.121b After the arachnoid has been dis-
sected, the petrosal vein, which crosses
superiorly over the eighth nerve, is visualized.
The brain stem origin of the eighth nerve is
identified, and its fan-like course over the
tumor can be appreciated.

3.121c Mobilizing the brain stem portion of
the tumor exposes the origin of the facial
nerve.
3.121d The eighth nerve is carefully separated from the tumor capsule and preserved.

3.121e Further dissection of the tumor capsule demonstrates the ability to preserve the seventh and eighth cranial nerves, despite the large size of the tumor.

3.121f After the tumor has been removed completely, the intact seventh and eighth nerves can be seen. Postoperatively, both cranial nerves functioned.
Case 8
Diagnosis: Acoustic neurinoma grade 2 – type III, facial nerve type A
Approach: Retromastoid

3.122a A horizontal CT demonstrates a grade 2 acoustic neurinoma. The striking feature is a total hearing loss in the case of such a small tumor. The patient also complains of constant noise in the ear.

3.122b Using a right retromastoid approach, the neurinoma becomes visible. The eighth nerve follows a course along the inferior surface of the tumor, and appears severely compressed by the labyrinthine artery, which traverses the nerve shortly after its origin from the brain stem.

3.122c The labyrinthine artery is sectioned and mobilized from the statoacoustic nerve.
3.122d The eighth nerve is separated from the tumor, and a groove remains from vascular compression.

3.122e The tumor is mobilized from the internal auditory meatus without drilling of the posterior metal wall.

3.122f After the neurinoma has been removed completely, the intact seventh and eighth nerves can be seen.
Surgical Management of Grades 3 and 4 Acoustic Neurinomas
This section deals with the common problem of how to remove large acoustic neurinomas. Whether to approach a tumor initially from the brain stem or through the meatus depends to a large degree on its anatomical location. The surgical steps shown in Figure 3.123a–c are considered the standard technique for tumor removal, and are used in about 90% of acoustic neurinomas.

3.123a The initial step in these large tumors is to debulk the tumor, after ensuring that the seventh nerve does not course in the area of capsule penetration.

3.123b The brain stem is approached first, and the seventh and eighth nerves and tumor origin are identified.

3.123c As the last step, the meatus is opened, and the tumor, seventh nerve, and eighth nerve are identified.

3.124a An alternative approach to these large tumors again begins with debulking to allow tumor capsule mobilization.

3.124b Initially, the meatus is opened and the tumor boundary and neural structures are identified. The tumor is then mobilized toward the brain stem and, as a final step, is dissected from its attachment to the eighth nerve at the brain stem.
Case 1
Diagnosis: Acoustic neurinoma grade 4
Approach: Retromastoid – brain stem dissection (initial step)

3.125a Using a suboccipital retromastoid approach, the cerebellum is elevated, and the arachnoid-covered tumor is visualized.

3.125b The large, and partially cystic, tumor has been centrally debulked.

3.125c The glossopharyngeal nerve is followed towards the brain stem, and the choroid plexus and foramen of Luschka are identified. This in turn locates the origin of the eighth nerve.
3.125d The origin of the eighth nerve is identified after preparing along the brainstem as described in the previous figure. The tumor is then mobilized laterally and removed as the last step through the opened internal meatus.
Case 2
Diagnosis: Acoustic neurinoma grade 3
Approach: Retromastoid – opening of the internal meatus (initial step)

3.126a A grade 3 acoustic neurinoma is visualized in the cerebellopontine angle.

3.126b The tumor has been debulked, and because of its location, the internal meatus has been opened as the initial step. The dural band, which lines the internal acoustic porus, is being elevated with a hook as the last step in exposing the contents of the meatus.

3.126c After the tumor has been mobilized from the acoustic meatus medially (and separated from the seventh nerve), attention is directed to the brain stem. This allows continuous evacuation of tumor, and progressive identification and preservation of the relationship of the tumor capsule to the facial nerve. The tumor is then mobilized away from the brain stem, and we can see the remaining portion of the vestibular nerve and the remaining tumor capsule lifted laterally.
3.126d The tumor has been removed, except for a small portion attached laterally to the facial nerve. Notice the distortion of the seventh nerve, with excellent preservation of its normal contour and blood supply.

3.126e The tumor has been completely resected, and the continuity of the seventh nerve and the nervus intermedius is visualized.
In the background, the large trigeminal nerve is seen, with the superior petrosal vein coursing from the cerebellum into the superior petrosal sinus.
Case 3
Diagnosis: Acoustic neurinoma grade 4
Approach: Retromastoid – opening of the internal meatus (first step)

3.127a A large grade 4 acoustic neurinoma is exposed in the cerebellopontine angle.

3.127b The large tumor is exposed in the meatus and mobilized toward the brain stem. The tumor has already been largely debulked and the meatus opened. The seventh nerve has been identified within the internal meatus. This is a beautiful example of the seventh nerve as it splays around the tumor capsule.

3.127c The tumor has been completely removed, and the splayed seventh nerve has folded over itself. Electrical as well as physiological function of this facial nerve was preserved.
3.128a This case serves as an example of the way in which even large recurrent tumors can be safely excised while maintaining facial nerve function. A large acoustic neurinoma has been exposed in the right cerebellopontine angle.

3.128b After the tumor has been debulked, the meatus is opened, the seventh nerve is identified, and the tumor is mobilized medially.

3.128c The facial nerve is splayed around the tumor capsule, part of which is adherent to the brain stem. The basilar artery and abducent nerve are seen deep in the angle.
3.128d After the tumor has been separated from the brain stem, the splayed seventh nerve is visualized as it courses from the internal acoustic meatus to the brain stem. Higher, the trigeminal nerve, the abducent nerve and the basilar artery are exposed.
Neurinomas of the Facial Nerve

Clinical Material

Case 1
Diagnosis: Neurinoma of the facial nerve
Approach: Retromastoid

3.129a The cerebellopontine angle is exposed, and a very large tumor is visualized behind the thinned out intact eighth nerve. Notice the seventh nerve as it proceeds from the brain stem directly into the tumor.

3.129b The tumor has been completely removed, and the eighth nerve can be visualized from the brain stem to the opened internal acoustic meatus.

3.129c The stump of the facial nerve is elevated as it exits from the brain stem. This nerve was re-constructed at its distal end with an interposition nerve graft (see p. 605).
Case 2
Diagnosis: Neurinoma of the facial nerve
Approach: Retromastoid

3.130a A large neurinoma of the facial nerve is exposed in the right cerebellopontine angle. The uninvolved and functioning eighth nerve is visualized at the lower circumference of the tumor.

3.130b The neurinoma has been partially removed, and the eighth nerve is separated from the tumor capsule. A solid part of the facial nerve is visualized as it enters the upper pole of the tumor.

3.130c Situation after total resection of the intracranial and intrameatal portions of the tumor. Note the two separate parts of the facial nerve as they proceed from the brain stem to the opened internal acoustic meatus. The uninvolved portion of the seventh nerve maintains its anatomical integrity, and is displaced anteriorly. A second, separate, part of the nerve has been resected with the tumor.
3.130d The microscope has been focused at the central stump of the facial nerve as it emerges from the brain stem and is displaced anterio-superiorly.

3.130e Note the straightened central stump of the facial nerve anastomosed to the distal portion of the nerve utilizing one 10-0 suture.
Neurinomas of the Trigeminal Nerve

Clinical Material

Case 1
Diagnosis: Neurinoma of the trigeminal nerve

3.131 Longitudinal section of the exit zone of the trigeminal nerve from the brain stem. There is a marked difference in color between the central ("glial") segment and the peripheral ("Schwannic") segment of the nerve. The central nerve fibers are surrounded by glial cells, and the more peripheral fibers by Schwann cells. Note a small neurinoma growing within the peripheral segment of the sensory portion of the trigeminal nerve.
Case 2
Diagnosis: Neurinoma of the trigeminal nerve
Approach: Retromastoid

3.132 Exposure of the superior aspect of the cerebellopontine angle reveals a large neurinoma attached to the trigeminal nerve. The most lateral intracranial portion of the trigeminal nerve is visible on the superior lateral aspect of the tumor. The seventh and eighth nerve complex can be seen coursing at the inferior aspect of the tumor. It was necessary to excise the trigeminal nerve to resect the tumor.
Case 3
Diagnosis: Neurinomas of the trigeminal and acoustic nerves (von Recklinghausen’s disease)
Approach: Retromastoid

3.133a A trigeminal and an acoustic neuroma are visualized using a right retromastoid approach.

3.133b After both tumors have been excised, the residual portion of the fifth nerve below the petrosal vein is visualized.
Neurinomas of the Glossopharyngeal Nerve

Clinical Material

Case 1
Diagnosis: Neurinoma of the glossopharyngeal nerve
Approach: Retromastoid

3.134a A view into the cerebellopontine angle reveals a tumor attached to the glossopharyngeal nerve. The seventh and eighth nerve complex can be seen above it.

3.134b The tumor has been removed, and the residual glossopharyngeal nerve, the vagus filaments, and the accessory nerve are visible. The eighth nerve is seen superiorly.
Neurinomas of the Vagus Nerve

Clinical Material

Case

Diagnosis: Neurinoma of the vagus nerve
Approach: Retromastoid

3.135 Below a large acoustic neurinoma (the inferior extent of which is visualized), multiple small tumors of the vagus nerve are exposed. This is obviously a case of von Recklinghausen’s disease.
Meningiomas of the Cerebellopontine Angle

Clinical Material

Case 1
Diagnosis: Meningioma of the posterior surface of the petrous bone
Approach: Retromastoid

3.136a Following exposure of the cerebellopontine angle, a meningioma with the typical vascular dural pattern is visualized. A small paddy is present above the tumor.

3.136b The tumor is debulked utilizing the CO₂ laser. Notice the lack of bleeding.

3.136c The trigeminal nerve can be visualized at the top of the picture following complete tumor removal. Lower down, the seventh and eighth nerve complex has been elevated with a hook.

3.136d By focusing farther one can see where the dural tumor attachment was burned with the laser.
3.137a An exposure of the inferior portion of the tentorium and petrous ridge reveals a bulging arachnoid membrane and the ambient cistern. Notice the typical dural vascular pattern surrounding the meningioma.

3.137b Following tumor extirpation, the tentorial edge is exposed. The trochlear nerve is visualized coursing in the arachnoidal folds of the ambient cistern. The superior cerebellar artery is seen. Note that the arachnoid of the ambient cistern has not been violated.

3.137c By refocusing, the seventh and eighth nerve complex and branch of the superior cerebellar artery are clearly demonstrated.

Case 2
Diagnosis: Meningioma of the inferior tentorial edge
Approach: Retromastoid
Case 3
Diagnosis: Meningioma originating within the internal auditory meatus
Approach: Retromastoid

3.138a A small tumor in the internal auditory meatus is identified using a right retromastoid approach.

3.138b Higher magnification reveals the tumor as it enters the internal auditory meatus.

3.138c When the tumor is dissected from the eighth nerve complex, it is obvious that it does not involve any fascicle of the eighth nerve.
3.138d Further mobilization of the tumor defines the plane between the nerve and the tumor.

3.138e After the internal auditory meatus has been opened, the meningioma is removed in one piece.

3.138f The tumor has been removed completely, and the vascularity and area of tumor attachment to the dura can be appreciated.
Epidermoid Cysts (Cholesteatomas) of the Cerebellopontine Angle

Clinical Material

Case 1

Diagnosis: Epidermoid cyst of the cerebellopontine angle and prepontine cistern

Approach: Retromastoid

3.139a–c A series of coronal MR images demonstrates a large epidermoid tumor located in the cerebellopontine angle and prepontine cistern. Note the marked distortion of the brain stem.

3.139d The left cerebellopontine angle is exposed using a retromastoid approach. A branch of the petrosal vein courses above the epidermoid tumor.
3.139e After the tumor has been partially resected, the individual cranial nerves become visible.

3.139f After most of the tumor has been resected, the cranial nerves are readily identified.

3.139g Postoperative CT scan verifies tumor removal.
Case 2
Diagnosis: Epidermoid cyst (cholesteatoma) – solid nodule
Approach: Right paramedian suboccipital

3.140a After a paramedian exposure of the posterior fossa, a solitary well-encased epidermoid cyst is seen below the right tonsil.

3.140b After resection of the epidermoid cyst, one can see the displaced brain stem, the upwardly displaced tonsils, and the laterally displaced cranial nerves.
Case 3
Diagnosis: Epidermoid of the cerebellopontine angle
Approach: Retromastoid
Position: Semi-sitting

3.141a The cerebellopontine angle is exposed using a right retromastoid approach. Underneath the arachnoid, the glistening epidermoid is visible.

3.141b After the arachnoid and tumor capsule have been opened, a typical pearly epidermoid is seen.

3.141c After the tumor has been excised, the empty cerebellopontine angle is visible. The fine vasculature of the individual cranial nerves has been preserved.
A dental mirror is used to observe the loop of the anterior inferior cerebellar artery behind the seventh and eighth nerve complex.
Choroid Plexus Papillomas of the Cerebellopontine Angle

Clinical Material

Case 1

Diagnosis: Choroid plexus papilloma of the cerebellopontine angle originating from the lateral recess

Approach: Retromastoid

Position: Sitting

3.142a A CT scan demonstrates a large choroid plexus papilloma in the cerebellopontine angle.

3.142b A CT scan with coronal reconstruction demonstrates the tumor location in the cerebellopontine angle.

3.142c A postoperative CT scan verifies tumor excision.
3.142d Using a right retromastoid approach, a choroid plexus papilloma is readily identified.

3.142e After the choroid plexus papilloma has been resected, its origin in the foramen of Magendie is apparent.
Case 2
Diagnosis: Choroid plexus papilloma in the cerebellopontine angle extending into the upper cervical spinal canal
Approach: Far lateral inferior suboccipital
Position: Park-bench

3.143a An MR image reveals a large lesion in a patient who experienced slowly, progressive loss of balance and difficulty in swallowing.

3.143b In this MR image, it is unclear whether the tumor is extrinsic or intrinsic.

3.143c A lateral selective vertebral arteriogram fails to reveal significant vascular stain, but demonstrates vessel distortion.

3.143d An anteroposterior view of a selective vertebral arteriogram reveals marked distortion of the anterior inferior cerebellar artery.
3.143e A modified park-bench position is used to expose the tumor. Note that the left side, the side of the tumor, is upwards.

3.143f A posterior fossa craniotomy exposes the dura.

3.143g After C1 and C2 have been resected, the dura is opened. Below the arachnoid, tumor is identified.
3.143i The large tumor is widely exposed with minimal cerebellar retraction.

3.143j The tumor is debulked by laser and bipolar coagulation.
3.143k The ipsilateral and contralateral vertebral arteries and the basilar artery are visible. Some tumor is still present superiorly.

3.143l With only a small portion of tumor remaining in the foramen of Magendie, the vertebral arteries and basilar artery are clearly visible. The cranial nerves are markedly distorted.

3.143m After the tumor has been completely removed, the overview of the operative site can be appreciated.
3.143n The foramen of Magendie has been slightly retracted to show the fourth ventricle.

3.143o View into the fourth ventricle through the foramen of Magendie.

3.143p Under high magnification, the vascularity of the floor of the fourth ventricle can be appreciated.
The residual portion of the choroid plexus papilloma from the foramen of Magendie.

A postoperative CT scan reveals complete tumor excision and a large subdural space without any shift of the fourth ventricle. At a four-year follow-up examination, the patient had no recurrence. He has no cranial nerve deficit. His long-standing lack of coordination has improved markedly.
In this photomicrograph, the border zone between the central myelin and peripheral myelin (Schwann cells) is clearly visualized. In contrast to the eighth nerve, this border is close to the brain stem. This anatomical detail has to be taken into consideration if one attempts intracranial reconstruction of the facial nerve.
3.145a The intracranial-intratemporal facial nerve grafting procedure. The outlined areas are where the bone is removed to expose the seventh nerve at the brain stem and in the mastoid bone. A Right lateral suboccipital craniectomy for exploration and total removal of a cerebellopontine angle tumor. Facial nerve destroyed by the tumor. B Mastoidectomy and opening of the facial nerve canal.

3.145b This anatomical preparation of the seventh nerve in the mastoid process correlates to the intramastoid facial nerve exposure in Fig. 3.145a
Clinical Material

Case 1
Diagnosis: Facial nerve reconstruction following acoustic neurinoma resection
Approach: Retromastoid and transmastoid

3.146a The stump of the seventh nerve is adjacent to a small portion of the tumor capsule adherent to the brain stem and has been anastomosed to an interposition saphenous nerve graft utilizing one 10-0 suture.

3.146b This saphenous nerve graft is visualized from its point of anastomosis to the facial nerve stump at the brain stem to its exit in front of the sigmoid sinus.

3.146c The interposition saphenous nerve graft emerges into the drilled-out mastoid bone where it is anastomosed to the distal facial nerve. Excellent facial nerve function can be anticipated if this procedure is performed accurately after intraoperative facial nerve sacrifice.
Case 2
Diagnosis: Direct facial nerve reconstruction within the cerebellopontine angle after total removal of facial nerve neurinoma
Approach: Retromastoid

3.147a A large neurinoma of the facial nerve is exposed in the right cerebellopontine angle. The uninvolved and functioning eighth nerve is visualized at the lower circumference of the tumor.

3.147b The neurinoma has been partially removed, and the eighth nerve is separated from the tumor capsule. A solid part of the facial nerve is visualized as it enters the upper pole of the tumor.

3.147c Situation after total resection of the intracranial and intrameatal portions of the tumor. Note the two separate parts of the facial nerve as they proceed from the brain stem to the opened internal acoustic meatus. The uninvolved portion of the seventh nerve maintains its anatomical integrity and is displaced anteriorly. A second, separate, part of the nerve has been resected with the tumor.
3.147d The microscope has been focused at the central stump of the facial nerve as it emerges from the brain stem and is displaced anterosuperiorly.

3.147e Note the straightened central stump of the facial nerve anastomosed to the distal portion of the nerve utilizing one 10-0 suture.
Tumors of the Brain Stem
(Pons and Medulla Oblongata)

Superficial Diffuse Tumors

Clinical Material

Case
Diagnosis: Superficial diffuse melanomatosis of the medulla oblongata
Approach: Midline suboccipital

3.148 Following midline exposure of the cisterna magna, the arachnoid is opened and the multiple punctate lesions of melanomatosis are visible.

Intrinsic Diffuse Tumors

Clinical Material

Case 1
Diagnosis: Intrinsic diffuse solid and cystic glioblastoma of the medulla oblongata and upper cervical cord
Approach: Midline suboccipital

3.149 A midline approach has exposed the base of the posterior fossa, revealing abnormal vascularity and tumor tissue emerging from the medulla oblongata associated with a superficial tumor cyst.
Case 2

Diagnosis: Intrinsic diffuse dorsal solid and cystic pilocytic astrocytoma of the medulla oblongata and pons

Approach: Midline suboccipital

3.150a A CT scan with sagittal reconstruction demonstrates a cystic tumor of the medulla and pons.

3.150b A sagittal MR image demonstrates cystic tumor below the fourth ventricle.

3.150c Using a midline suboccipital approach, the cerebellar hemisphere and tonsils are visible below the intact arachnoid.

3.150d A higher magnification after the arachnoid has been opened reveals a tumor bulging through the floor of the fourth ventricle.
Through a small opening into the tumor, a cystic and solid portion of the tumor is identified.

By staying within the tumor, a significant portion of the tumor is evacuated.

The tumor cavity within the medulla is shown after extensive tumor removal.
Case 3
Diagnosis: Intrinsic diffuse solid pilocytic astrocytoma of the dorsal portion of the midbrain, enveloping the aqueduct
Approach: Midline suboccipital

3.151a The cisterna magna is exposed through a midline suboccipital approach. A diffuse pilocytic astrocytoma is encountered.

3.151b The aqueduct has been obstructed by tumor.

3.151c The tumor is resected and the aqueduct is now patent.
3.151d A view from the fourth ventricle into the aqueduct.

3.151e A shunt inserted through the aqueduct connects the third ventricle to the cisterna magna.

3.151f A postoperative MR image demonstrates the shunt in good position.
Exophytic Diffuse Tumors

Clinical Material

Case 1

Diagnosis: Exophytic diffuse dorsal cystic pilocytic astrocytoma of the medulla oblongata and fourth ventricle

Approach: Midline suboccipital

3.152b With splitting of the lower vermis, it becomes obvious that the tumor cyst fills the entire fourth ventricle.

3.152c After aspirating the cyst contents, the tumor capsule is held up to expose the attachment to the floor of the fourth ventricle.
3.152d The capsule has been resected from the floor of the fourth ventricle without any gross evidence of further tumor involvement.
Case 2
Diagnosis: Exophytic diffuse dorsal solid and cystic anaplastic astrocytoma of the medulla oblongata and the fourth ventricle
Approach: Midline suboccipital

3.153a A large tumor cyst is visible following exposure of the fourth ventricle.

3.153b The tumor cyst has been aspirated, exposing the base of the tumor.

3.153c The tumor obviously infiltrates the caudal cerebellar peduncle and the floor of the fourth ventricle, making gross total removal impossible—as opposed to the previous case, in which the tumor appeared to be limited to the wall of the cyst.
Case 3
Diagnosis: Exophytic diffuse dorsal solid pilocytic astrocytoma of the medulla oblongata, pons, and fourth ventricle
Approach: Midline suboccipital

3.154a A large tumor is identified in a sagittal MR image.
3.154b The cerebellar hemisphere, vermis, and foramen of Magendie are exposed through a midline suboccipital exposure.
3.154c The two tonsils are separated, and the tumor is visible inside the fourth ventricle.
3.154d The floor of the fourth ventricle becomes visible through the distal membrane of the tumor, which has been largely evacuated.

3.154e After tumor evacuation, the floor of the fourth ventricle and tumor cavity become visible.
Intrinsic Focal Tumors
Clinical Material
Case 1
Diagnosis: Intrinsic focal solid lipoastrocytoma of the medulla oblongata and pons
Approach: Midline suboccipital

3.155a–c MR images demonstrate a large, unusual tumor in the fourth ventricle, which appears to infiltrate the brain stem.

3.155d The cerebellar hemispheres and tonsils are exposed through a midline suboccipital approach.
3.155e  A large, glistening tumor is encountered by splitting a portion of the vermis.

3.155f  A portion of the tumor contains fatty material.

3.155g  Removing the lipomatous portion of the tumor demonstrates that the tumor is not attached to the floor of the fourth ventricle.
Further resection of the tumor.

After maximal tumor resection, the floor of the fourth ventricle and the entrance to the aqueduct are visible.

A different angle on the proximal portion of the floor of the fourth ventricle reveals that it is uninvolved with the tumor.
3.155 k, I  Postoperative CT scans demonstrate a large cavity filled with cerebrospinal fluid and air, where the tumor was resected.
3. Case 2
Diagnosis: Intrinsic focal solid pilocytic astrocytoma of the medulla oblongata
Approach: Midline suboccipital

3.156a An axial CT image reveals a circumscribed solid tumor in the medulla oblongata.

3.156b A suboccipital exposure of the medulla just below the tonsils exposes a discolored area above the loop of the posterior inferior cerebellar artery.

3.156c The medulla is opened, and the pilocytic astrocytoma is removed.

3.156d The tumor bed is visible just above the posterior inferior cerebellar artery, which is in spasm.
Case 3
Diagnosis: Intrinsic focal solid pilocytic astrocytoma of the pons and medulla oblongata (with hemorrhages)
Approach: Midline suboccipital

3.157a The foramen of Magendie and tonsil are exposed through a midline suboccipital craniotomy.

3.157b The floor of the fourth ventricle is exposed, and discoloration on the floor of the fourth ventricle is visible.

3.157c As the floor of the fourth ventricle is exposed further, the second hemosiderin-stained area becomes visible.
3.157d Using an opening into the larger discoloration on the floor of the fourth ventricle, a pilocytic astrocytoma is exposed and removed piecemeal.

3.157e The tumor cavity after tumor removal.

3.157f Overview of the floor of the fourth ventricle shows the tumor cavity and the discoloration of the floor of the fourth ventricle. Notice the choroid plexus bilaterally.
Case 4
Diagnosis: Intrinsic focal dorsolateral solid pilocytic astrocytoma of the medulla oblongata
Approach: Paramedian suboccipital

3.158a A paramedian exposure of the cisterna magna reveals a markedly expanded medulla oblongata, with a tumor cyst sitting in the lateral subarachnoid space. The right tonsil is slightly displaced upwards by the mass.

3.158b Both tonsils, on either side of the markedly expanded medulla oblongata with a paramedullary exophytic tumor cyst, are exposed.

3.158c After emptying the tumor cyst located in the subarachnoid space, the medulla is opened. Another cyst and the tumor tissue are identified within the brain stem. Excellent differentiation between tumor and normal medulla allowed virtual total gross removal of this tumor.
Case 5
Diagnosis: Intrinsic dorsolateral diffuse solid pilocytic astrocytoma of the pons and left middle cerebellar peduncle
Approach: Paramedian suboccipital

3.159a Following a paramedian lateral exposure of the posterior fossa, the markedly expanded cerebellar peduncle is identified.

3.159b A small opening within the brainstem reveals a soft, friable astrocytoma, which was partially removed.
Exophytic Focal Tumors

Clinical Material

Case 1

Diagnosis: Exophytic dorsal focal cystic pilocytic astrocytoma of the medulla oblongata and fourth ventricle

Approach: Midline suboccipital

3.160a The floor of the fourth ventricle has been exposed through which a cyst emerges, associated with an intramedullary tumor.

3.160b With some further exposure, the cyst and tumor are better appreciated. Decompression of medulla oblongata by evacuation of cyst.
Case 2
Diagnosis: Exophytic dorsolateral focal cystic pilocytic astrocytoma of the pons (cerebellopontine angle)
Approach: Right retromastoid

3.161a After exposure of the right cerebellopontine angle, the ninth and tenth nerve complex and seventh and eighth nerve complex are visualized. The tumor cyst has been opened.

3.161b Following removal of the tumor cyst wall, the seventh and eighth nerve complex, the trigeminal nerve, the third nerve, and the optic tract are exposed.

3.161c By focusing deeper, the third nerve covered with some subarachnoid hemosiderin can be seen above the anterior cerebral artery, which disappears in front of the optic tract.
3.161d By moving the microscope farther medially, an unusual view of the pituitary stalk can be appreciated. This posterior visualization of the pituitary stalk was made possible by the large displacement and distortion produced by the tumor cyst.
Case 3
Diagnosis: Exophytic dorsolateral focal solid pilocytic astrocytoma of the medulla oblongata (cerebellopontine angle)
Approach: Paramedian suboccipital

3.162a Following exposure of the right cerebellopontine angle, a soft, friable mass is encountered.

3.162b Following removal of the exophytic astrocytoma, the eighth nerve can be seen in its entirety from the brain stem to the internal acoustic porus.
Cavernous Malformations
Clinical Material
Case 1
Diagnosis: Cavernous malformation of the medulla oblongata and the upper cervical cord (cranio-cervical junction)
Approach: Midline suboccipital and C1-C3 cervical

3.163a A mass lesion is identified at the cervicomedullary junction on a midline sagittal MR image.

3.163b With a transverse section, the lesion is identified at the left of the medulla.

3.163c Using a midline, suboccipital approach and a C1-C2 laminectomy, the tonsils and cervicomedullary junction become visible. The surface of the left medulla is discolored from multiple hemorrhages.

3.163d The medulla is opened and a typical cavernous malformation identified.
3.163e The cavernous malformation is mobilized and removed.

3.163f After the cavernous malformation has been removed, the appearance of the cavity is typical. A speckled, hemosiderin-like appearance demarcates the tumor from the medulla. However, in this case, a large venous malformation is adjacent to the cavernous malformation, and can be seen in the bed of the tumor cavity. This association has occurred in 5–8% of our series. Furthermore, another small cavernous malformation in the cervical spinal cord was removed 0.5 cm below the larger one, which was not directly contiguous with the other lesion.
3.163g Inspection of the bed reveals that both cavernous malformations have been completely removed. Great care was exercised to avoid injuring the associated venous malformation, which is responsible for a significant portion of the normal drainage of the surrounding brain stem tissue.

3.163h An overview shows the two tumor cavities and the preservation of the fine vascular network. Note the eleventh cranial nerve and the vertebral artery on the left.
Case 2
Diagnosis: Cavernous malformation of the medulla oblongata
Approach: Midline suboccipital

3.164a A coronal MR image reveals the typical appearance of a cavernous malformation within the medulla oblongata.

3.164b A sagittal MR image places the cavernous malformation in the floor of the fourth ventricle.

3.164c Using a midline suboccipital approach, the floor of the fourth ventricle has been exposed by elevating the vermis.

3.164d Higher magnification demonstrates the hemosiderin-containing wall of the cavernous malformation.

3.164e Diagram showing the surgical approach and anatomical structures involved.
3.164e The cavernous malformation is carefully exposed by dissecting along the wall of the lesion, which is clearly identified by the layer of hemosiderin.

3.164f A substantial portion of the tumor has been removed, and only a distal component remains.

3.164g After the cavernous malformation has been completely removed, the cavity is visualized. Note that the fine vasculature of the floor of the fourth ventricle is preserved.
Congenital Malformations

Clinical Material

Case 1
Diagnosis: Arachnoidal cyst of the cisterna magna with congenital cerebellar defect (child)
Approach: Midline suboccipital

3.165a A large cyst is encountered after opening the posterior fossa in the midline and opening the cisterna magna.

3.165b The congenital defect in the left cerebellar hemisphere becomes visible after partial resection of the cyst wall.

3.165c The floor of the fourth ventricle is exposed following further resection of the cyst wall.
Note the congenital lesion of the left cerebellar hemisphere. The patient presented with hydrocephalus.
Case 2
Diagnosis: Arnold-Chiari malformation (adult)
Approach: Midline suboccipital with laminectomy of C1 and C2

3.166a The opening of the arachnoid at the occipitocervical junction reveals dural adhesions and thickened arachnoid.

3.166b On opening the arachnoid, the markedly downward displaced and compressed tonsils are visualized. Below the right tonsil, the medullary malformation, i.e., the buckling that occurs in association with this condition, is seen.

3.166c Further dissection of the tonsils exposes the extensive buckling of the medulla oblongata. On initial inspection, this may be confused with a tumor mass, and a mistaken biopsy or resection is less than desirable.
The foramen of Magendie is opened. A large dural graft will be sewn into the dural opening to provide ample room for the tonsils, medulla and medullary kinking.

An MR scan (sagittal image) demonstrates the downward displacement of the cerebellar tonsils through the foramen magnum, and the buckling of the medulla oblongata at the foraminal level.
Case 3
Diagnosis: Arnold-Chiari malformation (adult), associated with syringomyelia
Approach: Midline suboccipital and C1-C3 spinal

3.167a MR Image, left lateral view, reveals an Arnold-chiari malformation with a myelodural cavity extending from the C1-level through the cervical cord.

3.167b Using a midline suboccipital craniotomy and cervical laminectomy, the opened dura reveals a typical Arnold-Chiari malformation.

3.167c After all the arachnoid adhesions have been separated carefully, the foramen of Magendie is still covered with a thin membrane.

3.167d With further dissection, the foramen of Magendie is completely opened.

3.167e Diagram of relevant anatomical structures.
3.167e An overview of the foramen of Magendie.

3.167f The lower cervical spinal cord is distended by an associated syrinx.

3.167g The syrinx has been opened through a midline myelotomy.

3.167h A small Silastic catheter has been inserted into the syrinx to go into the subarachnoid space. Notice the preservation of the vascularity and the collapsed spinal cord (Recently, decompression of the foramen magnum alone results in a high percentage of associated syringes that disappear over time.)
Case 4
Diagnosis: Dandy-Walker malformation (child)
Approach: Midline suboccipital

3.168a Following a midline approach, the opened dura reveals a large cisterna magna cyst.

3.168b After opening the cyst, one can appreciate the inner wall of the cyst, which is occluding the foramen of Magendie. The tonsils are high, and possibly maintained in this position by the large cyst.

3.168c After opening the inner wall of the cyst, the fourth ventricle can be seen, with some buckling of the medulla oblongata.
3.168d A lower magnification demonstrates the high, abnormal tonsils, with the cerebellar hemispheres laterally and superiorly.
Case 5
Diagnosis: Dandy-Walker malformation with extensive congenital cerebellar defects (child)
Approach: Midline suboccipital

3.169a This CT scan demonstrates a large posterior fossa subarachnoid cyst. Notice the enhancing membrane over the right portion of the remaining cerebellum. The pontine cisterns and fourth ventricle are slightly distorted. Subtle cerebellar symptoms progressing over the previous twelve years indicated this study.

3.169c Following a midline approach, a large cerebellar cyst occupied the greater portion of the posterior fossa. A malformed vermis extends over the misplaced foramen of Magendie. The cerebellar tonsils have been displaced by the cyst, and meet below the foramen of Magendie in the inferior portion of the posterior fossa. The arachnoid-covered tentorium and tentorial notch can be seen. Presumably, the large draining vessel from the cerebellum going anteriorly into the tentorial notch is an abnormal precentral cerebellar vein.

3.169b An MR scan demonstrates the subarachnoid cyst in white, overlying the residual vermis.
3.169d A higher magnified view of the tentorial notch demonstrates the precentral cerebellar vein and the obvious cerebellar malformation.

3.169e The foramen of Magendie with the abnormal inferior vermis is visualized.

3.169f The floor of the fourth ventricle is demonstrated by retracting the cerebellar hemispheres.
3.169g By looking farther into the fourth ventricle, the aqueduct of Sylvius is identified.
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