

Vinko V. Dolenc
Larry Rogers (eds.)

Cavernous Sinus

Developments and Future Perspectives

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Prof. Dr. Vinko V. Dolenc
University Ljubljana
Medical Center
Department of Neurosurgery
Ljubljana
Slovenia

Dr. Larry Rogers
Charlotte, NC, U.S.A.

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Preface

Treatment of cavernous sinus (CS) pathologies is still the subject of many discussions. The enthusiasm which was brought into the field of surgical treatment of vascular and tumorous pathologies of the region more than two decades ago has not faded away. On the contrary, the number of neurosurgeons who devoted enough time to the anatomy of the region are convinced that surgery will remain to be the most important modality of treatment for CS tumorous pathologies also in the future.

The introduction of radiosurgery into the field has not replaced neurosurgical treatment of tumors of the region; however, this is a very important adjunct treatment modality to surgery. The endovascular treatment of the ICA aneurysms in the CS becomes an important modality and has a great future because it is believed that the balloon(s), coils, and glue should be combined with the stenting of the ICA at the skull base aneurysms. However, even the most sophisticated and advanced endovascular treatment will not be able to rule out surgery, in particular in those fusiform aneurysms in which a long segment of the ICA has to be repaired in order to provide the patency of the ICA. And if endovascular treatment of this kind of lesions will not provide an acceptable solution, and direct neurosurgery will not be in the position to reconstruct the diseased ICA, then either a short high-flow by-pass or another kind of

by-passing of the blood flow will be needed, and will only be possible by surgical techniques. The alternative answer in this kind of treatment will be found in a combination of different procedures of different modalities in order to provide this end result.

The advancement in treatment of vascular and tumorous pathologies in the central skull base during the last two decades has been great in understanding of the normal and pathological anatomy as well as in eradicating the pathologies. In the surgical domain of treatment of tumorous pathologies of the central skull base, the major advancement has been in refining the approaches from above, that is transcranial, as well as from below, that is splanchnocranial.

The initial enthusiasm for each of the transcranial and splanchnocranial approaches has reached already the zenith and is now on the level which does allow co-existence of the other approaches as well. And again, in the future, a combination of the transcranial and splanchnocranial approaches will be used more frequently for the same pathology. It is evident that when surgery will not be successful in total eradicating the tumorous lesion, radiosurgery – Gamma Knife, Proton Beam treatment, etc. – will be included accordingly.

Vinko V. Dolenc
October 2008

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List of contributors

K. M. **Abdel Aziz**, Department of Neurosurgery, Allegheny General Hospital, Pittsburgh, PA, USA

O. **Al-Mefty**, Department of Neurosurgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

G. W. **Britz**, Department of Neurological Surgery, University of Washington, Seattle, WA, USA

P. **Cappabianca**, Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Naples, Italy

L. M. **Cavallo**, Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Naples, Italy

E. **de Divitiis**, Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Naples, Italy

O. **de Divitiis**, Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Naples, Italy

V. V. **Dolenc**, International Institute for Neurosurgery and Neuroresearch (IINN), Ljubljana, Slovenia

W. **Eisner**, Neurosurgical Department, Medical University Innsbruck, Innsbruck, Austria

F. **Esposito**, Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Naples, Italy

T. **Fiegele**, Neurosurgical Department, Medical University Innsbruck, Innsbruck, Austria

E. G. **Figueiredo**, Department of Neurological Surgery, University of Sao Paulo School of Medicine, Sao Paulo, Brazil

S. **Froelich**, Department of Neurosurgery, Strasbourg University, CHU de Hautepierre, Strasbourg, France

R. J. **Galzio**, Department of Neurosurgery, University of L'Aquila, L'Aquila, Italy

V. M. **Gerganov**, International Neuroscience Institute-Hannover, Hannover, Germany

B. **Ghodke**, Department of Neurological Surgery, University of Washington, Seattle, WA, USA

A. **Goel**, Department of Neurosurgery, King Edward Memorial Hospital, Seth G.S. Medical College, Parel, Mumbai, India

J. A. **Heth**, Department of Neurosurgery, University of Michigan Health System, Ann Arbor, MI, USA

J. T. **Keller**, Department of Neurosurgery, University of Cincinnati College of Medicine, Cincinnati, OH, USA

I. **Kocijančič**, International Institute for Neurosurgery and Neuroresearch (IINN), Ljubljana, Slovenia

J. L. **Leach**, The Neuroscience Institute,
Department of Radiology, University of Cincinnati
College of Medicine, Cincinnati, OH, USA

C. **Lindquist**, Gamma Knife Centre,
The Cromwell Hospital, London, UK

H. R. van **Loveren**, Department of Neurosurgery,
University of South Florida, Tampa, FL, USA

D. **Muzumdar**, Department of Neurosurgery,
King Edward VII Memorial Hospital and
Seth G.S. Medical College, Parel, Mumbai, India

T. D. **Nadkarni**, Department of Neurosurgery,
King Edward Memorial Hospital, Seth G.S.
Medical College, Parel, Mumbai, India

S. K. **Natarajan**, Department of Neurological
Surgery, University of Washington, Seattle,
WA, USA

E. **de Oliveira**, Instituto de Ciências
Neurológicas, Sao Paulo, Brazil

R. **Pregelj**, International Institute for Neurosurgery
and Neuroresearch (IINN), Ljubljana, Slovenia

A. L. **Rhoton, Jr.**, Department of Neurosurgery,
University of Florida, Gainesville, FL, USA

M. **Samii**, International Neuroscience
Institute-Hannover, Hannover, Germany

L. N. **Sekhar**, Department of Neurological Surgery,
University of Washington, Seattle, WA, USA

W. M. **Tavares**, Department of Neurological
Surgery, University of Sao Paulo School of Medicine,
Sao Paulo, Brazil

M. **Tschabitscher**, Microsurgical & Endoscopic
Anatomy, University of Vienna, Vienna, Austria

Chapter 1. Anatomy of the cavernous sinus

The middle cranial base and cavernous sinus

A. L. Rhoton, Jr.

Department of Neurosurgery, University of Florida, Gainesville, FL, USA

Introduction

The middle cranial base can be divided into a medial portion, the sellar and the parasellar region, where the pituitary gland and cavernous sinus are located and a lateral portion, containing the middle cranial fossa and the upper surface of the temporal bone (Fig. 1). The focus of this paper is the cavernous sinus and adjacent parts of the middle cranial fossa [22, 23].

The cavernous sinus

Although the anatomy of the cavernous sinus has been well described, the sinus remains a challenging and unfamiliar place for many neurosurgeons [23, 35]. Browder [3] and Parkinson [16] performed the first cavernous sinus approaches for the treatment of carotid–cavernous fistula, and Taptas [31], Dolenc [4–8], and Umansky [32, 33] were pioneers in studying this region. The paired cavernous sinuses are located near the center of the head on each side of the sella, pituitary gland, and sphenoid sinus (Fig. 2). Each sinus has dural walls that surround a venous plexus and space through which a segment of the internal carotid artery courses. The dural envelope contains not only the cavernous carotid artery, but is also the site of a venous confluence that receives the terminal end of multiple veins draining the cerebrum, cerebellum, brainstem, face, eye, orbit, nasopharynx, mastoid, and middle

ear [10, 11] and has free communication with the basilar, superior and inferior petrosal, and intercavernous sinuses. The oculomotor, trochlear, and ophthalmic nerves course in the lateral wall. The abducens nerve courses on the medial side of the ophthalmic nerve between it and the internal carotid artery.

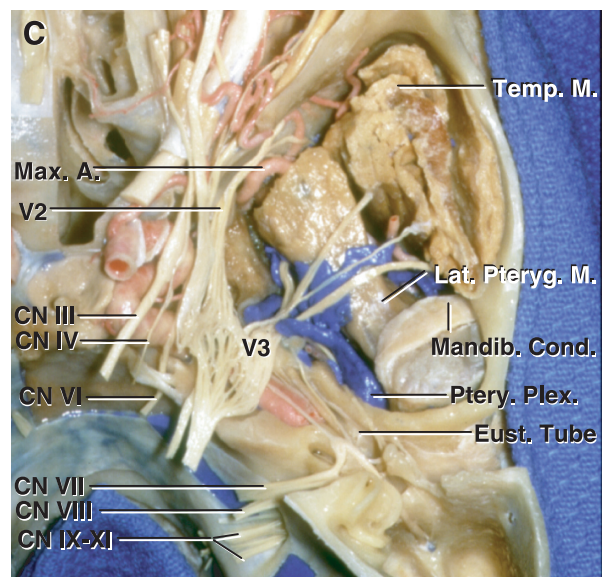
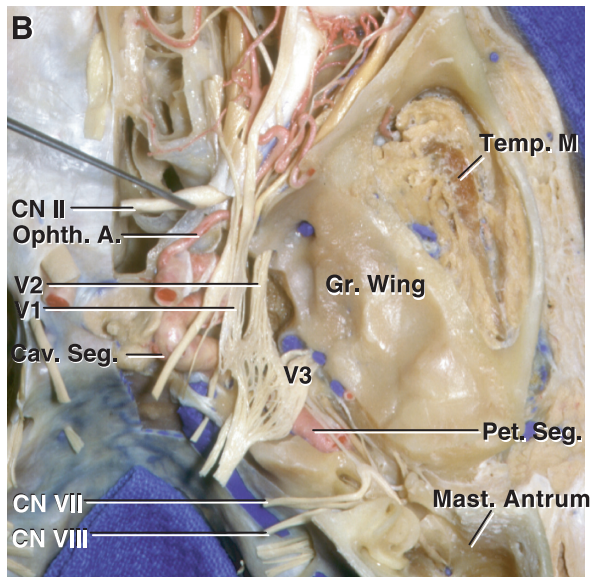
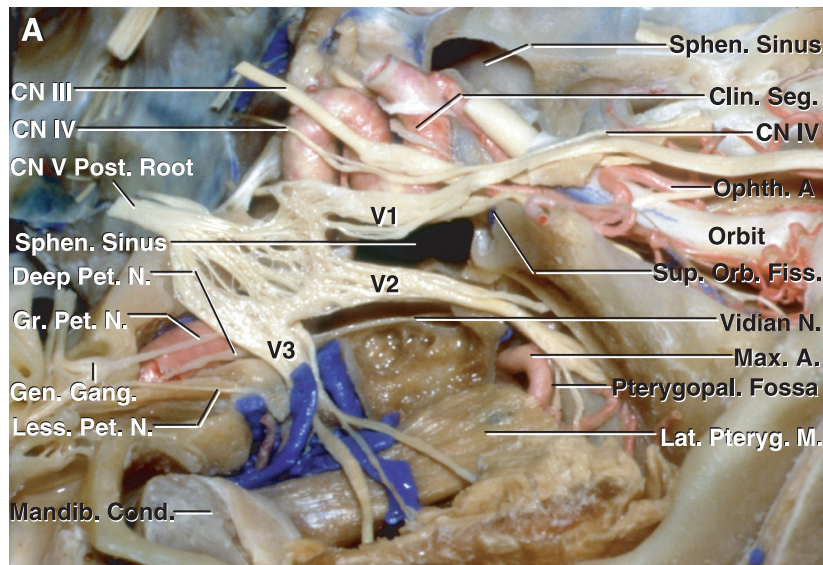
Overall, the sinus is shaped like a boat with its narrow keel located at the superior orbital fissure and its broader bow (posterior wall) located lateral to the dorsum sellae above the petrous apex (Fig. 3). The sinus has four walls: a roof and lateral, medial, and posterior walls. The wide deck or roof of the sinus faces upward and the narrow lower edge, at the junction of the medial and lateral walls, gives the sinus a triangular shape in cross-section. The roof is formed by the dura lining the lower margin of the anterior clinoid process anteriorly and the patch of dura, called the oculomotor triangle, through which the oculomotor nerve penetrates the sinus roof posteriorly.

The cavernous sinus has a wide posterior dural wall that it shares with the lateral part of the basilar sinus, which extends across the back of the upper clivus and dorsum sellae. The cavernous sinus opens into and communicates widely at its posterior end with the basilar sinus. The part of the posterior wall of the cavernous sinus shared with the basilar sinus is located lateral to the dorsum sellae, where the cavernous sinus opens into the basilar sinus and communicates with the superior and inferior petrosal sinuses. The lower margin of the posterior wall of the

cavernous sinus is located above the petrous apex at the upper margin of the petroclival fissure. The abducens nerve passes through the lower margin of the posterior wall and under the petrosphenoid ligament to enter the sinus. The upper edge of the posterior wall is located at the level of the posterior petroclinoid dural fold, which extends from the petrous apex to the posterior clinoid process. The lateral edge of the posterior wall is located just medial to the ostium of Meckel's cave, and the med-

ial edge is located at the lateral margin of the dorsum sellae.

The lateral wall extends from the medial edge of Meckel's cave posteriorly to the lateral margin of the superior orbital fissure anteriorly, and from the anterior petroclinoid dural fold above to the lower edge of the carotid sulcus below (Fig. 2). The carotid sulcus is the groove on the lateral aspect of the body of the sphenoid along which the internal carotid artery courses. The dura forming the posterior part of



the lateral wall of the sinus also forms the upper third of the medial wall of Meckel's cave.

The medial wall is formed by the dura that constitutes the lateral wall of the sella turcica and covers the lateral surface of the body of the sphenoid bone [36]. The medial wall extends from the lateral edge of the dorsum sellae posteriorly to the medial edge of the superior orbital fissure anteriorly, and from the interclinoid dural fold above to the lower edge of the carotid sulcus below. Anteriorly, the lower edge of the sinus, where the medial and lateral walls meet, is located just below where the ophthalmic nerve courses in the lateral sinus wall, and posteriorly, it is located medial to the junction of the upper and middle third of the gasserian ganglion and Meckel's cave. Only the upper part of the medial wall of Meckel's cave and the upper part of the gasserian ganglion are located directly lateral to the cavernous sinus; thus almost all of Meckel's cave is located below and lateral to the posterior part of the cavernous sinus.

The terminal part of the petrous carotid exits the carotid canal and passes under the trigeminal nerve and the petrolingual ligament, where it turns upward to enter the posterior part of the cavernous sinus.

The artery becomes enclosed in the dural envelope of the cavernous sinus after traveling below the petrolingual ligament to reach the carotid sulcus on the lateral surface of the sphenoid body (Fig. 2).

Numerous venous channels course along the lateral margin of the sella, the medial part of the middle fossa, the superior and inferior orbital fissures, the foramina ovale, rotundum, and spinosum and surrounding the pituitary gland. However, they course outside the dural envelope containing the internal carotid artery and open into the sinus through discrete ostia. The part of these veins outside the dural envelope form the pericavernous venous plexus. They become part of the cavernous venous plexus where they pass through the ostia in the dural wall of the sinus (Figs. 2 and 3).

Osseous relationships

The cavernous sinus sits on the lateral aspect of the body of the sphenoid bone and adjacent part of the petrous apex (Fig. 4) [24]. The lower edge of the posterior part of the lower edge of the sinus is positioned above the junction of the petrous apex and body of the sphenoid bone at the upper end of

Fig. 1. Lateral view of the right middle fossa. **A** The dura has been peeled away from the middle fossa and cavernous sinus and the floor of the middle fossa removed. The oculomotor and trochlear nerves enter the roof of the cavernous sinus and pass forward through the superior orbital fissure with the first trigeminal division. The cavernous sinus, located medial to the upper third of the gasserian ganglion, extends from the superior orbital fissure to the petrous apex. The carotid artery exits the cavernous sinus on the medial side of the anterior clinoid process, which has been removed. The bone between the first and second and the second and third trigeminal divisions has been drilled to expose the lateral wing of the sphenoid sinus. The vidian nerve, formed by the union of the greater and deep petrosal nerves, courses forward in the vidian canal to reach the pterygopalatine fossa. The posterior wall of the cavernous sinus extends laterally from the dorsum sellae to the medial edge of the ostium of Meckel's cave. Removal of the floor of the middle fossa exposes the infratemporal fossa, which contains the branches of the maxillary artery and the mandibular nerve, the pterygoid venous plexus, and the pterygoid muscles. The maxillary nerve courses just below the cavernous sinus and passes through the foramen rotundum to enter the pterygopalatine. **B** Superior view of middle cranial base. The floor of the middle fossa, except in the area above the temporalis muscle, has been preserved. The anterior part of the floor of the middle fossa is formed by the greater sphenoid wing, which roofs the infratemporal fossa, and the posterior part of the floor is formed by the upper surface of the temporal bone. The internal acoustic meatus, mastoid antrum, and tympanic cavities have been unroofed. The dural roof and lateral wall of the cavernous sinus have been removed. The petrous segment of the internal carotid artery is exposed lateral to the trigeminal nerve. The temporalis muscle is exposed in the temporal fossa lateral to the greater sphenoid wing. **C** The floor of the middle fossa has been removed to show the relationship below the floor. The temporalis muscle descends medial to the zygomatic arch in the temporal fossa to insert on the coronoid process of the mandible. The infratemporal fossa is located medial to the temporal fossa, below the greater sphenoid wing, and contains the pterygoid muscles and venous plexus and branches of the mandibular nerve and maxillary artery. The mandibular condyle rests in the mandibular fossa located below the posterior part of the middle fossa floor. A. artery; Cav. cavernous; Clin. clinoid; CN cranial nerve; Cond. condyle; Eust. eustachian; Fiss. fissure; Gang. ganglion; Gen. geniculate; Gr. greater; Lat. lateral; Less. lesser; M. muscle; Mandib. mandibular; Mast. mastoid; Max. maxillary; N. nerve; Ophth. ophthalmic; Orb. orbital; Pet. petrosal, petrous; Plex. plexus; Post. posterior; Pteryg. pterygoid; Pterygopal. pterygopalatine; Seg. segment; Sphen. sphenoid; Sup. superior; Temp. temporal

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