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
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Chapter 1. Anatomy of the cavernous sinus
The middle cranial base and cavernous sinus

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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
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 medial 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
the petroclival fissure. The posterior edge of the medial wall rests against the lateral edge of the dorsum sellae. The cavernous sinus extends downward and laterally from the lateral margin of the sella, across the sphenoid body to the junction of the body and greater sphenoid wing of the sphenoid, but does not extend laterally to include the margins of the foramina ovale, rotundum, or spinosum, although venous channels coursing through and around these foramina empty into the sinus and are part of the pericavernous venous plexus. The inconsistently occurring sphenoid emissary foramen, situated medial to the foramen ovale, transmits an emissary vein from the cavernous sinus.

The carotid sulcus is the shallow groove on the lateral aspect of the body of the sphenoid bone along
which the intracavernous carotid courses. The artery sits against and is separated from the sulcus by the dura of the medial sinus wall (Fig. 4). The sulcus begins below and lateral to the dorsum sellae at the intracranial end of the carotid canal, turns forward on the body of the sphenoid immediately below the lateral edge of the floor of the sella, and curves upward along the medial to the anterior clinoid process. The segment of the internal carotid artery that courses along the medial side of the clinoid is referred to as the clinoid segment. The carotid sulcus, in well-pneumatized sphenoid bones, forms a serpiginous prominence that can be seen in the lateral wall of the sphenoid sinus below the pituitary fossa. The bone in the lateral wall of the sphenoid sinus may be thin or even absent in some areas, thus allowing the artery to be observed through the sinus wall [9].

The clinoid processes

The anterior clinoid process projects posteriorly from the lesser wing of the sphenoid bone above the anterior part of the roof of the sinus (Fig. 4). The base of the clinoid has three sites of continuity with the adjacent parts of the sphenoid bone. The base is attached anteriorly at the medial edge of the lesser sphenoid wing, and medially to the anterior and posterior roots of the lesser wing. The anterior root of the lesser wing extends medially from the base of the anterior clinoid to the body of the sphenoid bone.

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Fig. 2. Stepwise dissection of the right cavernous sinus. A The lateral wall of the cavernous sinus extends downward from the tentorial edge and blends into the dura covering Meckel’s cave and the middle fossa. The oculomotor and trochlear nerves enter the roof of the cavernous sinus. The carotid artery exits the cavernous sinus on the medial side of the anterior clinoid process. B The outer layer of dura has been peeled away from the lateral wall of the cavernous sinus and Meckel’s cave. This exposes the oculomotor and trochlear nerves entering the roof of the cavernous sinus and passing forward through the superior orbital fissure. The thin layer covering Meckel’s cave consists in part of the arachnoid membrane extending forward from the posterior fossa and surrounding trigeminal nerve to the level of the midportion of the trigeminal ganglion. The superior petrosal sinus passes above the ostium of Meckel’s cave and joins the posterior part of the cavernous sinus. C The oculomotor nerve enters a short cistern in the sinus roof (red arrow) and does not become incorporated into the lateral sinus wall until it reaches the lower margin of the anterior clinoid process (yellow arrow). The arachnoid covering of Meckel’s cave, which extends forward around the posterior trigeminal root to the level of the midportion of the ganglion, has been removed. The cavernous sinus extends from the superior orbital fissure to the petrous apex. It is located medial to the upper third of the gasserian ganglion. The pericavernous venous plexus surrounds the maxillary and mandibular nerves in the region of the foramen rotundum and ovale. D The remaining dura covering the lateral sinus wall has been removed. The oculomotor, trochlear, and ophthalmic nerves pass forward and converge on the superior orbital fissure. The segment of the superior petrosal sinus above the posterior trigeminal root has been removed. The venous plexus surrounding the nerves has been removed to expose the trigeminal divisions and the nerves coursing in the wall of the cavernous sinus. The ophthalmic nerve has been depressed to expose the abducens nerve, which passes under the petrosphenoid ligament roofing Dorello’s canal, and courses medial to the ophthalmic nerve. The abducens nerve crosses below the ophthalmic nerve as it passes through the superior orbital fissure. E The anterior clinoid process has been removed. The optic strut separates the optic canal and superior orbital fissure. The dura extending medially off the upper surface of the anterior clinoid forms the upper dural ring around the internal carotid artery, and the dura lining the lower margin of the clinoid extends medially to form the lower dural ring. The clinoid segment of the carotid artery, located between the upper and lower ring, is enclosed in the dura sheath, referred to as the carotid collar. The trigeminal nerve has been folded downward to expose the petrolingual ligament, which extends above the internal carotid artery, just proximal to where the artery enters the cavernous sinus. The abducens nerve passes around the internal carotid artery and courses medial to the ophthalmic nerve in the lower part of the cavernous sinus. The margins of the cavernous sinus are shown with a broken line. The cavernous sinus does not extend laterally into the area of the trigeminal impression where Meckel’s cave’s sets. F Enlarged view. The optic nerve has been elevated to expose the ophthalmic artery coursing within the optic sheath. At the orbital apex, the artery penetrates the optic sheath and enters the orbital apex on the lateral side of the optic nerve. Removal of additional optic strut exposes the mucosa lining the sphenoid sinus on the medial side of the optic strut. A. artery; Ant. anterior; Car. carotid; Cav. cavernous; Cist. cistern; Clin. clinoid; CN cranial nerve; Div. division; Fiss. fissure; Gang. ganglion; Gr. greater; Impress. impression; Inf. inferior; Inf. Lat. inferolateral; Lig. ligament; Men. meningeal; Mid. middle; N. nerve; Oculom. oculomotor; Ophth. ophthalmic; Orb. orbital; Pericav. pericavernous; Pet. petrosal, petrous; Petroling. petrolingual; Petrophen. petrosphenoid; Plex. plexus; Post. posterior; Rec. recurrent; Seg. segment; Sup. superior; Tent. tentorial; Tr. trunk; Trig. trigeminal; Troch. trochlear; Ven. venous
and forms the roof of the optic canal. The posterior root of the lesser wing, called the optic strut, extends medially below the optic nerve to the sphenoid body and forms the floor of the optic canal. The base of the anterior clinoid forms the lateral margin of the optic canal.

The segment of the internal carotid artery that courses along the medial aspect of the anterior
The optic strut (posterior root of the lesser wing) is a small bridge of bone that extends from the inferomedial aspect of the base of the anterior clinoid process to the body of the sphenoid just in front of the carotid sulcus (Figs. 2–4) [25]. The strut, from its junction with the clinoid, slopes gently downward and medially as it approaches the body of the sphenoid. The strut separates the optic canal and superior orbital fissure. The superior surface of the strut, which slopes downward and forward from its intracranial edge, forms the floor of the optic canal. The lower surface of the optic strut forms the medial part of the roof of the superior orbital fissure and the anterior part of the roof of the cavernous sinus. The strut sits at the junction of the orbital apex anteriorly, with the superior orbital fissure and optic canal posteriorly. The anterior edge of the strut is a narrow ridge located at the junction of its superior and inferior surfaces. The posterior face of the optic strut, which faces slightly downward, is shaped to accommodate the anterior surface of the anterior part of the roof of the cavernous sinus. The air cells in the sphenoid sinus may also extend through the optic strut into the anterior clinoid.

**Fig. 3.** A Superior view of the cranial base in the region of the cavernous sinus. The cavernous sinus extends from the superior orbital fissure anteriorly, to the petrous apex posteriorly, and it is bordered by the sella medially and the middle fossa laterally. It fills the posterior margin of the superior orbital fissure, which is located below the anterior clinoid process and its posterior wall, extends from the lateral edge of the dorsum sellae to the medial margin of the trigeminal impression and Meckel’s cave. Numerous venous channels open into the cavernous sinus. These include the basilar, anterior and posterior intercavernous, and the superior and inferior petrosal sinuses; the sylvian and ophthalmic veins, and the veins exiting the foramen ovale, rotundum, and spinosum; and the carotid canal and the sphenoidal emissary foramen. Each structure is shown by colored arrows. The basilar sinus is the largest communicating channel between the cavernous sinuses. B Superior view. The anterior clinoid process has been removed. The outer layer of dura covering the roof and lateral wall of the cavernous sinus has been removed while preserving the inner layer in which the nerves course. The roof of the cavernous sinus is formed anteriorly by the dura lining the lower margin of the anterior clinoid and posteriorly by the dura covering the oculomotor triangle. The roof of the optic canal has been opened to facilitate exposure of the ophthalmic artery. Removing the anterior clinoid exposes the clinoideal triangle located between the optic and oculomotor nerves. The dura extending medially off the upper surface of the clinoid forms the upper dural ring. The dura separating the lower surface of the clinoid from the oculomotor nerve and extending medially around the carotid artery, referred to as the carotidoculomotor membrane, forms the floor of the clinoideal triangle and the anterior part of the roof of the cavernous sinus. The carotidoculomotor membrane extends medially to form the lower dural ring. The dura in the floor of the clinoideal triangle and roof of the oculomotor triangle together form the roof of the cavernous sinus. C The sinus has been cleared of the material in the venous system and the inner layer of dura has been removed to expose the clinoideal segment of the internal carotid artery in the clinoideal triangle and the posterior bend of the intercavernous carotid below the oculomotor triangle. The anterior part of the roof is formed by the dura that separates the anterior clinoid and oculomotor nerve and that extends medially to form the lower dural ring. The posterior part of the roof is formed by the dura forming the oculomotor triangle. D The dura has been removed from the roof and lateral wall of another cavernous sinus to expose the passage of nerves through the sinus. The abducens nerve passes below the petrosphenoid ligament and around the lateral surface of the internal carotid artery. E Superior view of the cavernous sinus with the anterior clinoid process and roof removed. The lateral wall of the cavernous sinus, in which the oculomotor, ophthalmic, and trochlear nerves course, has been retracted laterally to show the lower margin of the sinus from inside. Numerous ostia of veins drain the surrounding areas open into the cavernous sinus (arrows). The ophthalmic artery enters the optic canal. A. artery; Ant. anterior; Bas. basal; Car. carotid; Cav. cavernous; Clin. clinoid; CN cranial nerve; Em. emissary; For. foramen; Hyp. hypophyseal; Impress. impression; Inf. inferior; Intercav. intercavernous; Lig. ligament; Men. Hyp. meningohypophyseal; Oculom. oculomotor; Ophth. ophthalmic; P.C.A. posterior cerebral artery; Pet. petrosal; Petrosphen. petrosphenoid; Post. posterior; S.C.A. superior cerebellar artery; Seg. segment; Sphen. sphenoid; Sup. superior; Tent. tentorial; Triang. triangle; Trig. trigeminal; V. vein; Ven. venous
Dural relationships

The consistent nature of the dural layers and folds in the walls and roof of the cavernous sinus provides important landmarks used in surgery. The dural structures include the upper (or distal) and lower (or proximal) carotid dural rings, the carotid collar, and the triangles of the roof and lateral wall of the sinus (Figs. 2 and 3). The dura lining and extending medially from the upper surface of the anterior clinoid forms the lateral part of a dural ring, referred to as the upper or distal ring, which defines the upper margin of the carotid’s clinoid segment [29]. The dura forming the lateral part of the upper ring extends forward and medially below the optic nerve to line the upper surface of the optic strut and forms the anterior part of the upper ring. The dura lining the upper surface of the optic strut extends medially and posteriorly at the level of the upper part of the carotid sulcus to form the medial part of the upper ring. Further medially, the dura forming the upper ring blends into the diaphragma sellae.

The lower or proximal dural ring is formed by the layer of dura that lines and extends medially from the lower margin of the anterior clinoid. This layer of dura is called the carotidoculomotor membrane because it separates the lower margin of the clinoid from the oculomotor nerve and extends medially around the carotid artery.

The segment of the internal carotid artery located between the upper and lower dural rings, which is exposed by removing the anterior clinoid process, is referred to as the clinoid segment. It may be necessary to divide the dural rings to mobilize the carotid artery for dealing with aneurysms arising from the internal carotid artery at the level of the roof of the cavernous sinus and origin of the ophthalmic artery.

The dura lining the middle fossa lateral to the cavernous sinus has an inner layer that adheres to the
bone and is called the endosteal layer, and the outer layer faces the brain and is called the meningeal layer (Fig. 5) [35, 36]. The two layers separate at the lower lateral edge of the cavernous sinus and the meningeal layer and outer part of the endosteal extends upward to form the lateral wall of the cavernous sinus, whereas the inner part of the endosteal layer continuous medially to form part of the medial sinus wall. Dissections of the lateral sinus wall reveal that the thicker outer layer (a continuation of the meningeal layer) peels away, leaving the thin inner layer (a continuation of the endosteal layer) that invests the nerves in the lateral wall. The lateral sinus wall blends into the dura covering Meckel’s cave. The lower edge of the lateral wall of the cavernous sinus joins the medial wall of the cavernous sinus below the carotid sulcus in a “keel-like” formation at the level of the superior margin of the maxillary nerve.

The medial wall of the cavernous sinus is divided into a sellar part and a sphenoidal part. In our anatomic dissections, we have found the sellar part of the medial wall to be a continuation of the dura covering Meckel’s cave. The lower edge of the lateral wall of the cavernous sinus joins the medial wall of the cavernous sinus below the carotid sulcus in a “keel-like” formation at the level of the superior margin of the maxillary nerve.

Neural relationships

The nerves in the sinus wall or sinus are, from superior to inferior, the oculomotor, trochlear, ophthalmic, and abducens nerves (Figs. 1–3). A sympathetic nerve plexus accompanies the carotid artery through the sinus [10, 11]. The oculomotor, trochlear, and ophthalmic nerves course in the inner part of the lateral sinus wall. The abducens courses medial to the ophthalmic nerve and is adherent to the lateral surface of the intracavernous carotid medially, but it also is adherent laterally to the medial surface of the ophthalmic nerve and the inner part of the lateral sinus wall.

The oculomotor nerve pierces the roof of the cavernous sinus near the center of the oculomotor triangle, and the trochlear nerve enters the dura at the posterolateral edge of the triangle. A short length of both trochlear and oculomotor nerves are surrounded by a dural and arachnoid cuff to create the oculomotor and trochlear cisterns as they pass through the roof of the cavernous sinus and below the anterior clinoid process. Both nerves are situated medial to and slightly beneath the level of the free edge of the tentorium at their point of entry.

The trochlear nerve enters the roof of the sinus posterolateral to the oculomotor nerve and courses below the oculomotor nerve in the posterior part of the lateral wall. Anteriorly, below the base of the anterior clinoid process, it passes upward along the lateral surface of the oculomotor nerve. From there,
the trochlear nerve passes medially between the oculomotor nerve and dura lining the lower margin of the anterior clinoid and optic strut to reach the medial part of the orbit and the superior oblique muscle.

The ophthalmic nerve is the smallest of the three trigeminal divisions. It is inclined upward as it passes forward near the medial surface of the dura, forming the lower part of the lateral wall of the cavernous sinus, to reach the superior orbital fissure. The ophthalmic nerve splits into the lacrimal, frontal, and nasociliary nerves as it approaches the superior orbital fissure.

The superior petrosal sinus passes above the posterior root of the trigeminal root to form the upper margin of the ostium of Meckel’s cave, the dural and subarachnoid cavern, which communicates with the subarachnoid space in the posterior fossa. The cave extends forward around the posterior trigeminal root to the midportion of the ganglion.
The abducens nerve pierces the dura forming the lower part of the posterior wall of the sinus at the upper border of the petrous apex and enters a dural cave, referred to as Dorello’s canal, where it passes below the petrosphenoid ligament (Gruber’s ligament). The nerve bends laterally around the proximal portion of the intercavernous carotid and gently ascends as it passes forward inside the cavernous sinus medial to the ophthalmic nerve, on the lateral side of the internal carotid artery. After entering the sinus, it may split into as many as five rootlets as it courses between the internal carotid artery and ophthalmic nerve [10].

Sympathetic fiber bundles large enough to be recognized without a surgical microscope travel on the surface of the carotid as it emerges from the foramen lacerum. Some of the bundles join the V1th nerve within the sinus before ultimately being distributed through the first trigeminal division.

### Cavernous sinus and middle fossa triangles

Parkinson [17] described a triangle within the lateral wall of the cavernous sinus through which the intracavernous portion of the carotid artery and its branches might be exposed for the surgical treatment of carotid–cavernous fistulae. Since his pioneering work, a number of significant triangular relationships formed by the convergence and divergence of the cranial nerves in the region of the cavernous sinus and middle fossa have been defined. There are four cavernous sinus triangles, four middle fossae triangles

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**Fig. 4.** Osseous relationships of the cavernous sinus and carotid collar. A Superior view. The osseous structures, which nearly encircle the clinoid segment of the internal carotid artery, include the anterior clinoid laterally, the optic strut anteriorly, and the carotid sulcus medially. The carotid sulcus begins lateral to the dorsum sellae at the intracranial end of the carotid canal, extends forward just below the sellar floor, and turns upward along the posterior surface of the optic strut. The anterior clinoid process projects backward from the lesser wing of the sphenoid bone, often overlapping the lateral edge of the carotid sulcus. The anterior root of the lesser sphenoid wing extends medially to form the roof of the optic canal. The posterior root of the lesser wing, referred to as the optic strut, extends from the inferomedial aspect of the anterior clinoid to the sphenoid body. The bony collar around the carotid artery formed by the anterior clinoid, optic strut, and carotid sulcus is inclined downward as it slopes medially from the upper surface of the anterior clinoid to the carotid sulcus. Another small prominence, the middle clinoid process, situated on the upper border of the petrous apex and enters a dural cave, referred to as Dorello’s foramen; foramen lacerum. Some of the bundles join the V1th nerve within the sinus before ultimately being distributed through the first trigeminal division.

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**References:**

- Parkinson [17] described a triangle within the lateral wall of the cavernous sinus through which the intracavernous portion of the carotid artery and its branches might be exposed for the surgical treatment of carotid–cavernous fistulae. Since his pioneering work, a number of significant triangular relationships formed by the convergence and divergence of the cranial nerves in the region of the cavernous sinus and middle fossa have been defined. There are four cavernous sinus triangles, four middle fossae triangles.
lateral to the cavernous sinus, and two triangles in the paraclival area that are helpful in understanding and planning approaches to the cavernous sinus (Fig. 6). The cavernous sinus triangles are formed by the optic, oculomotor, trochlear, and ophthalmic nerves converging on the optic canal and superior orbital fissure. The middle fossa triangles are formed by the trigeminal divisions diverging as they pass from the gasserian ganglion to reach their foramina.

**Cavernous sinus triangles**

The roof and lateral wall of the cavernous sinus can be divided into four triangular areas: two in the roof and two on the lateral wall. The triangles in the roof are the clinoidal and oculomotor triangles (Fig. 6). The triangles on the lateral wall are the supratrochlear and infratrochlear triangles (or Parkinson’s triangle). The borders of the triangles in the roof of the cavernous sinus are formed by dural folds, whereas the borders of the triangles on the lateral wall are defined by neural structures.

**Clinoidal triangle (Dolenc’s triangle)** This triangle is situated in the interval between the upper and lower dural rings and the optic and oculomotor nerves. This triangle is exposed by removing the anterior clinoid process. The optic strut is in the anterior part, the clinoid segment of the internal
carotid artery is in the midportion, and the thin roof of the cavernous sinus is in the posterior part of this triangle.

**Oculomotor triangle**  This triangle is formed by the triangular patch of dura through which the oculomotor nerve enters the roof of the cavernous sinus. Two margins of this triangle are formed by the anterior and posterior petroclinoidal dural folds that extend, respectively, from the anterior and posterior clinoid processes to the petrous apex. The third side is formed by the interclinoïd dural fold that extends from the anterior to the posterior clinoid process.

**Supratrochlear triangle**  This triangle is situated between the lower surface of the oculomotor nerve and the upper surface of the trochlear nerve. A line joining the points of entrance of these nerves into the dura forms the third margin. This triangle is very narrow.

**Infra trochlear triangle (Parkinson’s triangle)**  This triangle is located between the lower margin of the trochlear nerve and the upper margin of the ophthalmic nerve. The third margin is formed by a line connecting the point where the ophthalmic nerve passes through the superior orbital fissure and the maxillary nerve passes through the foramen rotundum (Fig. 6). Removing bone in the triangular space between the ophthalmic or maxillary nerve opens into the sphenoid sinus.

Parkinson [16–18] first described the surgical exposure of the intercavernous portion of the carotid artery through this triangle for the treatment of carotid–cavernous fistulas. Parkinson [16], through an incision starting 4 mm beneath the dural entrance of the IIIrd nerve and extending anteriorly approximately 2 cm parallel to the slope of the IIIrd and IVth nerves, exposed the meningo hypophyseal trunk and the artery of the inferior cavernous sinus [10]. The VIth nerve at the bottom edge of the exposure was seen on retracting the superior aspect of the trigeminal nerve. Parkinson thought that the triangle would provide access to most spontaneous fistulas, assuming that they are due to ruptured aneurysms developing at the point of departure of the meningo hypophyseal trunk or artery of the inferior cavernous sinus.

**Middle fossa triangles**

**Anteromedial middle fossa triangle**  This triangle is situated between the lower margin of the ophthalmic and the upper margin of the maxillary nerves. The third edge is formed by a line connecting the point where the ophthalmic nerve passes through the superior orbital fissure and the maxillary nerve passes through the foramen rotundum (Fig. 6). Removing bone in the triangular space between the ophthalmic or maxillary nerve opens into the sphenoid sinus.

**Anterolateral middle fossa triangle**  This triangle is located between the lower surface of the maxillary nerve, the upper surface of the mandibular nerve, and a line connecting the foramen ovale and rotundum. Opening the bone in the medial wall of this triangle exposes the lateral wing of the sphenoid sinus.

**Posterolateral middle fossa triangle (Glasscock’s triangle)**  This triangle is formed on the anteriomedial side by the lateral surface of the mandibular nerve distal to the point at which the greater petrosal nerve crosses below the lateral surface of the trigeminal nerve. On the posterolateral side, it is formed by the anterior margin of the greater petrosal nerve. This triangle opens laterally to encompass the floor of the middle cranial fossa between these two structures. The middle meningeal artery passes through the foramen spinosum in this triangle. Opening the floor of the middle fossa in this triangle exposes the infratemporal fossa.

**Posteromedial middle fossa triangle (Kawase’s triangle)**  This triangle is located between the greater petrosal nerve, and the lateral edge of the trigeminal nerve behind the point where the greater petrosal nerve crosses below its lateral surface, and a line connecting the hiatus fallopii to the dural ostium of Meckel’s cave. The petrous segment of the internal carotid artery crosses the anterior margin of this triangle. The cochlea is located below the floor of the middle fossa in the lateral apex of the triangle. Removing the bone in the lateral part of the posteromedial triangle ex-
poses the cochlea and the anterior wall of the internal auditory canal, and removing the bone in the medial part of the posteromedial triangle exposes the side of the clivus and the inferior petrosal sinus. The approach directed through the petrous apex in this triangle is referred to as an anterior petrosectomy [12].

**Paraclinoid triangles**

**Inferolateral paraclival triangle** This triangle is located on the posterior surface of the clivus and temporal bone. The medial margin is formed by a line connecting the dural entry sites of the trochlear and abducens nerves; the upper margin ex-