2 Anatomy of the Pituitary Gland and Sellar Region

ALBERT L. RHOTON, JR., MD

INTRODUCTION

This chapter is divided into two sections. The first section deals with the relationships in the cranial base that are important in performing the various transcranial and subcranial approaches to the sellar region. The second section deals with the neural, arterial, and venous relationships in suprasellar and third ventricular regions that are important in planning surgery for pituitary adenomas.

SELLAR REGION

SPHENOID BONE The sphenoid bone is located in the center of the cranial base (Figures 1 and 2) *(1–4)*. The intimate contact of the body of the sphenoid bone with the nasal cavity below and the pituitary gland above has led to the transsphenoidal route being the operative approach of choice for most pituitary adenomas. Some part of it is also exposed in the transcranial approaches to the sellar region.

The neural relationships of the sphenoid bone are among the most complex of any bone: the olfactory tracts, gyrus rectus, and posterior part of the frontal lobe rest against the smooth upper surface of the lesser wing; the pons and mesencephalon lie posterior to the clival portion; the optic chiasm lies posterior to the chiasmatic sulcus; and the second through sixth cranial nerves are intimately related to the sphenoid bone. All exit the skull through the optic canal, superior orbital fissure, foramen rotundum, or foramen ovale, all foramina located in the sphenoid bone.

The sphenoid bone has many important arterial and venous relationships: the carotid arteries groove each side of the sphenoid bone and often form a serpiginous prominence in the lateral wall of the sphenoid sinus; the basilar artery rests against its posterior surface; the circle of Willis is located above its central portion; and the middle cerebral artery courses parallel to the sphenoid ridge of the lesser wing. The cavernous sinuses rest against the sphenoid bone, and intercavernous venous connections line the walls of the pituitary fossa and dorsum sellae.

In the anterior view the sphenoid bone resembles a bat with wings outstretched (Figures 1 and 2). It has a central portion called the body; the lesser wings, which spread outward from the superolateral part of the body; the two greater wings, which spread upward from the lower part of the body; and the superior orbital fissure, which is situated between the greater and lesser wings. The vomer, the pterygoid processes, and the medial and lateral pterygoid plates are directed downward from the body. The body of the sphenoid bone is more or less cubical and contains the sphenoid sinus. The superior orbital fissure, through which the oculomotor, trochlear, and abducens nerves and the ophthalmic division of the trigeminal nerve pass, is formed on its inferior and lateral margins by the greater wing and on its superior margin by the lesser wing. The inferior surface of the lesser wing forms the posterior part of the roof of each orbit, and the exposed surface of the greater wing forms a large part of the lateral wall of the orbit. The optic canals are situated above and are separated from the superomedial margin of the superior orbital fissure by the optic strut, a bridge of bone that extends from the lower margin of the base of the anterior clinoid process to the body of the sphenoid. The sphenoid ostia open from the nasal cavity into the sinus.

In the superior view, the pituitary fossa occupies the central part of the body and is bounded anteriorly by the tuberculum sellae and posteriorly by the dorsum sellae (Figure 1). The chiasmatic groove, a shallow depression between the optic foramina, is boundered posteriorly by the tuberculum sellae and anteriorly by the planum sphenoidale. The frontal lobes and the olfactory tracts rest against the smooth upper surface of the lesser wing and the planum sphenoidale. The posterior margin of the lesser wing forms a free edge called the sphenoid ridge, which projects into the Sylvian fissure to separate the frontal and temporal lobes. The anterior clinoid processes are located at the medial end of the lesser wings, the middle clinoid processes are lateral to the tuberculum sellae, and the posterior clinoid processes are situated at the superolateral margin of the dorsum sellae. The dorsum sellae is continuous with the clivus. The upper part of the clivus is formed by the sphenoid bone and the lower part by the occipital bone. The carotid sulcus extends along the lateral surface of the body of the sphenoid.

The superior aspect of each greater wing is concave upward and is filled by the tip of each temporal lobe. The foramen rotundum, through which the maxillary division of the trigeminal nerve passes, is located at the junction of the body and greater wing. The foramen ovale transmits the mandibular division of the trigeminal nerve, and the foramen spinosum transmits the middle meningeal artery. When viewed from inferiorly, the vomer, a separate bone,

From: *Diagnosis and Management of Pituitary Tumors* (K. Thapar, K. Kovacs, B. W. Scheithauer, and R. V. Lloyd, eds.), ©Humana Press Inc., Totowa, NJ.

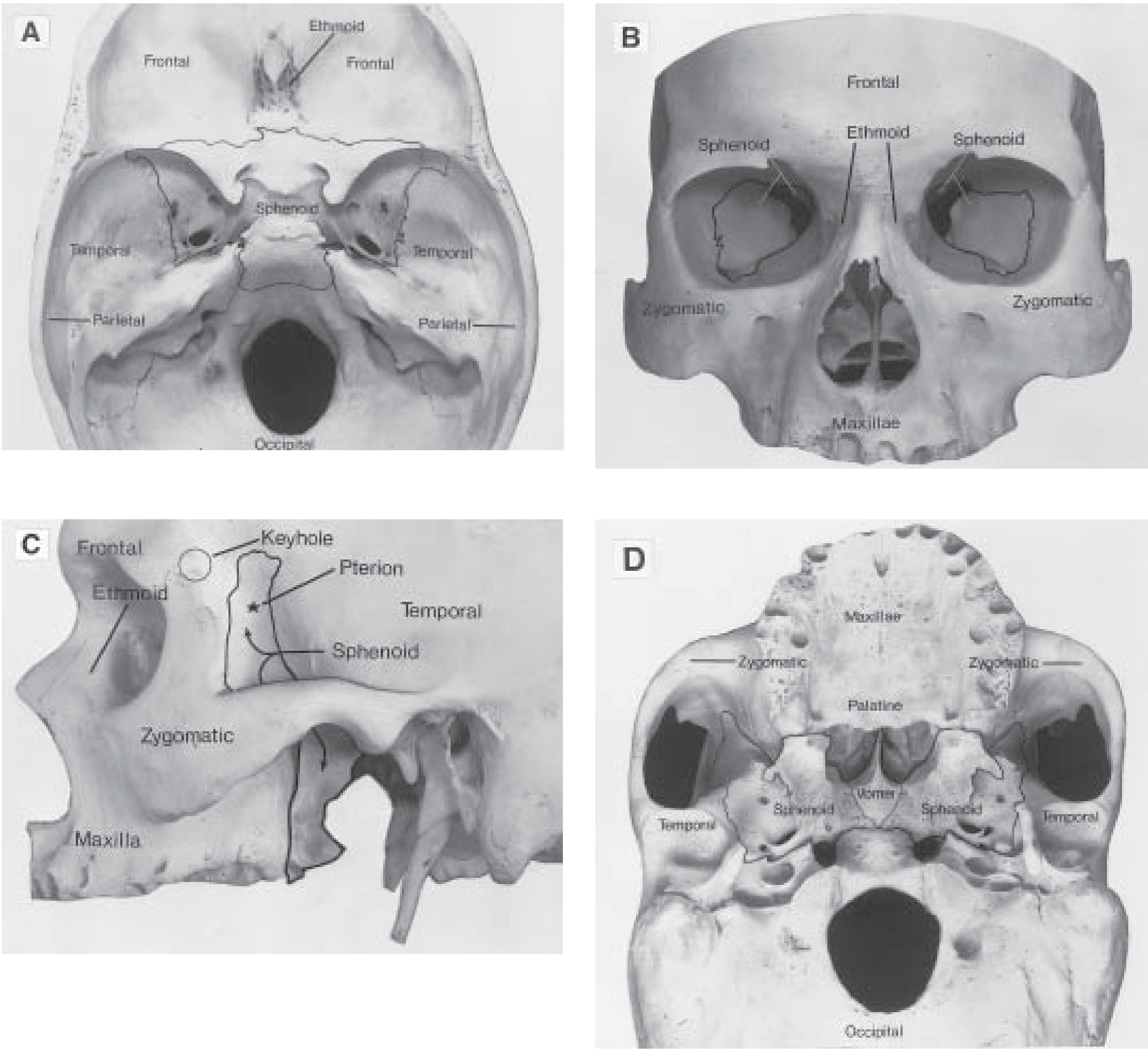


Figure 2-1 Osseous relationships of the sphenoid bone. The sphenoid bone is outlined in each view. **(A)** Superior view. **(B)** Anterior view. **(C)** Lateral view. **(D)** Inferior view *(2)*.

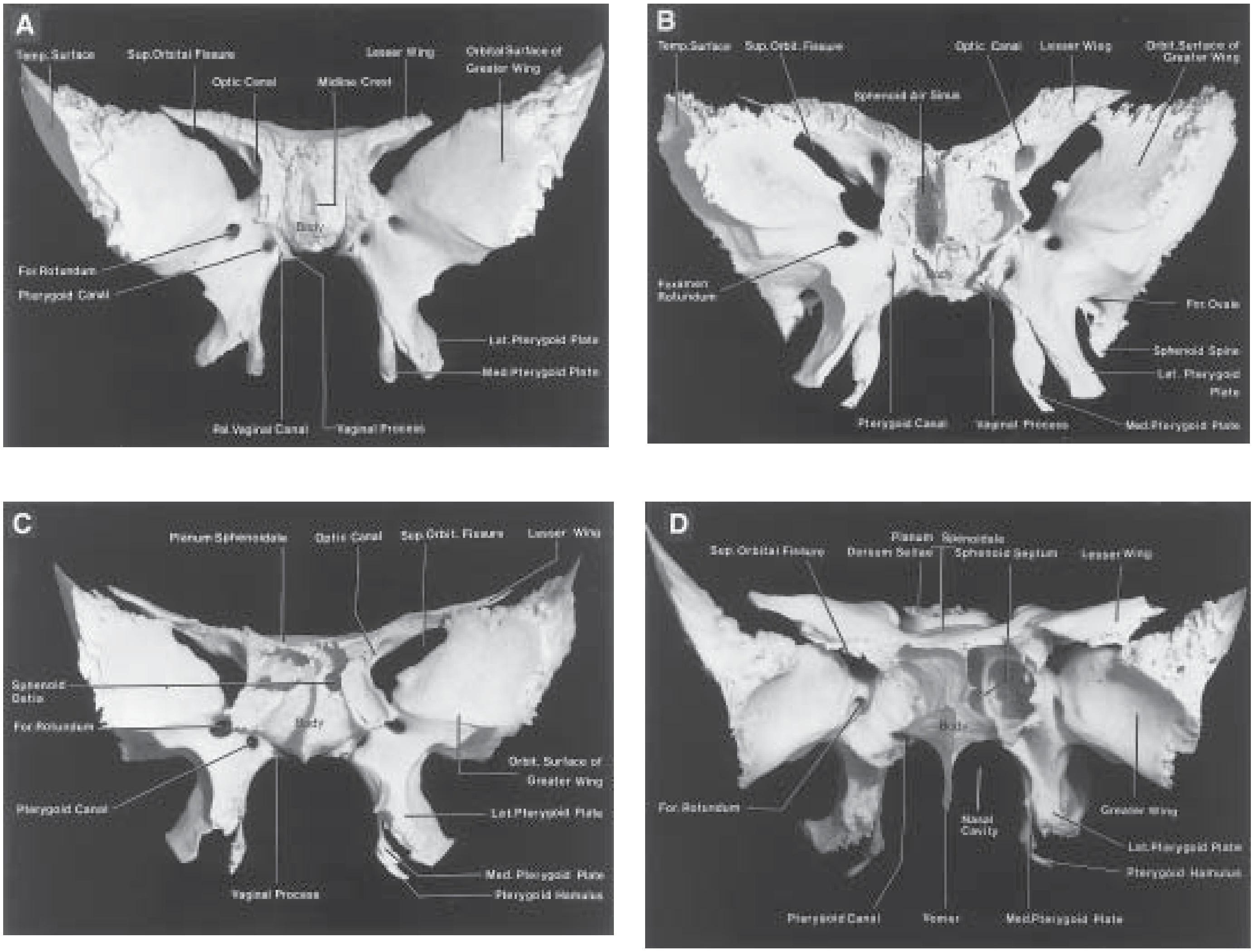


Figure 2-2 Sphenoid bone. Anterior views. **(A)** Conchal-type sphenoid bone. **(B)** Bone with presellar type sphenoid sinus. **(C)** Bone with sellar type sphenoid sinus and well-defined sphenoid ostia. **(D)** Bone with sellar type sphenoid sinus with poorly defined sphenoid ostia and obliquely oriented sphenoidal septae *(2)*.

frequently remains attached to the anterior half of the body of the sphenoid, and its most anterior portion separates the sphenoid ostia.

The pterion and the "keyhole" are two important anatomical landmarks in the region of the greater wing in the lateral view (Figure 1). The pterion is located over the upper part of the greater wing. The "keyhole" is located just behind the junction of the temporal line and the zygomatic process of the frontal bone several centimeters anterior to the pterion. A burr hole placed over the pterion will be located at the lateral end of the sphenoid ridge. A burr hole placed at the keyhole will expose the orbit at its lower margin and dura over the frontal lobe at its upper margin.

SPHENOID SINUS The sphenoid sinus is subject to considerable variation in size and shape and to variation in the degree of pneumatization (Figure 2) *(5–7)*. It is present as minute cavities at birth, but its main development takes place after puberty. In early life, it extends backward into the presellar area, and subsequently expands into the area below and behind the sella turcica, reaching its full size during adolescence. As the sinus enlarges, it may partially encircle the optic canals. When the sinus is exceptionally large, it extends into the roots of the pterygoid processes or greater wing of the sphenoid bone, and may even extend into the basilar part of the occipital bone. As age advances, the sinus frequently undergoes further enlargement associated with absorption of its bony walls. Occasionally there are gaps in its bone with the mucous membrane lying directly against the dura mater.

There are three types of sphenoid sinus in the adult: conchal, presellar, and sellar types, depending on the extent to which the sphenoid bone is pneumatized (Figure 2). In the conchal type, the area below the sella is a solid block of bone without an air cavity. In the presellar type of sphenoid sinus, the air cavity does not penetrate beyond a vertical plane parallel to the anterior sellar wall. The sellar type of sphenoid sinus is the most common, and here the air cavity extends into the body of sphenoid below the sella and as far posteriorly as the clivus. In our previous study in adult cadavers, this sinus was of a presellar type in 24% and of the sellar type in 75% *(8)*. In the conchal type, which is infrequent in the adult, the thickness of bone separating the sella from the sphenoid sinus is at least 10 mm.

The septae within the sphenoid sinus vary greatly in size, shape, thickness, location, completeness, and relation to the sellar floor

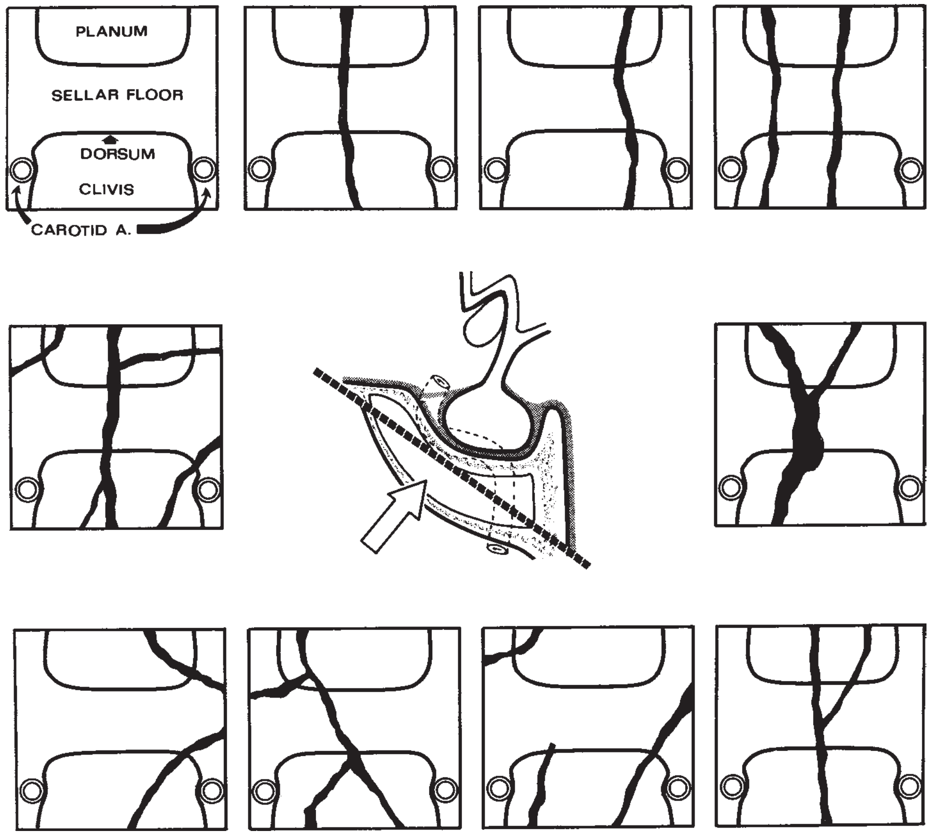


Figure 2-3 Septa in the sphenoid sinus. The heavy broken line on the central diagram shows the plane of the section of each specimen from which the drawings were taken, and the large arrow shows the direction of view. The planum is above, the dorsum and clivus are below, and the sella is in an intermediate position on each diagram. The heavy dark lines on the drawings show the location of the septae in the sphenoid sinus. A wide variety of septae separate the sinus into cavities that vary in size and shape, seldom being symmetrical from side to side *(8)*.

(Figure 3). The cavities within the sinus are seldom symmetrical from side to side and are often subdivided by irregular minor septae. The septae are often located off the midline as they cross the floor of the sella. In our previous study, a single major septum separated the sinus into two large cavities in only 68% of specimens, and even in these cases, the septae were often located off the midline or were deflected to one side *(8)*. The most common type of sphenoid sinus has multiple small cavities in the large paired sinuses. The smaller cavities are separated by septae oriented in all directions. CT or MRI of the sella provide the definition of the relationship of the septae to the floor of the sella needed for transsphenoidal surgery. Major septae may be found as far as 8 mm off the midline *(8)*.

The carotid artery frequently produces a serpiginous prominence into the sinus wall below the floor and along the anterior margin of the sella (Figures 4–6) *(8,9)*. Usually, the optic canals protrude into the superolateral portion of the sinus, and the second division of the trigeminal nerve protrudes into the inferolateral part. A diverticulum of the sinus, called the opticocarotid recess, often projects laterally between the optic canal and the carotid prominence.

Removing the mucosa and bone from the lateral wall of the sinus exposes the dura mater covering the medial surface of the cavernous sinus and optic canals (Figures 4–6). Opening this dura exposes the carotid arteries and optic and trigeminal nerves within the sinus. The abducent nerve is located between the lateral side of the carotid artery and the medial side of the first trigeminal division. The second and third trigeminal divisions are seen in the lower margin of the opening through the lateral wall of sphenoid sinus. In half of the cases, the optic and trigeminal nerves and the carotid arteries have areas where bone 0.5 mm or less in thickness separates them from the mucosa of the sphenoid sinus, and in a few cases, the bone separating these structures from the sinus is absent *(8,9)*. The absence of such bony protection within the walls of the sinus may explain some of the cases of cranial nerve deficits and carotid artery injury after transsphenoidal operations *(11)*. The bone is often thinner over the carotid arteries than over the anterior margin of the pituitary gland.

DIAPHRAGMA SELLAE The diaphragma sellae forms the roof of the sella turcica. It covers the pituitary gland, except for a small central opening in its center, which transmits the pituitary stalk (Figures 7 and 8). The diaphragma is more rectangular than circular, tends to be convex or concave rather than flat, and is thinner around the infundibulum and somewhat thicker at the periphery. It frequently is a thin, tenuous structure that would not be an adequate barrier for protecting the suprasellar structures during transsphenoidal operation. In a prior anatomic study, Renn and Rhoton *(8)* found that the diaphragma was at least as thick as one layer of dura in 38% and in these would furnish an adequate barrier during transsphenoidal hypophysectomy. In the remaining 62%, the diaphragma was extremely thin over some portion of the pituitary gland. It was concave when viewed from above in 54% of the specimens, convex in 4%, and flat in 42%.

The opening in its center is large when compared to the size of the pituitary stalk. The diaphragmal opening is 5 mm or greater in

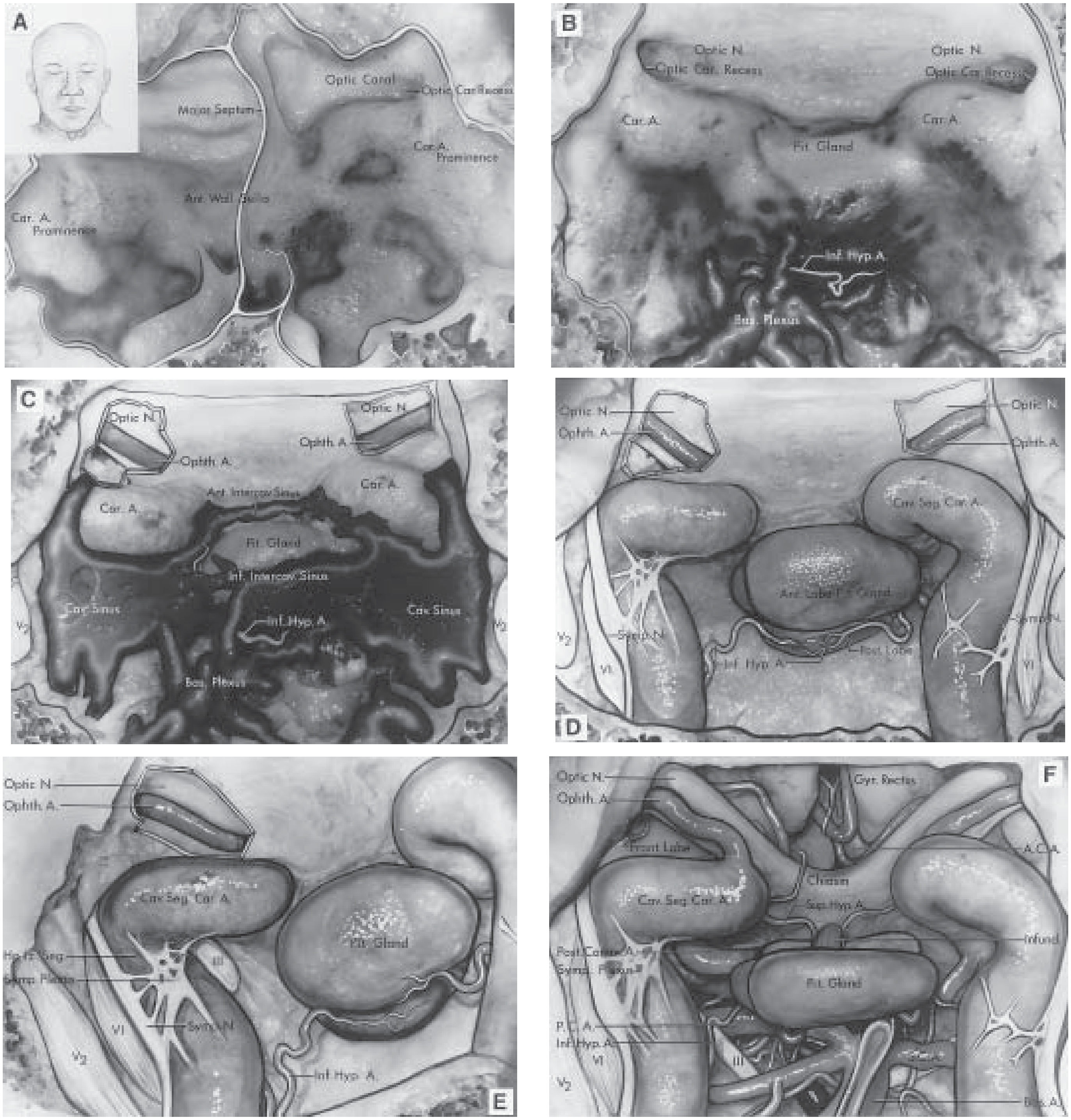


Figure 2-4 Transnasal view of sphenoid sinus and sellar region. **(A)** Orientation is as shown in the insert. Anterior view into a sphenoid sinus (Sphenoid Sinus) with the mucosa removed. The structures in the exposure include the major sphenoidal septum, anterior sellar wall (Ant. Wall Sella), and the bony prominences over the carotid artery (Car. A. Prominence) and optic canal. The opticocarotid recess (Optic Car. Recess) is located between the carotid artery and the optic nerve. **(B)** The bone in the walls of the sphenoid sinus has been removed. The pituitary gland (Pit. Gland), carotid artery (Car. A.), and optic nerve (Optic N.) are seen through the dura. The basilar venous plexus (Bas. Plexus), which forms the largest connection between the cavernous sinuses, is situated on the clivus behind the dorsum sellae. The inferior hypophyseal artery (Inf. Hyp. A.) courses inside the dura covering the posterior lobe of the pituitary gland. **(C)** The dura covering the medial and lower walls of the cavernous sinuses (Cav. Sinus) has been removed. Anterior (Ant. Intercav. Sinus) and inferior intercavernous sinuses (Inf. Intercav. Sinus) connect the paired cavernous sinuses. The dura in the floor of the optic canals has been opened to expose the ophthalmic arteries (Ophth. A.) and the optic nerves. The maxillary trigeminal division (V_2) courses in the lateral edge of the exposure. **(D)** The dark latex in the venous spaces has been removed to expose the cavernous segment of the carotid arteries (Cav. Seg. Car. A.), anterior (Ant. Lobe) and posterior (Post. Lobe) lobes of the pituitary gland, and the sympathetic (Symp. N.) and abducent (VI) nerves. **(E)** Oblique view of the cavernous segment of the right carotid artery. The oculomotor nerve (III) passes above the horizontal segment (Horiz. Seg.). The sympathetic plexus (Symp. Plexus) encircles the carotid artery. **(F)** The dura has been removed to expose the intradural structures in the region of the cavernous sinuses. Structures in the exposure include the gyrus rectus (Gyr. Rectus), pituitary stalk (Infund.), and superior hypophyseal (Sup. Hyp. A.), posterior communicating (Post. Comm. A.), anterior cerebral (A.C.A.), posterior cerebral (P.C.A.), basilar (Bas. A.), and superior cerebellar arteries (S.C.A.) *(10)*.

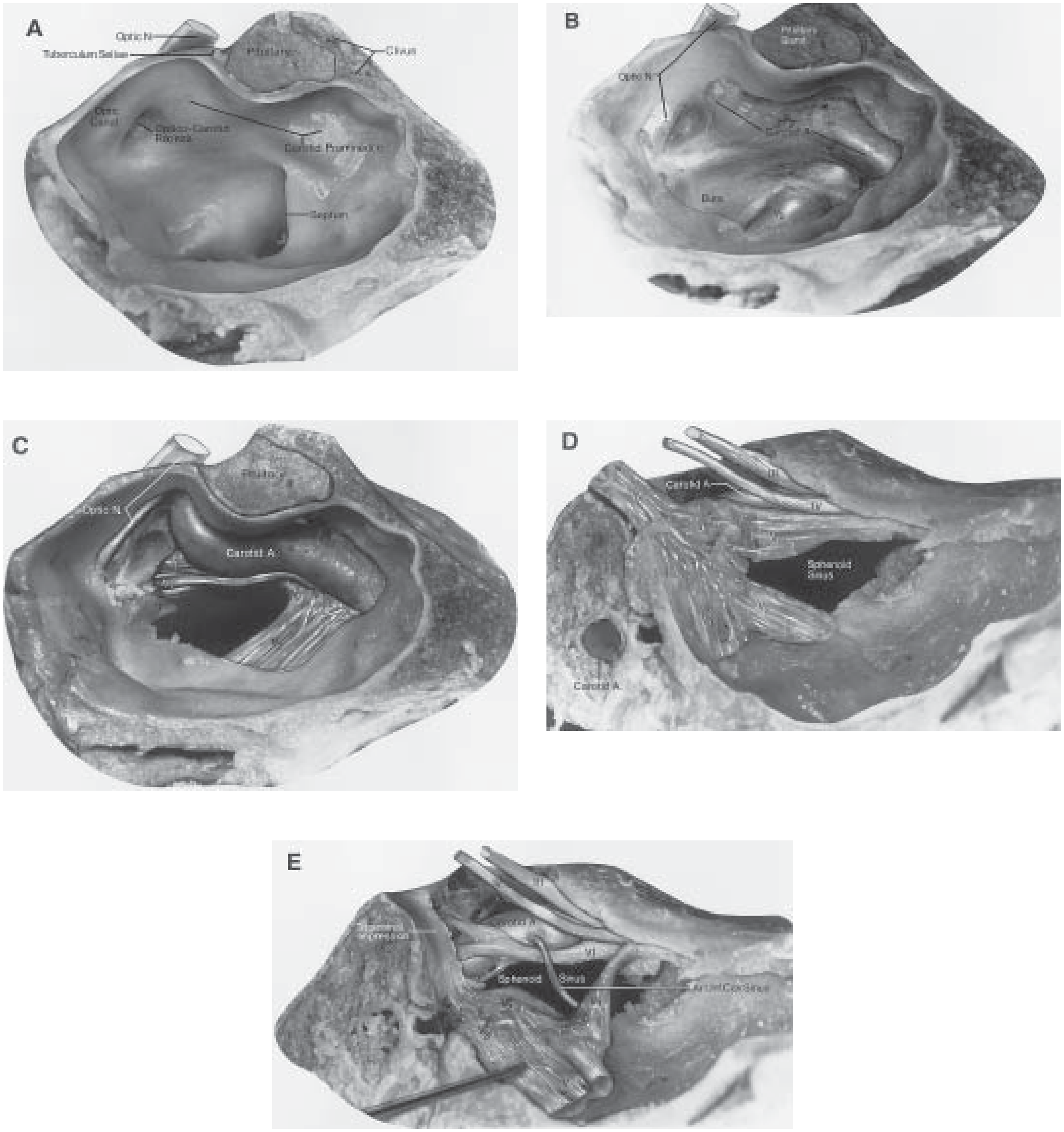


Figure 2-5 Stepwise dissection of the lateral wall of the right half of a sellar-type sphenoid sinus. **(A)** The opticocarotid recess separates the carotid prominence and optic canal. The optic nerve (Optic N.) is exposed proximal to the optic canal. The septum in the posterior part of the sinus is incomplete. **(B)** The sinus mucosa and thin bone forming the sinus wall have been removed to expose dura mater covering the carotid artery (Carotid A.), the second trigeminal division (V_2) just distal to the trigeminal ganglion, and the optic nerve. **(C)** The dura has been opened to expose the carotid artery, the optic nerve in the optic canal, the second trigeminal division below the carotid artery, and the abducens nerve (VI) between the first trigeminal division (V_1) and the carotid artery. **(D)** Lateral view of the specimen showing the cavernous sinus. The carotid artery courses medial to the oculomotor (III), and trochlear (IV) nerves and the ophthalmic division (V_1) of the trigeminal nerve. The petrous portion of the carotid artery is seen in cross-section behind the third (V_3) trigeminal division. **(E)** The trigeminal nerve has been reflected forward to expose the carotid artery, the trigeminal impression, the artery of the inferior cavernous sinus (Art. Inf. Cav. Sinus), and the abducens nerve, which splits into three bundles as it passes around the carotid artery *(6)*.

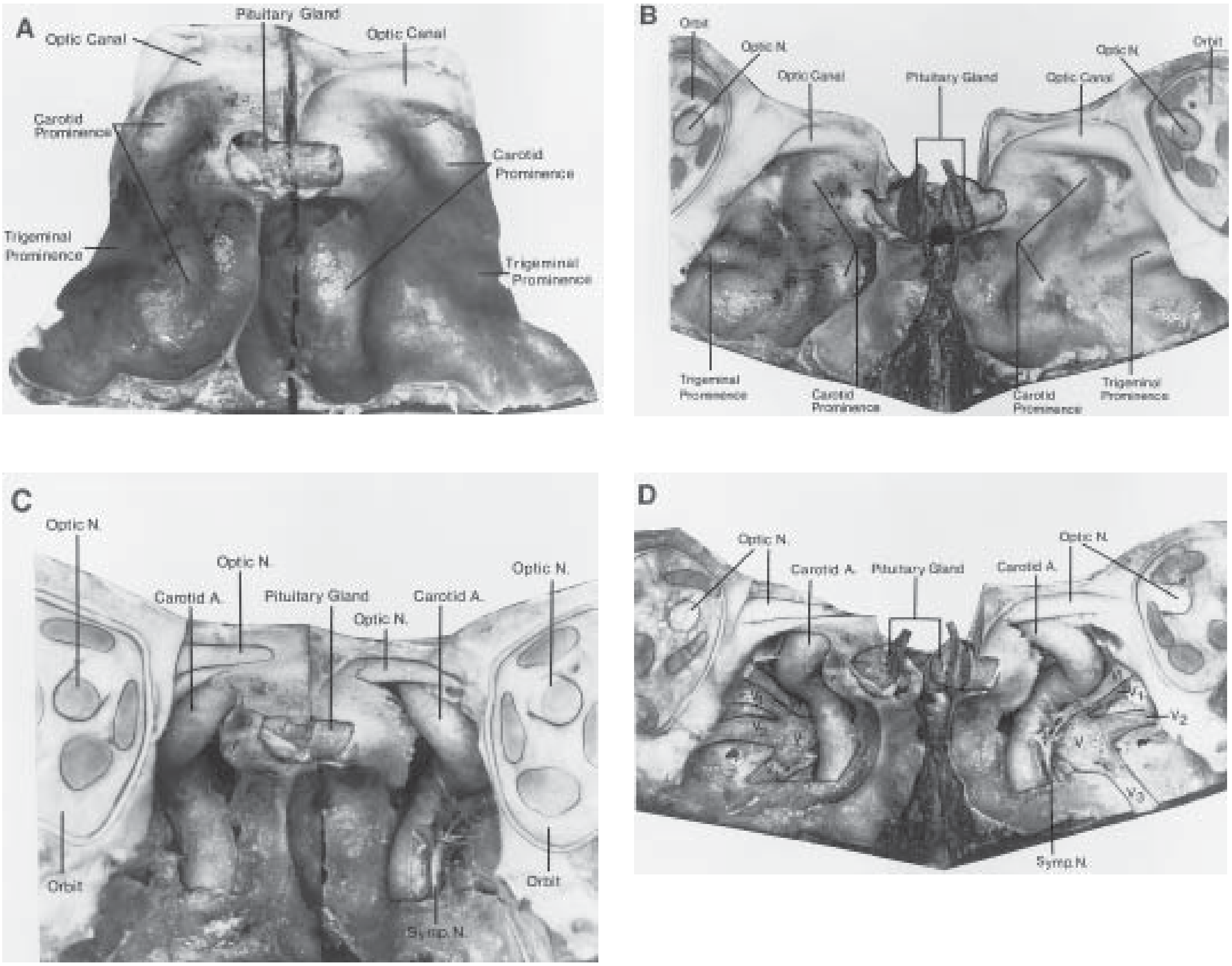


Figure 2-6 **(A)** Anterior views of a sellar-type sphenoid sinus. The anterior wall of the sella has been removed to expose the pituitary gland. The specimen was split at the midline. The air cavity is wider below than above, as is typical in a well-pneumatized sinus. The optic canals are above. The prominences over the carotid arteries form serpiginous bulges in the lateral walls of the sinus. The trigeminal prominences are situated below the carotid prominences. **(B)** The specimen is opened slightly to provide a better view of the carotid and trigeminal prominences in the lateral wall of the sinus. **(C)** The mucosa, dura, and bone in the lateral wall of the sinus have been removed to expose the intracavernous segment of the carotid artery. Sympathetic nerves (Symp. N.) ascend on the carotid arteries. The orbital contents appear laterally. **(D)** The halves of the specimen have been spread to show the abducens nerve (VI) and the ophthalmic (V_1), maxillary (V_2), and mandibular (V_3) divisions of the trigeminal nerve (V) *(6)*.

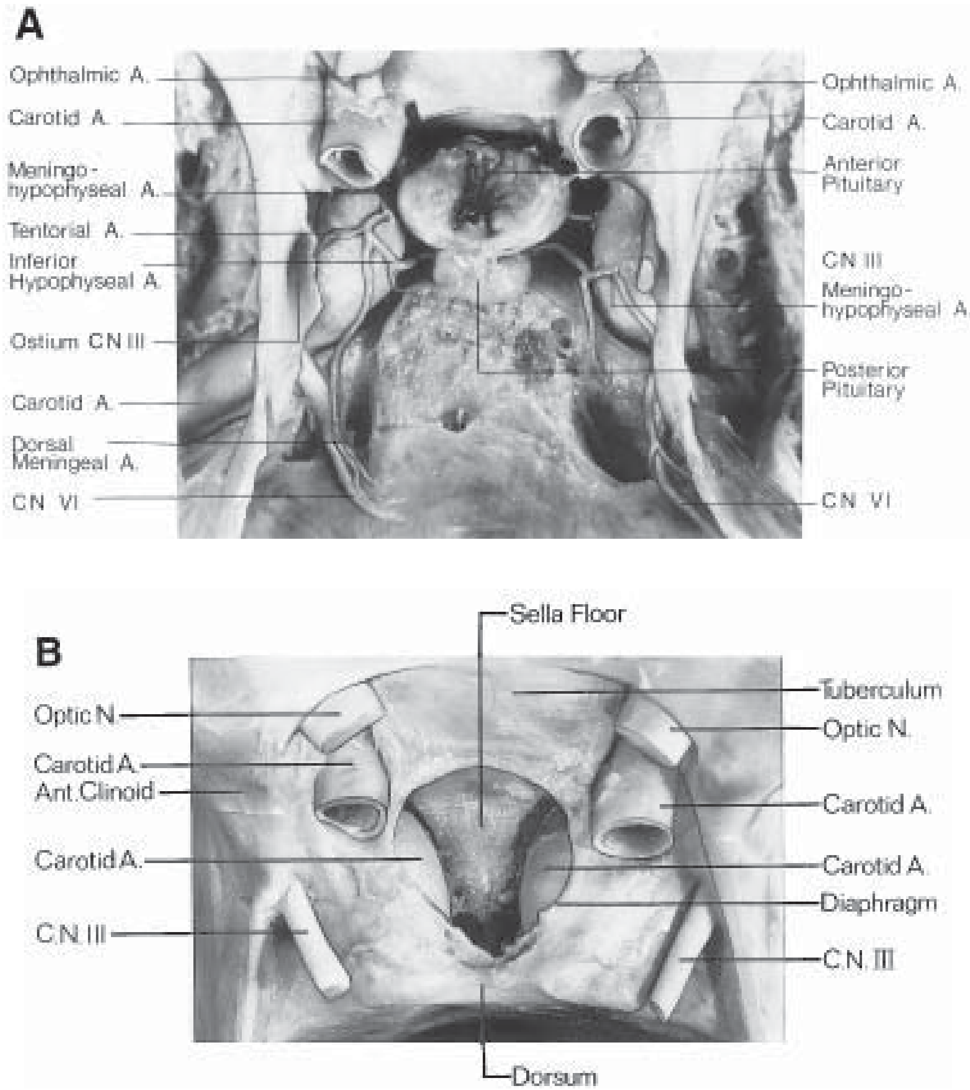
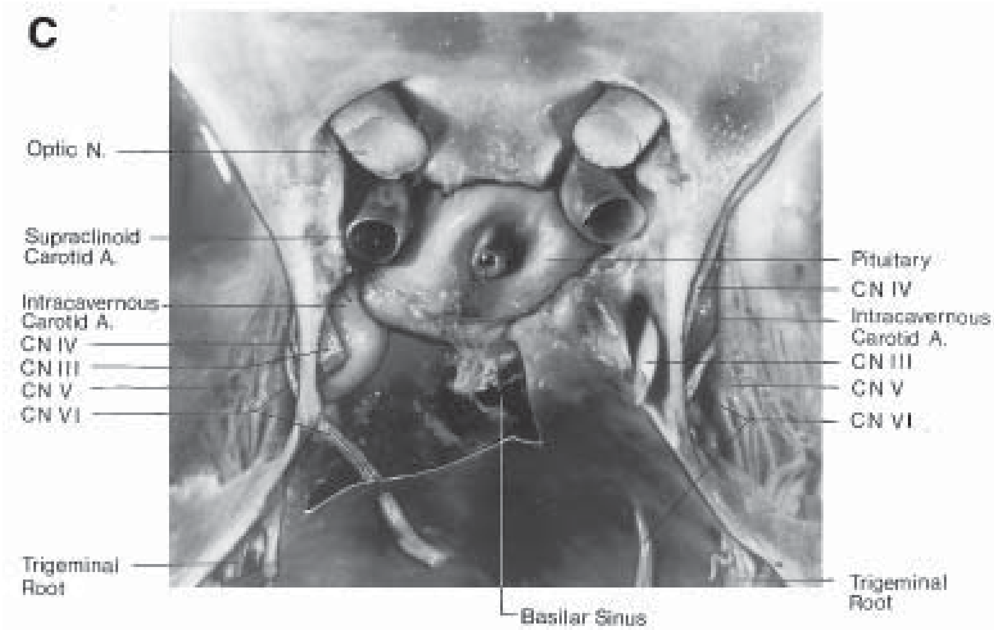


Figure 2-7 *(continued on next page)* Superior views of the sellar region. **(A)** The ophthalmic artery arises below the optic nerve. The dorsum was removed to expose the posterior lobe of the pituitary. The meningohypophyseal trunk arises from the carotid artery and gives rise to the inferior hypophyseal, tentorial, and dorsal meningeal arteries. The sixth cranial nerve (CN VI) receives a branch from the dorsal meningeal artery. The oculomotor nerve (CN III) passes through a dural ostium in the roof of the cavernous sinus. **(B)** Carotid arteries bulge into the pituitary fossa.

56%, and in these cases, it would not form a barrier during transsphenoidal pituitary surgery. The opening was round in 54% of the cases, and elliptical with the short diameter of the ellipse oriented in an anteroposterior direction in 46%. A deficiency of the diaphragma sellae is assumed to be a precondition to formation of an empty sella. An outpouching of the arachnoid protrudes through the central opening in the diaphragma into the sella turcica in about half of the patients. This outpouching represents a potential source of postoperative cerebrospinal fluid leakage *(11)*.

PITUITARY GLAND When exposed from above by opening the diaphragma, the superior surface of the posterior lobe of the pituitary gland is lighter in color than the anterior lobe. The anterior lobe wraps around the lower part of the pituitary stalk to form the pars tuberalis (Figures 9 and 10) *(2,14)*. The posterior lobe is more densely adherent to the sellar wall than the anterior lobe. The gland's width is equal to or greater than either its depth or its length in most patients. Its inferior surface usually conforms to the shape of the sellar floor, but its lateral and superior margins vary in shape, because these walls are composed of soft tissue rather than bone. If there is a large opening in the diaphragma, the gland tends to be concave superiorly in the area around the stalk. The superior surface may become triangular as a result of being compressed laterally and posteriorly by the carotid arteries (Figure 7). Since the anterior lobe is separated from the posterior lobe, there is a tendency for the pars tuberalis to be retained with the posterior lobe. Intermediate lobe cysts are frequently encountered during separation of the anterior and posterior lobes.

PITUITARY GLAND AND CAROTID ARTERY The distance separating the medial margin of the carotid artery and the lateral surface of the pituitary gland usually varies from 1 to 3 mm; however, in some cases, the artery will protrude through the medial wall of the cavernous sinus to indent the gland (Figure 7) *(5,8,12)*. Heavy arterial bleeding during transsphenoidal surgery has been reported to be caused by carotid artery injury, but may also be caused by a tear in an arterial branch of the carotid artery (e.g., the inferior hypophyseal artery) or by avulsion of a small capsular branch from the carotid artery *(11)*.



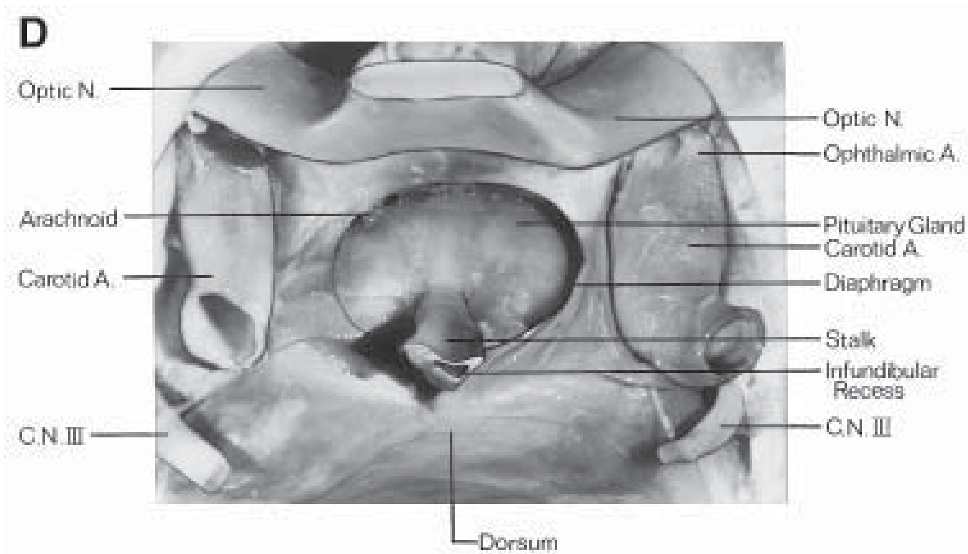


Figure 2-7 Superior views of the sellar region. **(C)** The carotid arteries indent the lateral margins of the pituitary gland, and a tongue of pituitary gland extends over the top of the arteries. **(D)** The optic chiasm has been reflected forward. A congenitally absent diaphragma exposes the superior surface of the gland. A and C are from *(12)*; B and C are from *(8)*.

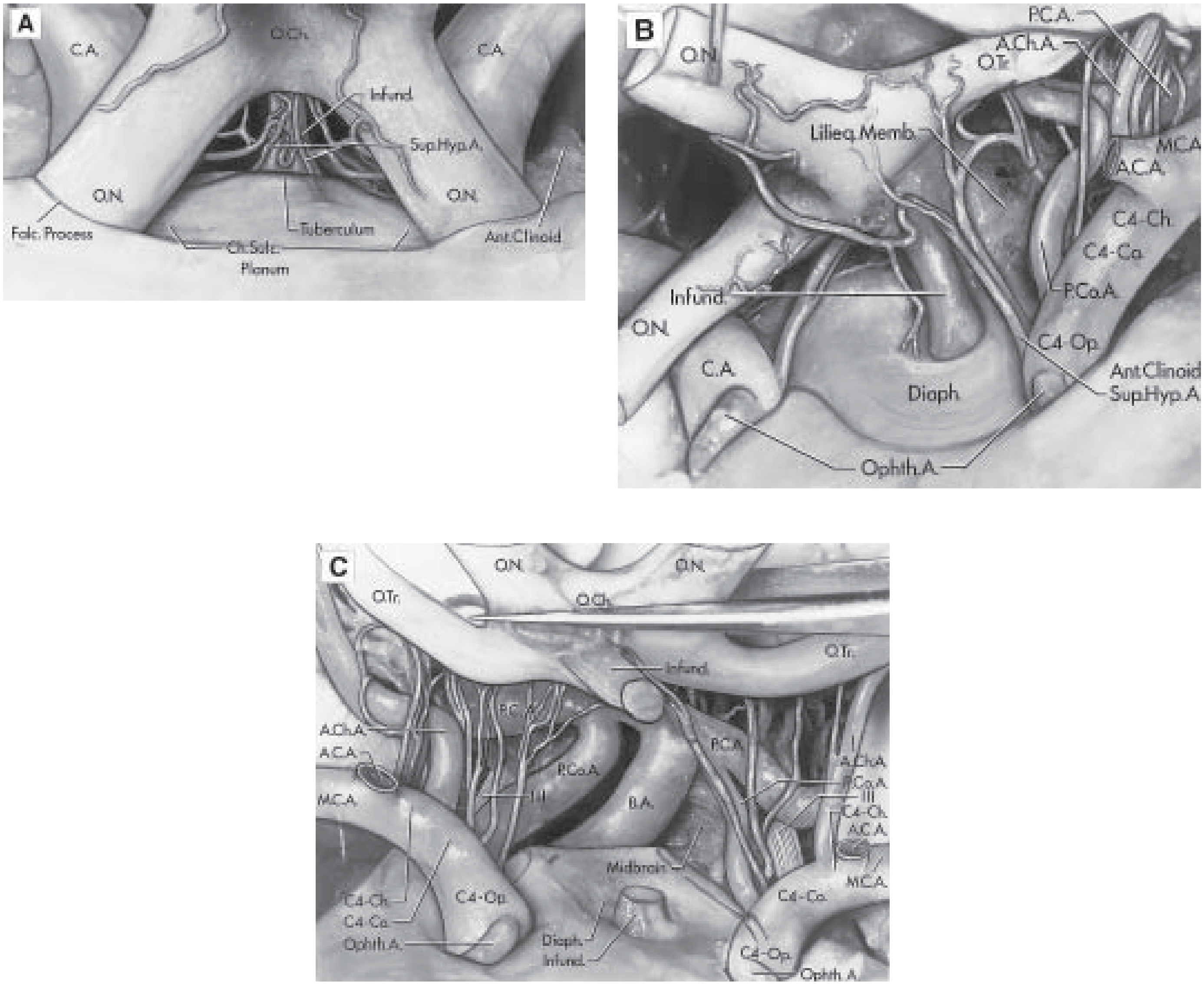


Figure 2-8 *(continued on next page)* Relationships in the sellar and suprasellar areas. **(A)** Anterior view. The optic nerves (O.N.) enter the optic canals medial to the anterior clinoid processes (Ant. Clinoid). The infundibulum (Infund.) is exposed below the optic chiasm (O.Ch.) and behind the planum sphenoidale, chiasmatic sulcus (Ch. Sulc.) and tuberculum sellae. The superior hypophyseal arteries (Sup. Hyp. A.) pass from the carotid artery (C.A.) to the infundibulum. The falciform process (Falc. Process) is a fold of dura mater that passes above the optic nerve proximal to the optic foramen. **(B)** The optic nerves have been divided and elevated to show the perforating branches of the carotid arteries. The supraclinoid portion of the carotid artery is divided into three segments based on the origin of its major branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery (Ophth. A.) to the origin of the posterior communicating artery (P.Co.A.), the communicating segment (C4-Co.) extends from the origin of the posterior communicating artery to the origin of the anterior choroidal artery (A.Ch.A.), and the choroidal segment (C4-Ch.) extends from the origin of the anterior choroidal artery to the bifurcation of the carotid artery into the anterior (A.C.A.) and middle cerebral arteries (M.C.A.). The perforating branches arising from the ophthalmic segment pass to the optic nerve, chiasm, infundibulum, and floor of the third ventricle. The perforating branches arising from the communicating segment pass to the optic tract and the floor of the third ventricle. The perforating branches arising from the choroidal segment pass upward and enter the brain through the anterior perforated substance (Ant. Perf. Subst.). The diaphragma sellae (Diaph.) surrounds the infundibulum above the pituitary gland. Liliequist's membrane (Lilieq. Memb.) is situated between the infundibulum and posterior cerebral arteries (P.C.A.). **(C)** The optic nerves, anterior cerebral arteries, and infundibulum have been divided and the optic nerves and chiasm elevated to expose the diaphragma sellae, basilar artery (B.A.), and oculomotor nerves (III). The perforating branches of the carotid artery supply the infundibulum, optic chiasm and tracts, and the floor of the third ventricle.

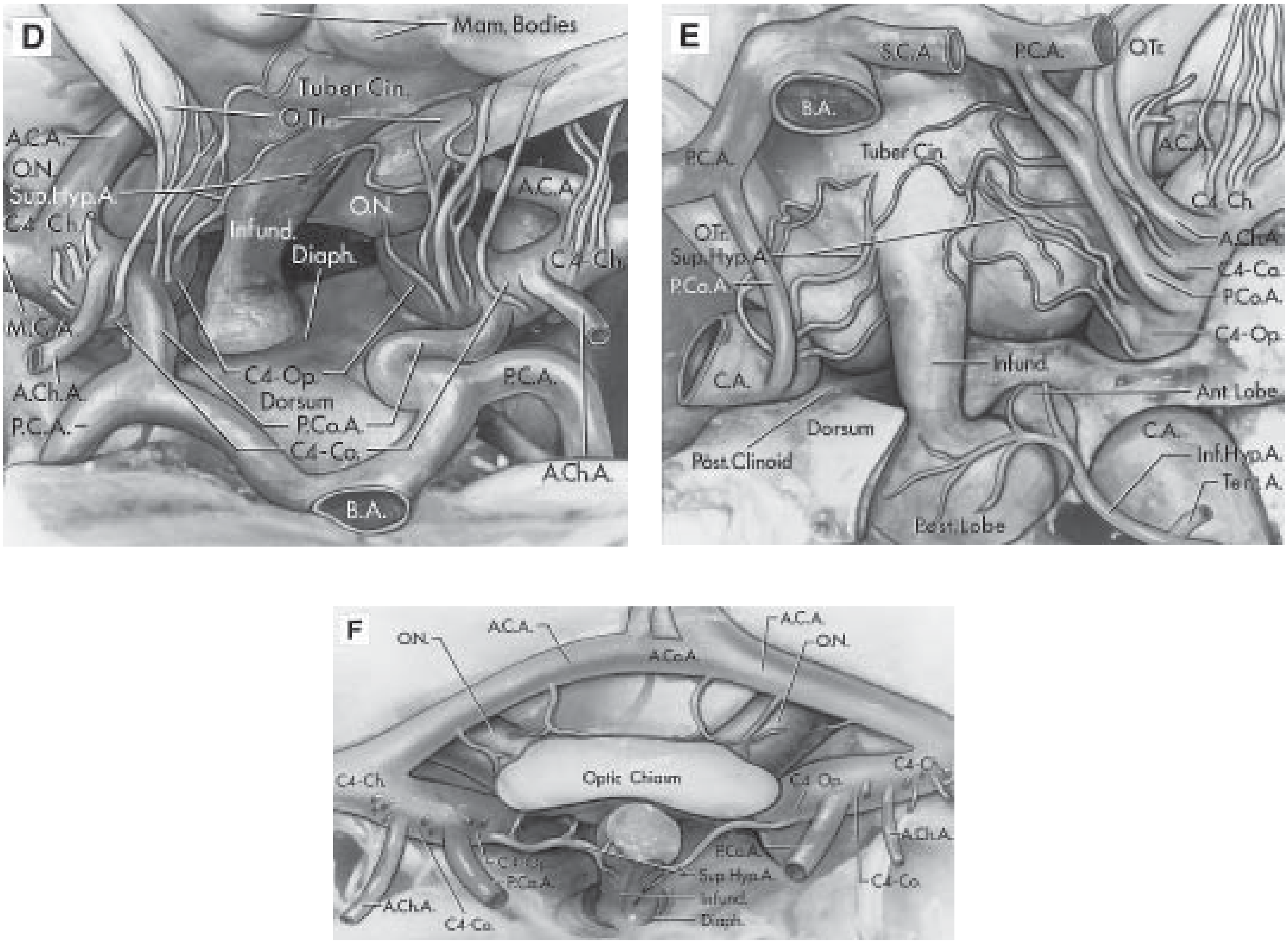


Figure 2-8 Relationships in the sellar and suprasellar areas. **(D)** Posterior view. The basilar artery and brainstem have been divided and the floor of the third ventricle elevated to provide this posterior view of the arteries in the suprasellar area. The tuber cinereum (Tuber Cin.) and mamillary bodies (Mam. Bodies) are exposed between the optic tracts. **(E)** The right half of the dorsum and the right posterior clinoid process (Post. Clinoid) have been removed to expose the anterior (Ant. Lobe) and posterior (Post. Lobe) lobes of the pituitary gland. The basilar, posterior cerebral and superior cerebellar arteries (S.C.A.) have been elevated to expose the pituitary stalk and floor of the third ventricle. The inferior hypophyseal (Inf. Hyp. A.) and the tentorial arteries (Tent. A.) arise from the carotid artery. **(F)** Posterior view of the anterior part of the circle of Willis. The optic chiasm has been divided posterior to its junction with the optic nerves and anterior to where the infundibulum arises from the floor of the third ventricle. The superior hypophyseal arteries pass to the infundibulum and send branches to the lower surface of the optic chiasm. The anterior cerebral arteries send branches to the upper surface of the optic chiasm. The anterior communicating artery (A.Co.A.) is situated above the optic chiasm *(13)*.

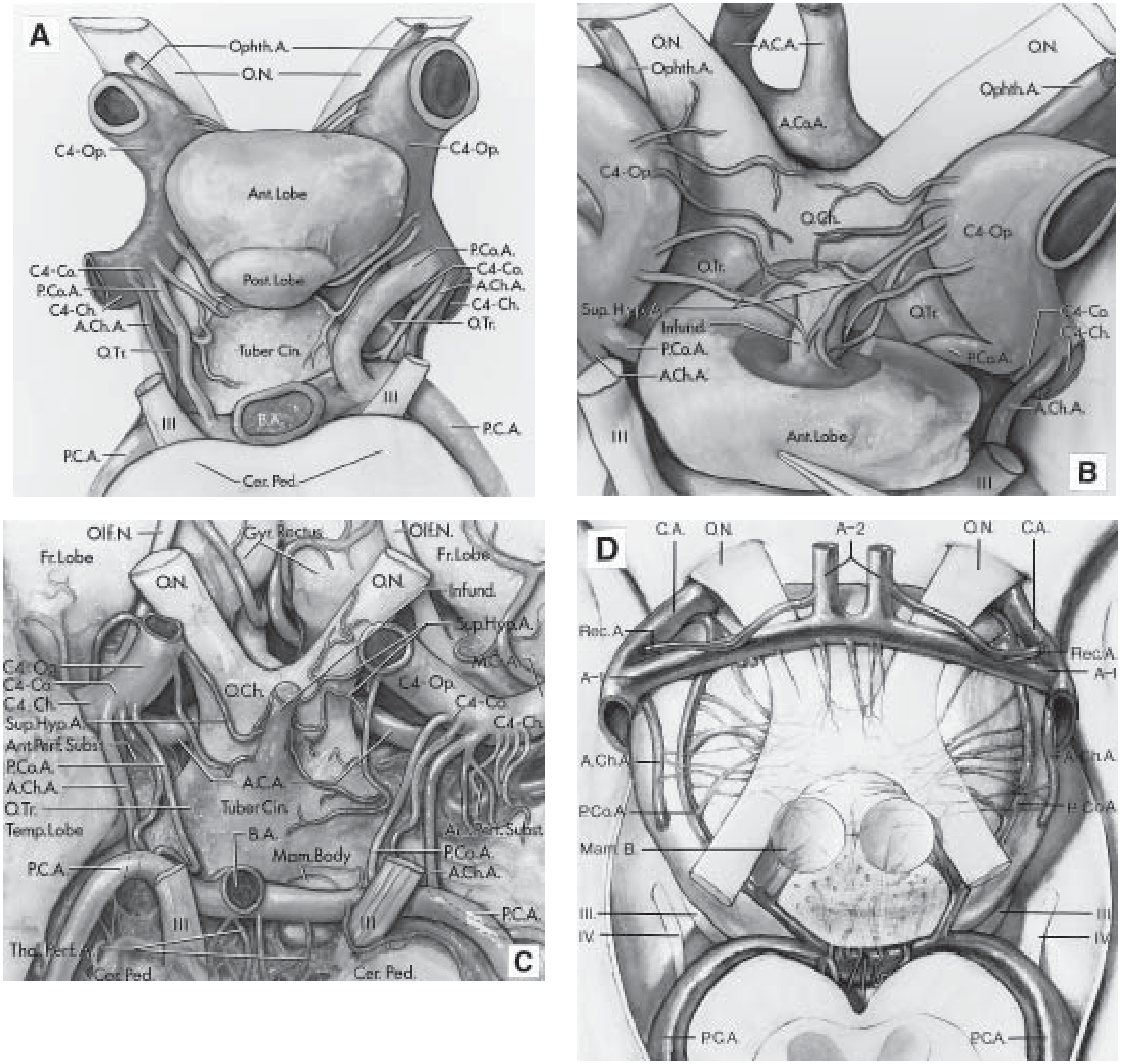


Figure 2-9 Relationships in the sellar and suprasellar areas. **(A)** Inferior view. The supraclinoid portion of the carotid artery is divided into three segments based on the site of origin of its major branches: the ophthalmic segment (C4-Op.) extends from the origin of the ophthalmic artery (Ophth. A.) to the origin of the posterior communicating artery (P.Co.A.); the communicating segment (C4-Co.) extends from the origin of the posterior communicating artery to the origin of the anterior choroidal artery (A.Ch.A.); and the choroidal segment (C4-Ch.) extends from the origin of the anterior choroidal artery to the bifurcation of the carotid artery. The optic nerves (O.N.) are above the ophthalmic arteries. The optic chiasm and optic tracts (O.Tr.) are above the anterior (Ant. Lobe) and posterior (Post. Lobe) lobes of the pituitary gland. The tuber cinereum (Tuber Cin.) is anterior to the apex of the basilar artery (B.A.). The posterior cerebral arteries (P.C.A.) pass around the cerebral peduncles (Cer. Ped.) above the oculomotor nerves (III). The perforating branches arising from the ophthalmic segment pass to the anterior lobe, optic nerve, and chiasm, and to the anterior part of the tuber cinereum. A single perforating branch arises from the communicating segment on each side and passes upward to the optic tract and the floor of the third ventricle. **(B)** The pituitary gland has been reflected backward to show the superior hypophyseal arteries (Sup. Hyp. A.) passing from the ophthalmic segments to the infundibulum (Infund.). The anterior cerebral (A.C.A.) and the anterior communicating (A.Co.A.) arteries pass above the optic chiasm (O.Ch.). **(C)** The superior hypophyseal arteries pass to the infundibulum of the hypophysis. The communicating segment sends one perforating branch on each side to the optic tracts and the region around the mamillary bodies (Mam. Body). The choroidal segment sends its perforating branches into the anterior perforated substance (Ant. Perf. Subst.). The thalamoperforating arteries (Thal. Perf. A.) arise from the basilar artery. Other structures in the exposure include the temporal (Temp. Lobe), and frontal lobes (Fr. Lobe), gyrus rectus (Gyr. Rectus), and olfactory nerves (Olf. N.). **(D)** Superior view of multiple arteries stretched around the suprasellar extension of a pituitary adenoma. The anterior cerebral arteries send branches to the superior surface of the optic nerves and chiasm. The posterior communicating, internal carotid, and posterior cerebral arteries send branches into the area below and behind the chiasm. The recurrent arteries (Rec. A.) arise just distal to the anterior communicating artery. The trochlear nerve (IV) is also exposed *(13)*.

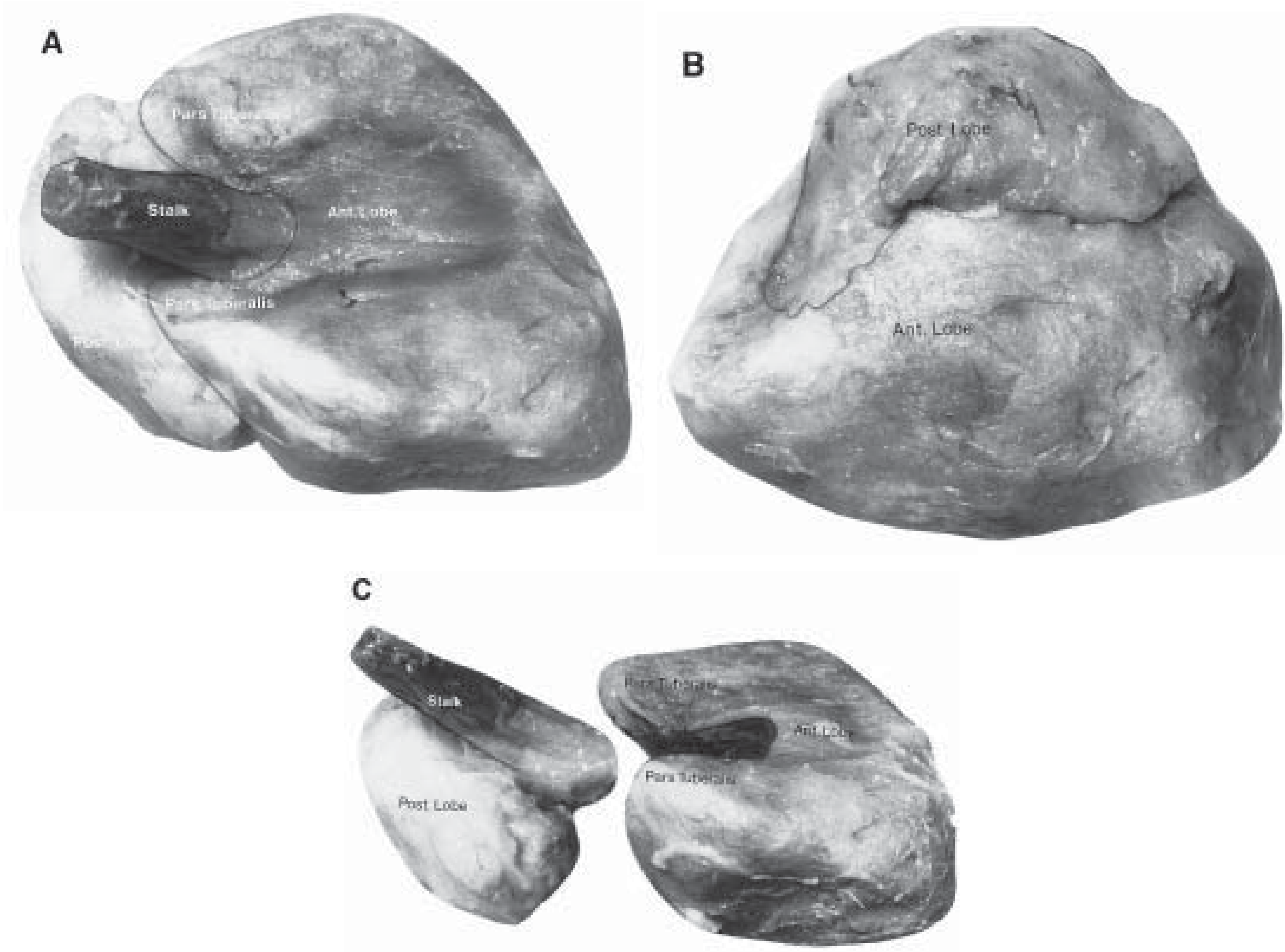


Figure 2-10 **(A)** Pituitary gland: superolateral view. The posterior lobe is a lighter color and has a different consistency, being less firm than the anterior lobe. The pars tuberalis partially encircles the stalk. The gland is concave around the stalk. **(B)** Pituitary gland: inferior view. Note the cleavage plane between the anterior and posterior lobes. **(C)** The anterior and posterior lobes have been separated. The pars tuberalis partially encircles the stalk *(2)*.

If the carotid arteries indent the lateral surfaces of the gland, the gland does lose its rounded shape and conforms to the wall of the artery, often developing protrusions above or below the artery. Intrasellar tumors are subjected to the same forces, which prevent them from being spherical, and the increased pressure within the tumor increases the degree to which the tumor insinuates into surrounding crevices and tissue planes. Separation of these extensions from the main mass of gland or tumor may explain cases in which the tumor and elevated pituitary hormone levels persist or recur after adenoma removal.

INTRACAVERNOUS VENOUS CONNECTIONS Venous sinuses may be found in the margins of the diaphragma and around the gland *(8)*. The intercavernous connections within the sella are named on the basis of their relationship to the pituitary gland; the anterior intercavernous sinuses pass anterior to the hypophysis, and the posterior intercavernous sinuses pass behind the gland (Figures 11 and 12). Actually, these intercavernous connections can occur at any site along the anterior, inferior, or posterior surface of the gland. The anterior sinus is usually larger than the posterior sinus, but either or both may be absent. If the anterior and posterior connections coexist, the whole structure constitutes the "circular sinus." Entering an anterior intercavernous connection that extends downward in front of the gland during transsphenoidal operation may produce brisk bleeding. However, this usually stops with temporary compression of the channel or with light coagulation, which serves to glue the walls of the channel together.

A large intercavernous venous connection called the basilar sinus often passes posterior to the dorsum sellae and upper clivus (Figures 11 and 12). The basilar sinus connects the posterior aspect of both cavernous sinuses, and is usually the largest and most constant intercavernous connection across the midline. The superior and inferior petrosal sinuses join the basilar sinus. The abducent nerve often enters the posterior part of the cavernous sinus by passing through the basilar sinus.

CAVERNOUS SINUS The cavernous sinus surrounds the horizontal portion of the carotid artery and a segment of the abducent nerve (Figures 5, 7, and 13). The oculomotor and trochlear nerves, and the ophthalmic division of the trigeminal nerve are found in the roof and lateral wall of the sinus *(10,12,15,16)*. The lateral wall of the cavernous sinus extends from the superior orbital fissure in front to the apex of the petrous portion of the temporal bone behind. The oculomotor nerve enters the roof of the sinus

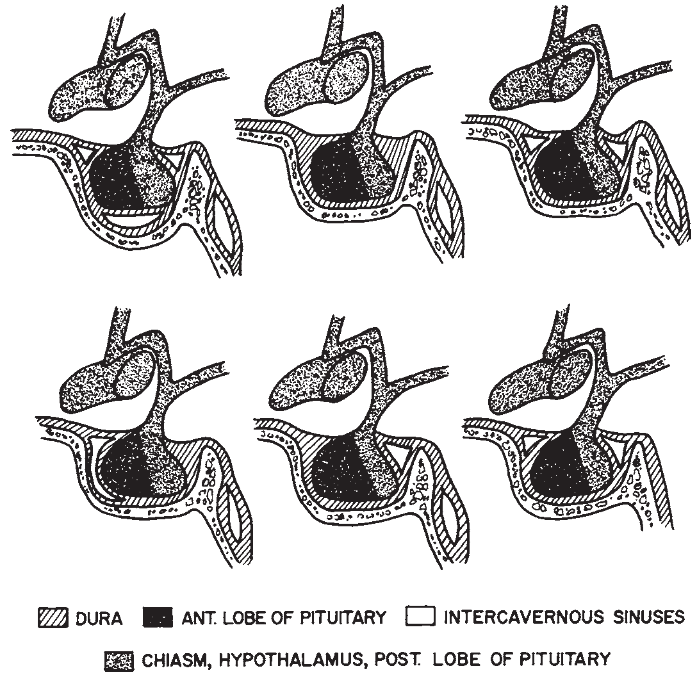


Figure 2-11 Six sagittal sections of the sellar region showing variations in the intercavernous venous connections within the dura. The variations shown include combinations of anterior, posterior, and inferior intercavernous connections and the frequent presence of a basilar sinus posterior to the dorsum. Either the anterior (lower center) or posterior (lower left) intercavernous connections or both (top center) may be absent. The anterior intercavernous sinus may extend along the whole anterior margin of the gland (lower left). The basilar sinus may be absent (lower right) *(8)*.

lateral to the dorsum sellae. The trochlear nerve enters the roof of the sinus posterolateral to the third nerve, and both nerves enter the dura mater immediately below and medial to the free edge of the tentorium. The ophthalmic division enters the low part of the lateral wall of the sinus and runs obliquely upward to pass through the superior orbital fissure. The abducent nerve enters the posterior wall of the sinus by passing through the dura lining the upper clivus and courses forward between the carotid artery medially and the ophthalmic division laterally. It frequently splits into multiple rootlets in its course lateral to the carotid artery.

The branches of the intracavernous portion of the carotid artery are the meningohypophyseal trunk, the artery of the inferior cavernous sinus, and McConnell's capsular arteries (Figure 7A). The ophthalmic artery may also take origin from the carotid artery within the sinus in few cases *(8,10)*. The most proximal branch of the intracavernous carotid artery, the meningohypophyseal trunk, usually arises below the level of the dorsum sellae near the apex of the curve between the petrous and intracavernous segments of the artery. The three branches of the meningohypophyseal artery are the tentorial artery (of Bernasconi-Cassinari), which courses toward the tentorium; the inferior hypophyseal artery, which courses medially to supply the posterior part of the capsule of the pituitary gland; and the dorsal meningeal artery, which perforates the dura of the posterior wall of the sinus to supply the region of the clivus and the sixth nerve (Figures 4 and 7).

The artery of the inferior cavernous sinus, which is also called the inferolateral trunk, originates from the lateral side of the horizontal segment of the carotid artery distal to the origin of the meningohypophyseal trunk (Figure 5E) *(10,12)*. It passes above the abducent nerve and downward medially to the first trigeminal division to supply the dura of the lateral wall of the sinus. In a few cases, it arises from the meningohypophyseal trunk. McConnell's capsular arteries, if present, arise from the medial side of the carotid artery and pass to the capsule of the gland, distal to the point of origin of the artery of the inferior cavernous sinus.

SUPRASELLAR AND THIRD VENTRICULAR REGION

This section deals with neural, arterial, and venous relationships in the suprasellar and third ventricular regions that are important in planning surgery for pituitary adenomas.

NEURAL RELATIONSHIPS The third ventricle is located in the center of the head, above the sella turcica, pituitary gland, and midbrain, between the cerebral hemispheres, thalami, and the walls of the hypothalamus, and below the corpus callosum and the body of the lateral ventricle (Figure 14). It is intimately related to the circle of Willis and deep venous system of the brain. Manipulation of the walls of the third ventricle may cause hypothalamic dysfunction as manifested by disturbances of consciousness, temperature control, respiration, and hypophyseal secretion, visual loss owing to damage of the optic chiasm and tracts, and memory loss owing to injury to the columns of the fornix in the walls of the third ventricle *(14,17,18)*. The third ventricle is a narrow, funnel-shaped, unilocular, midline cavity. It has a floor, a roof, and an anterior, posterior, and two lateral walls.

FLOOR The floor extends from the optic chiasm anteriorly to the orifice of the aqueduct of Sylvius posteriorly (Figures 14–16). The anterior half of the floor is formed by diencephalic structures, and the posterior half is formed by mesencephalic structures.

When viewed from inferiorly, the structures forming the floor from anterior to posterior include the optic chiasm, infundibulum of the hypothalamus, tuber cinereum, mamillary bodies, posterior perforated substance, and (most posteriorly), the part of the teg-

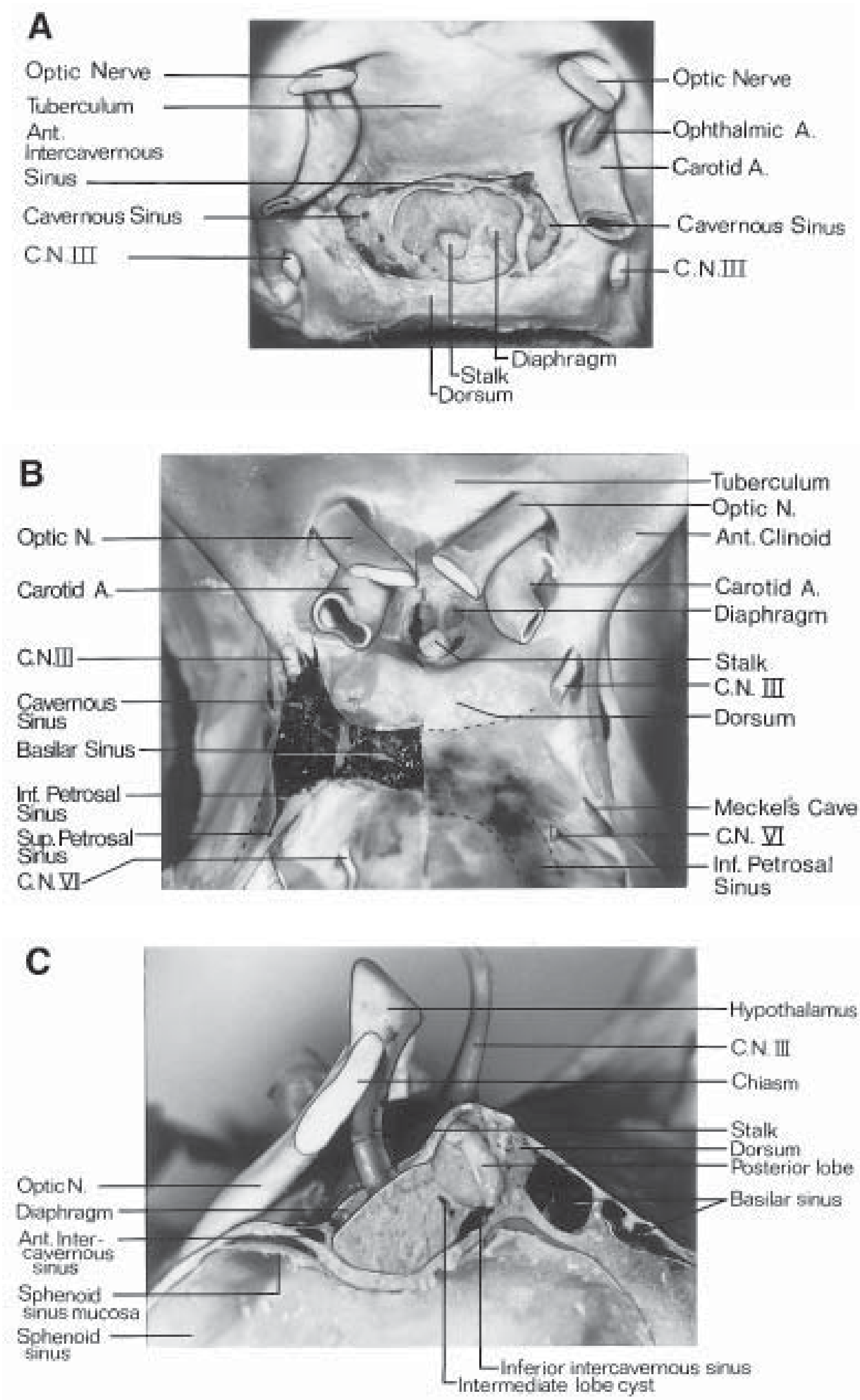


Figure 2-12 Intercavernous venous connections. **(A)** The ophthalmic artery arises from the superior aspect of the carotid artery and courses laterally beneath the optic nerve to the optic foramen. The dura over the cavernous and anterior intercavernous sinuses has been opened to show the venous connection across the midline. **(B)** The basilar sinus connects the posterior portion of the two cavernous sinuses. The dura over the posterior aspect of the left cavernous sinus and the left half of the basilar sinus has been removed. The course of the basilar, inferior petrosal, and superior petrosal sinuses within the dura is shown by the dotted lines. **(C)** Midsagittal section of the sellar region. The anterior and inferior intercavernous sinuses are small. The basilar sinus, dorsal to the clivus and joining the posterior aspect of the two cavernous sinuses, is the largest connection across the midline *(8)*.

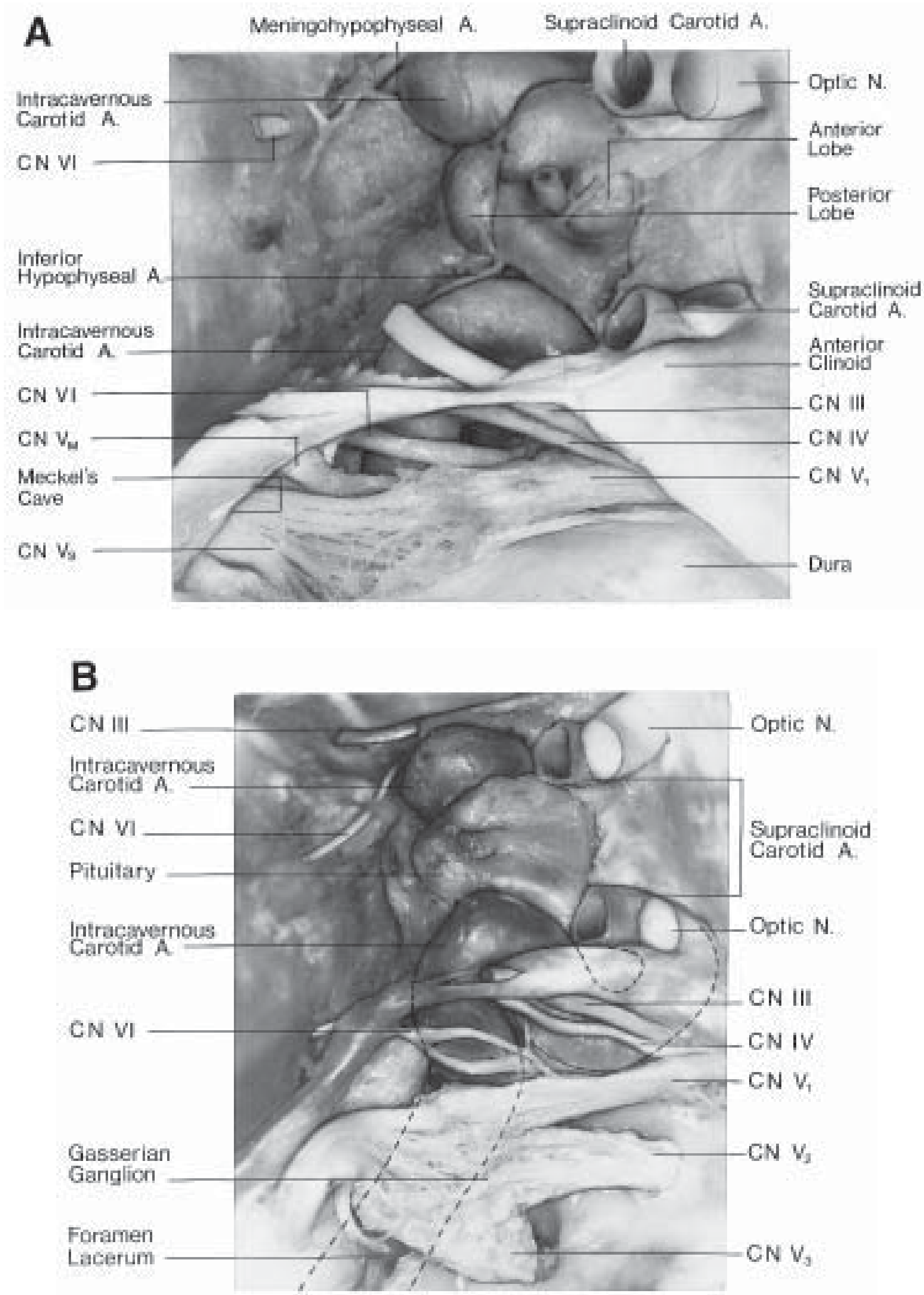


Figure 2-13 *(continued on next page)* Superolateral view of the pituitary gland and right cavernous sinus. **(A)** The lateral dural wall of the cavernous sinus has been removed. A tortuous carotid artery bulges superiorly, pushing the interclinoid ligament and roof of the cavernous sinus upward, and indenting the lateral margin of the pituitary gland. The inferior hypophyseal artery passes to the pituitary gland. The third (CN III) and fourth cranial nerves (CN IV) course in the upper part of the cavernous sinus. The sixth cranial nerve (CN VI) passes above the trigeminal sensory (CN V_s) and motor (CN V_m) roots, and medial to the first division (CN V_1). **(B)** Further dural removal exposes the trigeminal root and its second (CN V_2) and third (CN V_3) divisions below the cavernous sinus. The trigeminal root has been displaced laterally to show a second rootlet of the sixth cranial nerve lateral to the carotid artery.

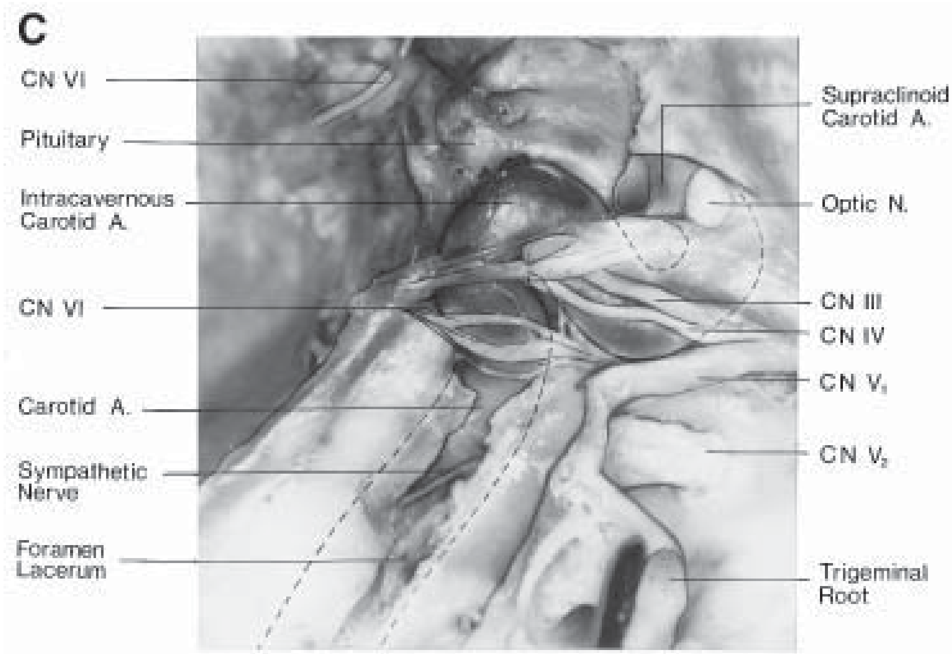


Figure 2-13 Superolateral view of the pituitary gland and right cavernous sinus. **(C)** The trigeminal root has been reflected forward, exposing the carotid artery in the foramen lacerum. A sympathetic nerve bundle courses on the carotid artery in the foramen lacerum. Three rootlets of the sixth cranial nerve pass around the carotid artery. The carotid artery is outlined in the areas where it is out of view in the temporal bone and cavernous sinus *(12)*.

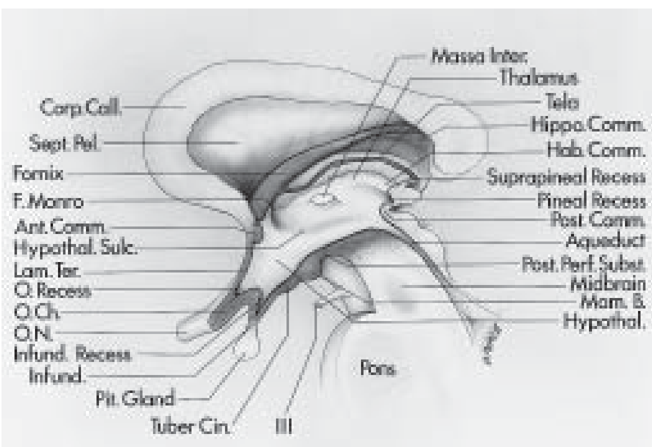


Figure 2-14 Midsagittal section of the third ventricle. The floor extends from the optic chiasm (O.Ch.) to the aqueduct of Sylvius and includes the lower surface of the optic chiasm, infundibulum (Infund.), infundibular recess (Infund. Recess), pituitary gland (Pit. Gland), tuber cinereum (Tuber Cin.), mamillary bodies (Mam. B.), posterior perforated substance (Post. Perf. Subst.), and the part of the midbrain anterior to the aqueduct. The anterior wall extends from the optic chiasm to the foramen of Monro (F. Monro) and includes the upper surface of the optic chiasm, optic recess (O. Recess), lamina terminalis (Lam. Ter.), anterior commissure (Ant. Comm.), and foramen of Monro. The roof extends from the foramen of Monro to the suprapineal recess and is formed by the fornix and the layers of the tela choroidea (Tela), between which course the internal cerebral veins and the medial posterior choroidal arteries. The hippocampal commissure (Hippo. Comm.), corpus callosum (Corp. Call.), and septum pellucidum (Sept. Pel.) are above the roof. The posterior wall extends from the suprapineal recess to the aqueduct and includes the habenular commissure (Hab. Comm.), pineal gland, pineal recess, and posterior commissure (Post. Comm.). The oculomotor nerve (III) exits from the midbrain. The hypothalamic sulcus (Hypothal. Sulc.) forms a groove between the thalamic and hypothalamic (Hypothal.) surfaces of the third ventricle *(17)*.

mentum of the midbrain located above the medial aspect of the cerebral peduncles. The optic chiasm is located at the junction of the floor and the anterior wall. The lower surface of the chiasm forms the anterior part of the floor, and the superior surface forms the lower part of the anterior wall. The optic tracts arise from the posterolateral margin of the chiasm and course obliquely away from the floor toward the lateral margin of the midbrain. The infundibulum, tuber cinereum, mamillary bodies, and posterior perforated substance are located in the space limited anteriorly and laterally by the optic chiasm and tracts, and posteriorly by the cerebral peduncles.

The infundibulum of the hypothalamus is a hollow, funnel-shaped structure located between the optic chiasm and the tuber cinereum. The pituitary gland (hypophysis) is attached to the infundibulum, and the axons in the infundibulum extend to the posterior lobe of the hypophysis. The tuber cinereum is a prominent mass of hypothalamic gray matter located anterior to the mamillary bodies. The tuber cinereum merges anteriorly into the infundibulum. The tuber cinereum, around the base of the infundibulum, is raised to form a prominence called the median eminence. The mamillary bodies form paired, round prominences posterior to the tuber cinereum. The posterior perforated substance is a depressed, punctuated area of gray matter located in the interval between the mamillary bodies anteriorly and the medial surface of the cerebral peduncles posteriorly. The posterior part of the floor extends posterior and superior to the medial part of the cerebral peduncles and superior to the tegmentum of the midbrain.

When viewed from above and inside the third ventricle, the optic chiasm forms a prominence at the anterior margin of the floor (Figures 15 and 16). The infundibular recess extends into the infundibulum behind the optic chiasm. The mamillary bodies form paired prominences on the inner surface of the floor posterior to the infundibular recess. The part of the floor between the mamillary bodies and the aqueduct of Sylvius has a smooth sur-

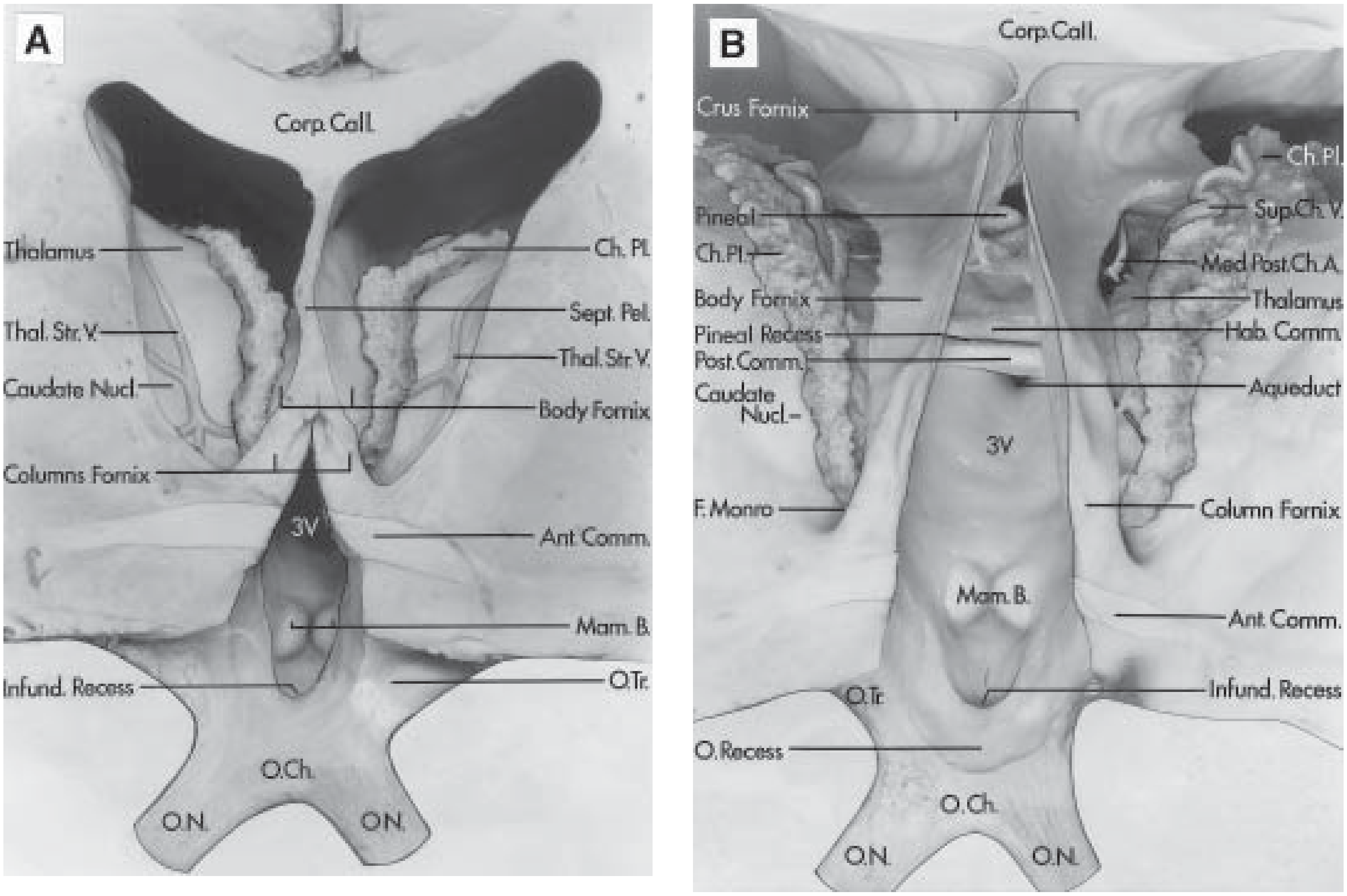


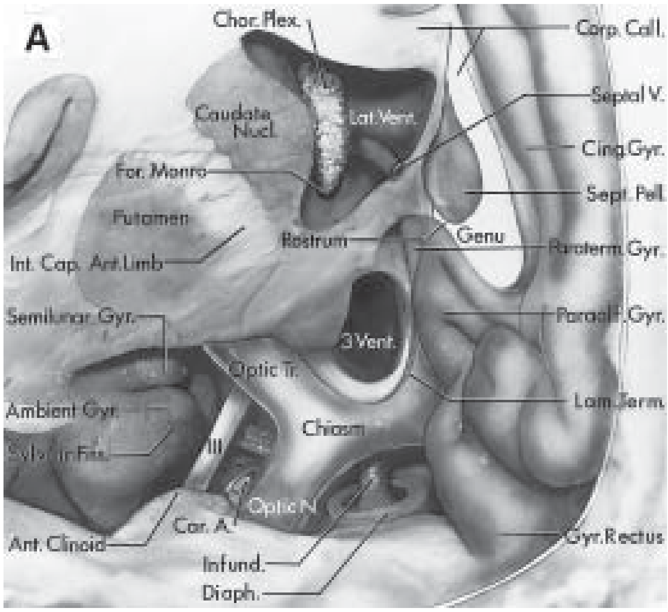
Figure 2-15 Anterosuperior views of the third ventricle. **(A)** The anterior part of the cerebral hemispheres and part of the anterior wall of the third ventricle have been removed. The optic chiasm (O. Ch.) and nerves (O. N.) are at the lower margin of the anterior wall. The optic tracts (O. Tr.) extend laterally below the floor of third ventricle (3V). The infundibular recess (Infund. Recess) extends downward posterior to the optic chiasm and anterior to the mamillary bodies (Mam. B.). The midportion of the anterior commissure (Ant. Comm.) has been removed to expose the columns of the fornix anterior to the foramina of Monro. The body and columns of the fornix join anterior to the foramina of Monro. The choroid plexus (Ch. Pl.) is attached along the cleft between the thalamus and fornix on each side. The thalamostriate veins (Thal. Str. V.) course between the caudate nucleus (Caudate Nucl.) and the thalamus. Other structures in the exposure include the septum pellucidum (Sept. Pel.) and corpus callosum (Corp. Call.). **(B)** The septum pellucidum and the medial part of the body of the fornix have been removed to expose the foramen of Monro (F. Monro) and the full length of the floor of the third ventricle. The floor extends from the optic chiasm to the aqueduct of Sylvius. The habenular commissure (Hab. Comm.) forms the upper margin of the stalk of the pineal gland, and the posterior commissure (Post. Comm.) forms the lower part of the stalk. The optic recess (O. Recess) extends anterior to the upper one-half of the optic chiasm between the chiasm and the lamina terminalis, which has been removed. Other structures in the exposure include the medial posterior choroidal arteries (Med. Post. Ch. A.) and superior choroidal veins (Sup. Ch. V.) *(17)*.

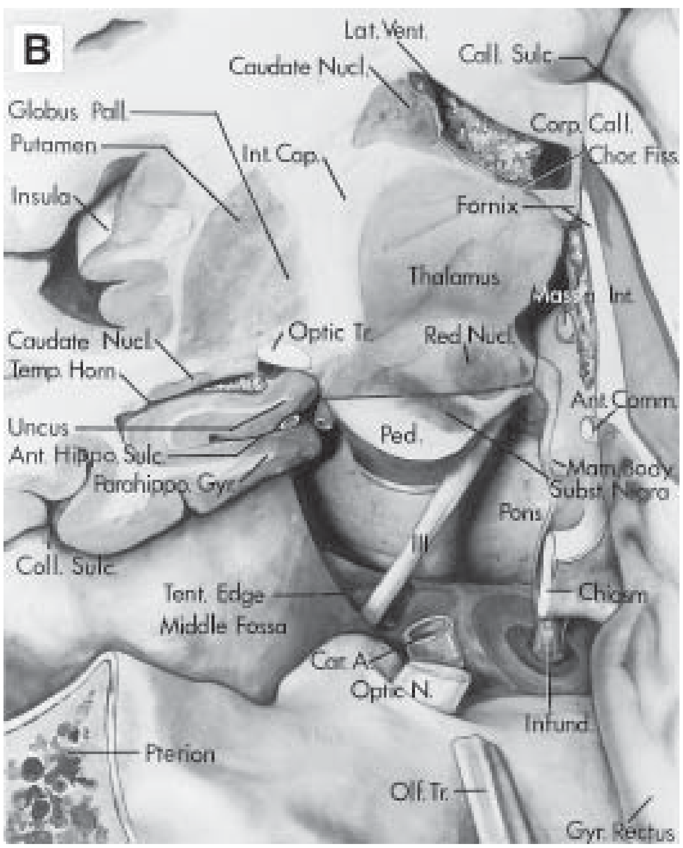
face, which is concave from side to side. This smooth surface lies above the posterior perforated substance anteriorly and the medial part of the cerebral peduncles and the tegmentum of the midbrain posteriorly.

ANTERIOR WALL The anterior wall of the third ventricle extends from the foramen of Monro above to the optic chiasm below (Figures 14–16). Only the lower two-thirds of the anterior surface is seen on the external surface of the brain; the upper one-third is hidden posterior to the rostrum of the corpus callosum. The part of the anterior wall visible on the surface is formed by the optic chiasm and the lamina terminalis. The lamina terminalis is a thin sheet of gray matter and pia mater that attaches to the upper surface of the chiasm and stretches upward to fill the interval between the optic chiasm and the rostrum of the corpus callosum.

When viewed from within, the boundaries of the anterior wall from superiorly to inferiorly are formed by the columns of the fornix, foramen of Monro, anterior commissure, lamina terminalis, optic recess, and optic chiasm. The opening of the foramen of Monro into each lateral ventricle is located at the junction of the roof and the anterior wall of the third ventricle (Figures 14 and 17). The foramen is a duct-like canal that opens between the fornix and the thalamus into each lateral ventricle, and extends inferiorly below the fornix into the third ventricle as a single channel. The foramen of Monro is bounded anteriorly by the junction of the body and the columns of the fornix, and posteriorly by the anterior pole of the thalamus.

POSTERIOR WALL The posterior wall of the third ventricle extends from the suprapineal recess above to the aqueduct of Sylvius below (Figures 14–17). When viewed from anteriorly within the third ventricle, it consists, from above to below, of the suprapineal recess, the habenular commissure, the pineal body and its recess, the posterior commissure, and the aqueduct of Sylvius.





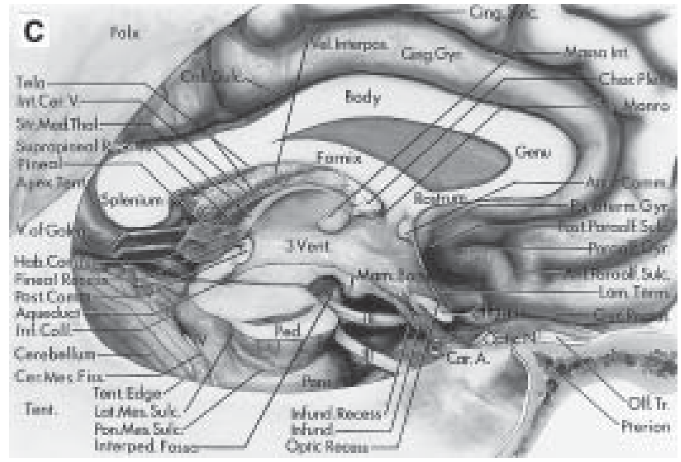


Figure 2-16 Suprasellar and third ventricular regions. Stepwise dissection. **(A)** Anterior-superior view. The anterior part of the frontal lobe has been removed to expose the anterior incisural space and suprasellar region. The section of the frontal lobe passes adjacent to the septum pellucidum (Sept. Pell.) and through the rostrum and genu of the corpus callosum (Corp. Call.), frontal horn of the lateral ventricle (Lat. Vent.), and the anterior limb of the internal capsule (Int. Cap. Ant. Limb). The anterior incisural space is located anterior to the midbrain and extends upward around the optic chiasm, lamina terminalis (Lam. Term.), and anterior part of the third ventricle (3 Vent.). The optic tract (Optic Tr.) extends posteriorly above the oculomotor nerve (III). The infundibulum (Infund.) of the pituitary gland passes through the diaphragma sellae (Diaph.). Choroid plexus (Chor. Plex.) extends through the foramen of Monro (For. Monro). Other structures in the exposure include the carotid artery (Car. A.), caudate nucleus (Caudate Nucl.), optic nerve (Optic N.), septal vein (Septal V.), cingulate (Cing. Gyr.), paraterminal (Paraterm. Gyr.), paraolfactory (Paraolf. Gyr.), semilunar (Semilunar Gyr.) and ambient gyri (Ambient Gyr.), gyrus rectus (Gyr. Rectus), sylvian fissure (Sylvian Fiss.), and anterior clinoid process (Ant. Clinoid). **(B)** The transverse section has been extended behind the foramen of Monro to include part of the cerebral peduncle (Ped.). The posterior part of the right optic nerve and the right half of the optic chiasm have been removed to expose the posterior part of the anterior incisural space. The thalamus and internal capsule are located directly above the cerebral peduncle. Other structures in the exposure include the olfactory tract (Olf. Tr.), substantia nigra (Subst. Nigra), red nucleus (Red Nucl.), parahippocampal gyrus (Parahippo. Gyr.), tentorial edge (Tent. Edge), temporal horn (Temp. Horn), globus pallidus (Globus Pall.), collateral (Coll. Sulc.), callosal (Call. Sulc.) and anterior hippocampal sulci (Ant. Hippo. Sulc.), anterior commissure (Ant. Comm.), mamillary bodies (Mam. Body), massa intermedia (Massa Int.), and choroidal fissure (Chor. Fiss.). **(C)** The right cerebral hemisphere has been removed to expose all of the third ventricle. The optic recess extends inferiorly between the optic chiasm and the lamina terminalis, and the infundibular recess (Infund. Recess) extends into the infundibulum behind the chiasm. The layer of tela choroidea that forms the upper wall of the velum interpositum (Vel. Interpos.) is adherent to the lower margin of the body and crus of the fornix. The layer of tela choroidea that forms the lower wall of the velum interpositum is attached anteriorly to the striae medullaris thalami (Str. Med. Thal.) and posteriorly to the superior margin of the pineal body. The striae medullaris thalami extend forward from the habenular commissure (Hab. Comm.) along the superomedial margin of the thalamus. Other structures in the exposure include the interpeduncular fossa (Interped. Fossa), tentorial apex (Apex Tent.), internal cerebral vein (Int. Cer. V.), lateral mesencephalic (Lat. Mes. Sulc.) and pontomesencephalic sulci (Pont. Mes. Sulc.), posterior commissure (Post. Comm.), vein of Galen (V. of Galen), trochlear nerve (IV), inferior colliculus (Inf. Coll.), cerebellomesencephalic fissure (Cer. Mes. Fiss.), and the anterior (Ant. Paraolf. Sulc.) and posterior paraolfactory sulci (Post. Paraolf. Sulc.) *(19)*.

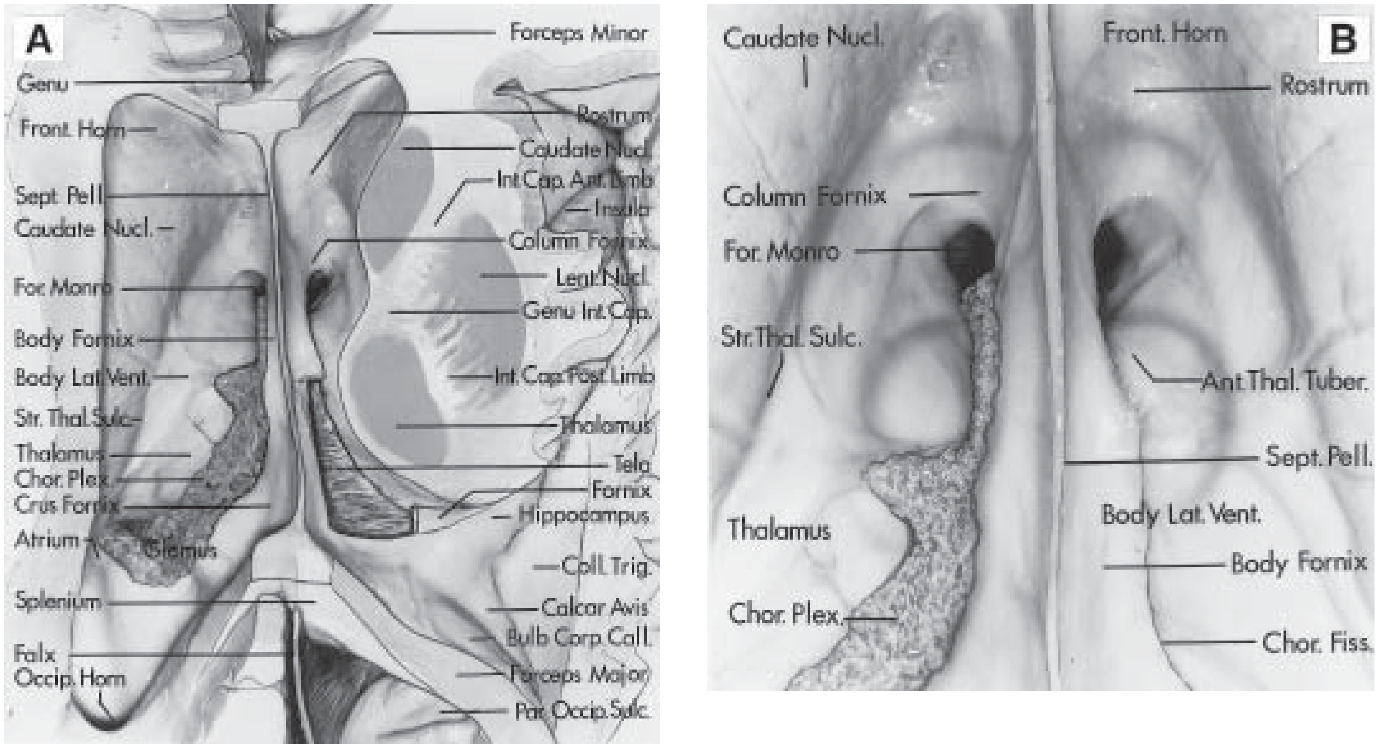


Figure 2-17 *(continued on next page)* Neural relationships. **(A)** Superior view. The upper part of the cerebral hemispheres have been removed to expose the lateral ventricles and roof of the third ventricle. The upper part of the roof of the third ventricle is formed by the body and crus of the fornix. The columns of the fornix pass anterior and superior to the foramen of Monro (For. Monro). Part of the fornix has been removed on the right side to expose the tela choroidea (Tela) in the roof of the third ventricle. The choroid plexus (Chor. Plex) has been removed on the right side. The anterior limb of the internal capsule (Int. Cap. Ant. Limb) is located between the head of the caudate nucleus (Caudate Nucl.) and the lentiform nuclei (Lent. Nucl.). The posterior limb of the internal capsule (Int. Cap. Post. Limb) is located between the thalamus and the lentiform nucleus. The genu of the internal capsule (Genu Int. Cap.) touches the lateral wall of the ventricle between the caudate nucleus and the thalamus. Other structures in the exposure include the frontal horn (Front. Horn), body (Body Lat. Vent.), and occipital horn (Occip. Horn) of the lateral ventricle, septum pellucidum (Sept. Pell.), parietooccipital (Par. Occip. Sulc.), and striothalamic sulci (Str. Thal. Sulc.), bulb of the corpus callosum (Bulb Corp. Call.), and collateral trigone (Coll. Trig.). **(B)** Enlarged view of the region of the foramen of Monro. The choroid plexus has been removed from its attachment along the choroidal fissure (Chor. Fiss.) on the right side. The anterior thalamic tubercle (Ant. Thal. Tuber.), which overlies the anterior nucleus of the thalamus, bulges upward at the posterior margin of the foramen of Monro. The columns of the fornix pass anterior and superior to the foramen of Monro.

ROOF The roof of the third ventricle forms a gentle upward arch, extending from the foramen of Monro anteriorly to the suprapineal recess posteriorly (Figures 14, 16, and 17). It is infrequent that pituitary adenomas are approached through the roof of the third ventricle. However, other tumors involving the third ventricle are approached from above. The roof has four layers: one neural layer formed by the fornix, two thin membranous layers of tela choroidea, and a layer of blood vessels between the two sheets of tela choroidea (Figures 16 and 17).

The upper, or neural, layer is formed by the fornix. The upper layer of the anterior part of the roof of the third ventricle is formed by the body of the fornix, and the posterior part of the roof is formed by the crura and the hippocampal commissure. The body of the fornix splits into two columns at the anterior margin of the opening of each foramen of Monro into the lateral ventricle. The columns descend in the lateral walls of the third ventricle and terminate in the mamillary bodies.

The tela choroidea forms two of the three layers in the roof below the layer formed by the fornix (Figures 16 and 17). The tela choroidea consists of two thin, semiopaque membranes derived from pia mater, which are interconnected by loosely organized trabeculae. The final layer in the roof is a vascular layer located between the two layers of tela choroidea. The vascular layer consists of the medial posterior choroidal arteries and their branches and the internal cerebral veins and their tributaries. Parallel strands of choroid plexus project downward on each side of the midline from the inferior layer of tela choroidea into the superior part of the third ventricle.

The velum interpositum is the space between the two layers of tela choroidea in the roof of the third ventricle. The upper layer of the tela choroidea is attached to the lower surface of the fornix and the hippocampal commissure (Figures 16 and 17). The lower wall is attached to the teniae thalami, small ridges on the free edge of a fiber tract, the striae medullaris thalami, which extends along the superomedial border of the thalamus from the foramen of Monro to the habenular commissure. The posterior part of the lower wall is attached to the superior surface of the pineal body. The internal cerebral veins arise in the anterior part of the velum interpositum, just behind the foramen of Monro, and they exit the velum interpositum above the pineal body to enter the quadrigeminal cistern and join the great vein. The velum interpositum is usually a closed space that tapers to a narrow apex just behind the foramen

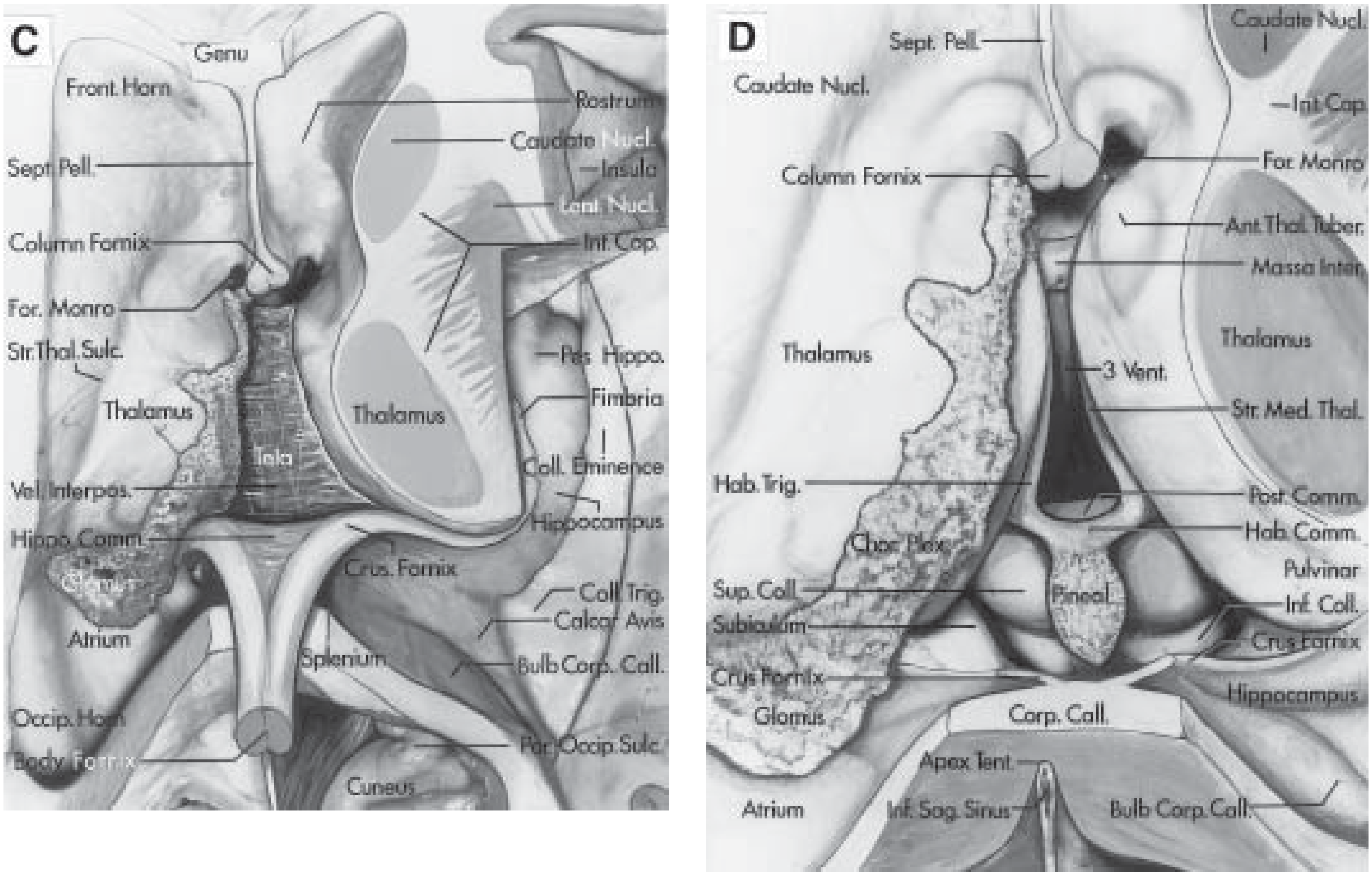


Figure 2-17 Neural relationships. **(C)** The fornix has been divided at the junction of its body and the columns above the foramen of Monro, and reflected backward to expose the velum interpositum (Vel. Interpos.) located between the layers of tela choroidea in the roof of the third ventricle. Other structures in the exposure include the pes hippocampus (Pes Hipp.), collateral eminence (Coll. Eminence), and hippocampal commissure (Hipp. Comm.). **(D)** The body and anterior part of the crura of the fornix have been removed to expose the third ventricle (3 Vent.). The massa intermedia (Massa Inter.) extends into the anterior part of the third ventricle, and the habenular (Hab. Comm.) and posterior commissures (Post. Comm.) cross the posterior part of the third ventricle. The layer of tela choroidea, which form the upper wall of the velum interpositum, is attached to the lower margin of the fornix and the layer that forms the lower wall is attached to the striae medullaris thalami (Str. Med. Thal.). Other structures in the exposure include the habenular trigones (Hab. Trig.), superior (Sup. Coll.) and inferior colliculi (Inf. Coll.), inferior sagittal sinus (Inf. Sag. Sinus), and tentorial apex (Apex. Tent.) *(20)*.

of Monro, but it may infrequently have an opening situated between splenium and the pineal body that communicates with the quadrigeminal cistern to form the cisterna velum interpositum.

LATERAL WALL The lateral walls are not visible on the external surface of the brain, but are hidden between the cerebral hemispheres (Figures 14 and 16). They are formed by the hypothalamus inferiorly and the thalamus superiorly. The lateral walls have an outline like the lateral silhouette of a bird's head with an open beak. The head is formed by the oval medial surface of the thalamus; the open beaks, which project anteriorly and inferiorly, are represented by the recesses in the hypothalamus: the pointed upper beak is formed by the optic recess, and the lower beak is formed by the infundibular recess. The hypothalamic and thalamic surfaces are separated by the hypothalamic sulcus, a groove that is often ill-defined and extends from the foramen of Monro to the aqueduct of Sylvius. The superior limit of the thalamic surfaces of the third ventricle is marked by narrow, raised ridges, known as the striae medullaris thalami. These striae extend forward from the habenulae along the superomedial surface of the thalamus at the site of the attachment of the lower layer of the tela choroidea.

The massa intermedia projects into the upper one-half of the third ventricle and often connects the opposing surfaces of the thalamus. The massa intermedia was present in 76% of the brains examined and was located 2.5–6.0 mm (average, 3.9 mm) posterior to the foramen of Monro *(17)*. The columns of the fornix form distinct prominences in the lateral walls of the third ventricle just below the foramen of Monro, but inferiorly they sink below the surface.

SUPRASELLAR CISTERNS AND TENTORIAL INCISURA The suprasellar region is commonly approached through the cisterns surrounding the anterior part of the tentorial incisura *(19)*. The incisura is a triangular space situated between the free edges of the tentorium. The upper part of the brainstem formed by the midbrain sits in the center of the incisura. The area between the midbrain and the free edges is divided into:

1. An anterior incisural space located in front of the midbrain.
2. Paired middle incisural spaces situated lateral to the midbrain.
3. A posterior incisural space located behind the midbrain (Figure 16C).

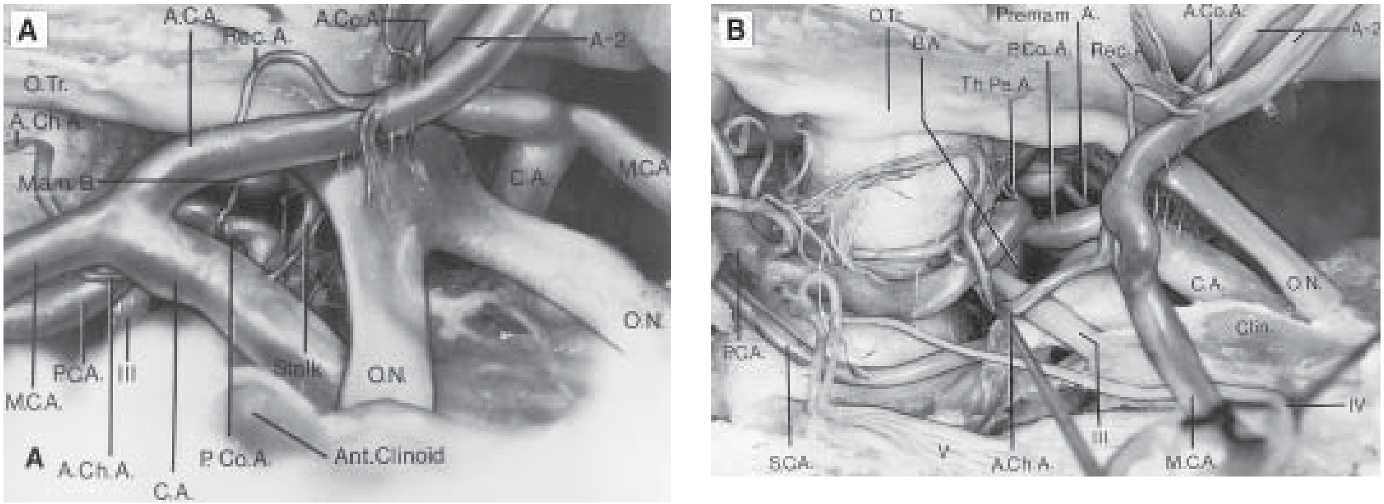


Figure 2-18 Right anterior and lateral views of the suprasellar area. **(A)** Right anterolateral view. The anterior clinoid process (Ant. Clinoid) and carotid artery (C.A.) are lateral to the optic nerve (O.N.). Perforating arteries pass from the carotid artery to terminate in the optic chiasm (O.Ch.) and tract (O.Tr.) and the hypothalamus anterior to the mamillary body (Mam. B.). The posterior communicating artery (P.Co.A.) courses medial to the carotid artery. The anterior choroidal artery (A.Ch.A.) arises from the carotid and passes above the posterior cerebral artery (P.C.A.). The third nerve (III) passes below the posterior cerebral artery. The recurrent artery (Rec. A.) arises from the anterior cerebral artery (A.C.A.) proximal to the anterior communicating artery (A.Co.A.). Other structures in the exposure include the middle cerebral (M.C.A.) and distal segment of the anterior cerebral arteries (A-2). **(B)** Right lateral view with the temporal lobe removed. The anterior clinoid process (Clin.) is lateral to the carotid artery. The premamillary artery (Premam. A.) arises from the posterior communicating artery, and the thalamoperforating arteries (Th. Pe. A.) arise from the posterior cerebral artery. The third and fourth (IV) cranial nerves course between the posterior cerebral and superior cerebellar arteries (S.C.A.). Other structures in the exposure include the trigeminal nerve (IV) and basilar artery (B.A.) *(21)*.

Pituitary adenomas commonly involve the anterior incisural space.

The anterior incisural space corresponds roughly to the suprasellar area. From the front of the midbrain, it extends obliquely forward and upward around the optic chiasm to the subcallosal area. It opens laterally into the sylvian fissure and posteriorly between the uncus and the brainstem into the middle incisural space (Figure 16).

The part of the anterior incisural space located below the optic chiasm has posterior and posterolateral walls. The posterior wall is formed by the cerebral peduncles. The posterolateral wall is formed by the anterior one-third of the uncus, which hangs over the free edge above the oculomotor nerve. The infundibulum of the pituitary gland crosses the anterior incisural space to reach the opening in the diaphragma sellae. The part of the anterior incisural space situated above the optic chiasm is limited superiorly by the rostrum of the corpus callosum, posteriorly by the lamina terminalis, and laterally by the part of the medial surfaces of the frontal lobes located below the rostrum.

The anterior incisural space opens laterally into the part of the sylvian fissure situated below the anterior perforated substance. The anterior limb of the internal capsule, the head of the caudate nucleus, and the anterior part of the lentiform nucleus are located above the anterior perforated substance. The interpeduncular cistern, which sits in the posterior part of the anterior incisural space between the cerebral peduncles and the dorsum sellae, communicates anteriorly with the chiasmatic cistern, which is located below the optic chiasm. The interpeduncular and chiasmatic cisterns are separated by Liliequist's membrane, an arachnoidal sheet extending from the dorsum sellae to the anterior edge of the mamillary bodies. The chiasmatic cistern communicates around the optic chiasm with the cisterna laminae terminalis, which lies anterior to the lamina terminalis.

CRANIAL NERVES The optic and oculomotor nerves and the posterior part of the olfactory tracts pass through the suprasellar region and anterior incisural space (Figures 16 and 18). Each olfactory tract runs posteriorly and splits just above the anterior clinoid process to form the medial and lateral olfactory striae, which course along the anterior margin of the anterior perforated substance.

The optic nerves and chiasm and the anterior part of the optic tracts cross the anterior incisural space. The optic nerves emerge from the optic canals medial to the attachment of the free edges to the anterior clinoid processes and are directed posterior, superior, and medial toward the optic chiasm. From the chiasm, the optic tracts continue in a posterolateral direction around the cerebral peduncles to enter the middle incisural spaces. The optic nerve proximal to its entrance into the optic canal is covered by a reflected leaf of dura mater, the falciform process, which extends medially from the anterior clinoid process across the top of the optic nerve *(8)*. The length of nerve covered by dura only at the intracranial end of the optic canal may vary from <1 mm to as great as 1 cm. Coagulation of the dura above the optic nerve just proximal to the optic canal on the assumption that bone separates the dura mater from the nerve could lead to nerve injury. Compression of the optic nerve against the sharp edge of the falciform process may result in a visual field deficit even if the compressing lesion does not damage the nerve enough to cause visual loss. Normally the optic nerve is separated medially from the sphenoid sinus by a thin layer of bone, but in a few cases, this bone is absent and the optic nerves may protrude directly into the sphenoid sinus, separated from the sinus by only mucosa and the dural sheath of the nerve *(6,8)*.

OPTIC CHIASM The relationship of the chiasm to the sella is an important determinant of the ease with which the pituitary fossa can be exposed by the transfrontal surgical route (Figure 19).

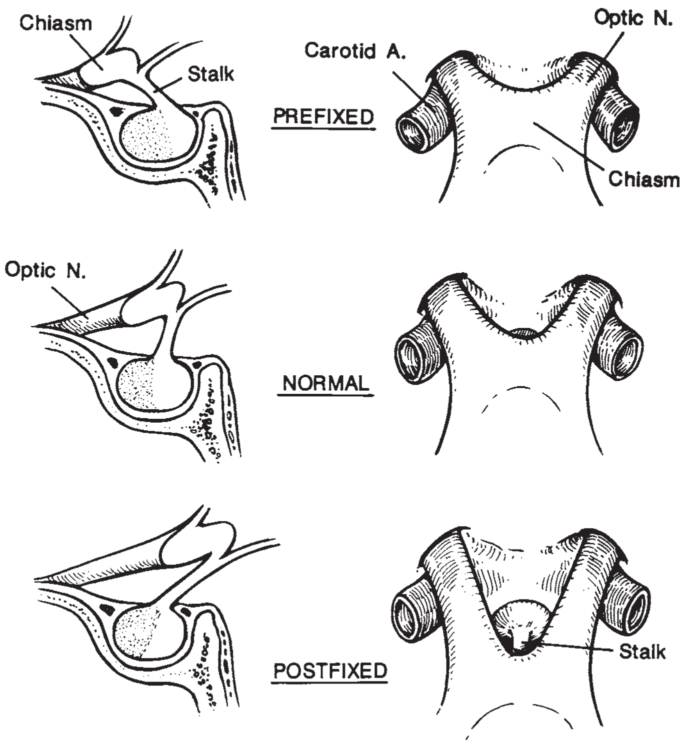


Figure 2-19 Sagittal sections and superior views of the sellar region showing the optic nerve (Optic N.) and chiasm, and carotid artery (Carotid A.). The prefixed chiasm is located above the tuberculum. The normal chiasm is located above the diaphragma. The postfixed chiasm is situated above the dorsum.

The normal chiasm overlies the diaphragma sellae and the pituitary gland, the prefixed chiasm overlies the tuberculum sellae, and the postfixed chiasm overlies the dorsum sellae. In approx 70% of cases, the chiasm is in the normal position. Of the remaining 30%, about half are "prefixed" and half "postfixed" *(8)*.

A prominent tuberculum sellae may restrict access to the sellae even in the presence of a normal chiasm. The tuberculum may vary from being almost flat to protruding upward as much as 3 mm, and it may project posteriorly to the margin of a normal chiasm *(8)*.

A prefixed chiasm, a normal chiasm with a small area between the tuberculum and the chiasm, and a superior protruding tuberculum sellae do not limit exposure by the transsphenoidal approach, but they limit the access to the suprasellar area provided by the transcranial approach. There are several methods of gaining access to the suprasellar area when these variants are present. One is to expose the sphenoid sinus from above by opening through the tuberculum and planum sphenoidale, thus converting the approach to a transfrontal-transsphenoidal exposure. If the chiasm is prefixed and the tumor is seen through a thin, stretched anterior wall of the third ventricle, the lamina terminalis may be opened to expose the tumor, but this exposure is infrequently used for pituitary adenomas. If the space between the carotid artery and the optic nerve has been enlarged (e.g., by a lateral or parasellar extension of tumor), the tumor may be removed through this space *(14,18)*.

An understanding of the relationship of the carotid artery, optic nerve, and anterior clinoid process is fundamental to all surgical approaches to the sellar and parasellar areas (Figure 18). The carotid artery and the optic nerve are medial to the anterior clinoid process. The artery exits the cavernous sinus beneath and slightly lateral to the optic nerve. The optic nerve pursues a posteromedial course toward the chiasm, and the carotid artery pursues a posterolateral course toward its bifurcation into the anterior and middle cerebral arteries.

ARTERIAL RELATIONSHIPS The arterial relationships in the suprasellar area are among the most complex in the head because this area contains all the components of the circle of Willis (Figures 8, 9, and 18). Numerous arteries, including the internal carotid and basilar arteries and the circle of Willis and its branches, may be stretched around tumors in this area: the posterior part of the circle of Willis and the apex of the basilar artery are located in the anterior incisural space below the floor of the third ventricle; the anterior part of the circle of Willis and the anterior cerebral and anterior communicating arteries are intimately related to the anterior wall of the third ventricle; both the anterior and posterior cerebral arteries send branches into the roof of the third ventricle; the internal carotid, anterior choroidal, anterior and posterior cerebral, and anterior and posterior communicating arteries give rise to perforating branches that reach the walls of the third ventricle and anterior incisural space; and all the arterial components of the circle of Willis and the adjacent segments of the carotid and basilar arteries, as well as their perforating branches may be stretched around suprasellar extensions of pituitary tumors *(13,21–24)*. Arterial lesions at the anterior part of the circle of Willis are more likely to result in disturbances in memory and personality, and those at the posterior part of the circle are more likely to result in disorders of the level of consciousness and are frequently combined with disorders of extraocular motion *(21,24)*.

INTERNAL CAROTID ARTERY The internal carotid artery exits the cavernous sinus along the medial surface of the anterior clinoid process to reach the anterior incisural space (Figures 8, 9, and 18). After entering this space, it courses posterior, superior, and lateral to reach the site of its bifurcation below the anterior perforated substance. It is first below and then lateral to the optic nerve and chiasm. It sends perforating branches to the optic nerve, chiasm, and tract, and to the floor of the third ventricle. These branches pass across the interval between the internal carotid artery and the optic nerve, and may serve as an obstacle to the operative approaches directed through the triangular space between the internal carotid artery, the optic nerve, and the anterior cerebral artery. The internal carotid artery also gives off the superior hypophyseal artery, which runs medially below the floor of the third ventricle to reach the tuber cinereum and joins its mate of the opposite side to form a ring around the infundibulum (Figures 8 and 9) *(13)*.

The supraclinoid (C_4) portion of the internal carotid artery is divided into three segments based on the origin of its major branches: the ophthalmic segment extends from the origin of the ophthalmic artery to the origin of the posterior communicating artery; the communicating segment extends from the origin of the posterior communicating artery to the origin of the anterior choroidal artery; and the choroidal segment extends from the origin of the anterior choroidal artery to the bifurcation (Figures 8 and 9) *(13)*. Each segment gives off a series of perforating branches with a relatively constant site of termination. The branches arising from the ophthalmic segment pass to the optic nerve and chiasm, infundibulum, and the floor of the third ventricle. The branches arising from the communicating segment pass to the optic tract and the floor of the third ventricle. The branches arising from the choroidal segment pass upward and enter the brain through the anterior perforated substance.

OPHTHALMIC ARTERY The ophthalmic artery is the first branch of the internal carotid artery above the cavernous sinus (Figures 8 and 9). It arises and enters the optic canal below the optic nerve. Its origin and proximal segment may be visible below the optic nerve without retracting the nerve, although elevation of the optic nerve away from the carotid artery is usually required to see the segment proximal to the optic foramen. The artery arises from the supraclinoid segment of the carotid artery in most cases, but it may also arise within the cavernous sinus or be absent in a few cases *(8,10,12)*.

POSTERIOR COMMUNICATING ARTERY The posterior communicating artery arises from the posterior wall of the internal carotid artery and courses posteromedially below the optic tracts and the floor of the third ventricle to join the posterior cerebral artery (Figures 8, 9, and 18). Its branches penetrate the floor between the optic chiasm and the cerebral peduncle, and reach the thalamus, hypothalamus, subthalamus, and internal capsule. Its posterior course varies depending on whether the artery provides the major supply to the distal posterior cerebral artery. If it is normal, with the posterior cerebral artery arising predominately from the basilar artery, it is directed posteromedially above the oculomotor nerve toward the interpeduncular fossa *(21,25)*. If the posterior cerebral artery has a fetal-type configuration in which it arises from the carotid artery, the posterior communicating artery is directed posterolaterally below the optic tract. The oculomotor nerve pierces the dura mater of the roof of the cavernous sinus 2–7 mm (average 5 mm) posterior to the initial supraclinoid segment of the carotid artery *(2,12)*.

ANTERIOR CHOROIDAL ARTERY The anterior choroidal artery arises from the posterior surface of the internal carotid artery 0.1–3.0 mm above the origin of the posterior communicating artery (Figures 8, 9, and 18). It is directed posterolaterally below the optic tract between the uncus and cerebral peduncle. It passes through the choroidal fissure behind the uncus to supply the choroid plexus in the temporal horn. It sends branches into the optic tract and posterior part of the floor that reach the optic radiations, globus pallidus, internal capsule, midbrain, and thalamus *(9,26)*.

ANTERIOR CEREBRAL AND ANTERIOR COMMUNICATING ARTERIES The anterior cerebral artery arises from the internal carotid artery below the anterior perforated substance and courses anteromedially above the optic nerve and chiasm to reach the interhemispheric fissure, where it is joined to the opposite anterior cerebral artery by the anterior communicating artery (Figures 8, 9, 18, 20, and 21) *(24,27)*. The junction of the anterior communicating artery with the right and left A_1 segments is usually above the chiasm rather than above the optic nerves. In our studies, 70% were above the chiasm and 30% were in a prefixed position above the optic nerves *(3,8)*. The shorter A_1 segments are stretched tightly over the chiasm, and the larger ones pass anteriorly over the nerves. Displacement of the chiasm against these arteries may result in visual loss before that caused by direct compression of the visual pathways by the tumor. The arteries with a more forward course are often tortuous and elongated, and some may course forward and rest on the tuberculum sellae or planum sphenoidale. The anterior cerebral artery ascends in front of the lamina terminalis and the anterior wall of the third ventricle, and passes around the corpus callosum.

The anterior cerebral and anterior communicating arteries give rise to perforating branches that terminate in the whole anterior wall of the third ventricle and reach the adjacent parts of the hypothalamus, fornix, septum pellucidum, and striatum (Figures 8, 20, and 21) *(24,27)*. A precallosal artery may originate from the anterior cerebral or the anterior communicating artery, run upward across the lamina terminalis, and send branches into the anterior wall of the third ventricle (Figure 20).

The recurrent branch of the anterior cerebral artery, which is referred to as the recurrent artery of Heubner, is encountered frequently in approaches to the anterior part of the third ventricle (Figures 18, 20, and 21). It arises from the anterior cerebral artery in the region of the anterior communicating artery, courses laterally above the bifurcation of the internal carotid artery, and enters the anterior perforated substance *(24,28)*. The recurrent artery courses anterior to the A_1 segment of the anterior cerebral artery and would be seen when elevating the frontal lobe before visualizing the A_1 segment in about two-thirds of cases. Of the remaining one-third, most coursed superior to A_1. Some of its branches reach the anterior limb and genu of the internal capsule.

POSTERIOR CEREBRAL ARTERY The bifurcation of the basilar artery into the posterior cerebral arteries is located in the posterior part of the suprasellar area below the posterior half of the floor of the third ventricle (Figures 8, 9, and 18) *(21,25)*. A high basilar bifurcation may indent the floor. The posterior cerebral artery courses laterally around the cerebral peduncle, above the oculomotor nerve, and passes between the uncus and the cerebral peduncle to reach the quadrigeminal cistern. Its branches reach the floor, roof, and posterior, and lateral walls of the third ventricle.

The thalamoperforating arteries are a pair of larger perforating branches that arise from the posterior cerebral artery in the sellar region (Figures 9 and 18). The thalamoperforating arteries arise from the proximal part of the posterior cerebral arteries and the posterior part of the posterior communicating arteries, and enter the brain through the posterior part of the floor and the lateral walls. Infarction in the distribution of the thalamoperforating branches of the posterior cerebral artery may cause coma and death after the removal of a suprasellar tumor.

The medial posterior choroidal arteries also arise from the proximal portions of the posterior cerebral arteries in the suprasellar area and course around the midbrain to reach the quadrigeminal cistern (Figure 15) *(9,26)*. They turn forward at the side of the pineal body to reach the velum interpositum, and supply the choroid plexus in the roof of the third ventricle and the body of the lateral ventricle.

VENOUS RELATIONSHIPS The deep cerebral venous system is intimately related to the walls of the third ventricle (Figure 22) *(19,20)*. However, the veins do not pose a formidable obstacle to operative approaches to the suprasellar area and anterior third ventricle as they do in the region of the posterior third ventricle, because the veins in the suprasellar region are small.

The suprasellar area is drained, almost totally, by tributaries of the basal vein *(19,20)*. The basal veins are formed by the union of veins draining the suprasellar area, and proceed posteriorly between the midbrain and the temporal lobes to empty into the internal cerebral or great vein (Figure 22). The veins joining below the anterior perforated substance to form the basal vein include the olfactory vein, which runs posteriorly in the olfactory sulcus; the fronto-orbital vein, which courses along the orbital surface of the frontal lobe; the deep middle cerebral vein, which receives the veins from the insula and passes medially across the limen insulae; the uncal veins, which course medially from the uncus; and the anterior cerebral vein, which descends on the lamina terminalis and

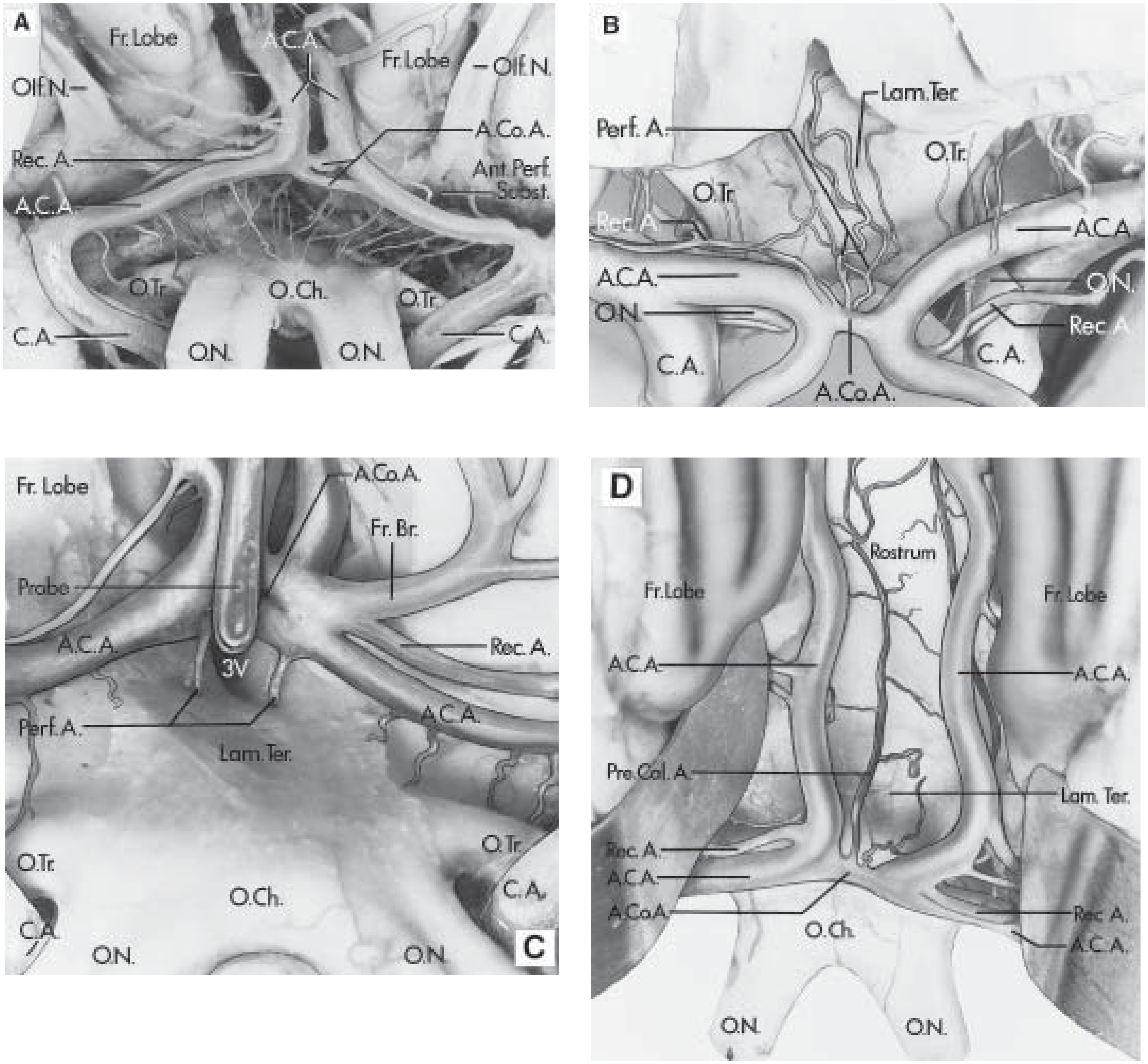


Figure 2-20 Arteries of the anterior wall of the third ventricle. Anterior views. **(A)** The anterior cerebral arteries give rise to perforating branches that enter the upper surface of the optic chiasm (O.Ch.). The recurrent arteries (Rec. A.) arise from the anterior cerebral arteries (A.C.A.) near the level of the anterior communicating artery (A.Co.A.). Other structures in the exposure include the optic nerves (O.N.) and tracts (O.Tr.), frontal lobes (Fr. Lobe), anterior perforated substance (Ant. Perf. Subst.), and olfactory nerves (Olf.N.). **(B)** The anterior communicating artery gives rise to a series of perforating arteries (Perf. A.) that enter the region of the lamina terminalis (Lam. Ter.). **(C)** A probe elevates the anterior communicating artery to expose two perforating arteries that pass through the lamina terminalis to reach the walls of the third ventricle (3V). The left recurrent artery arises in a common trunk with a branch to the frontal lobe (Fr. Br.). **(D)** A precallosal artery (Pre. Cal. A.) arises from the anterior communicating artery and passes upward on the lamina terminalis to reach the rostrum of the corpus callosum *(17)*.

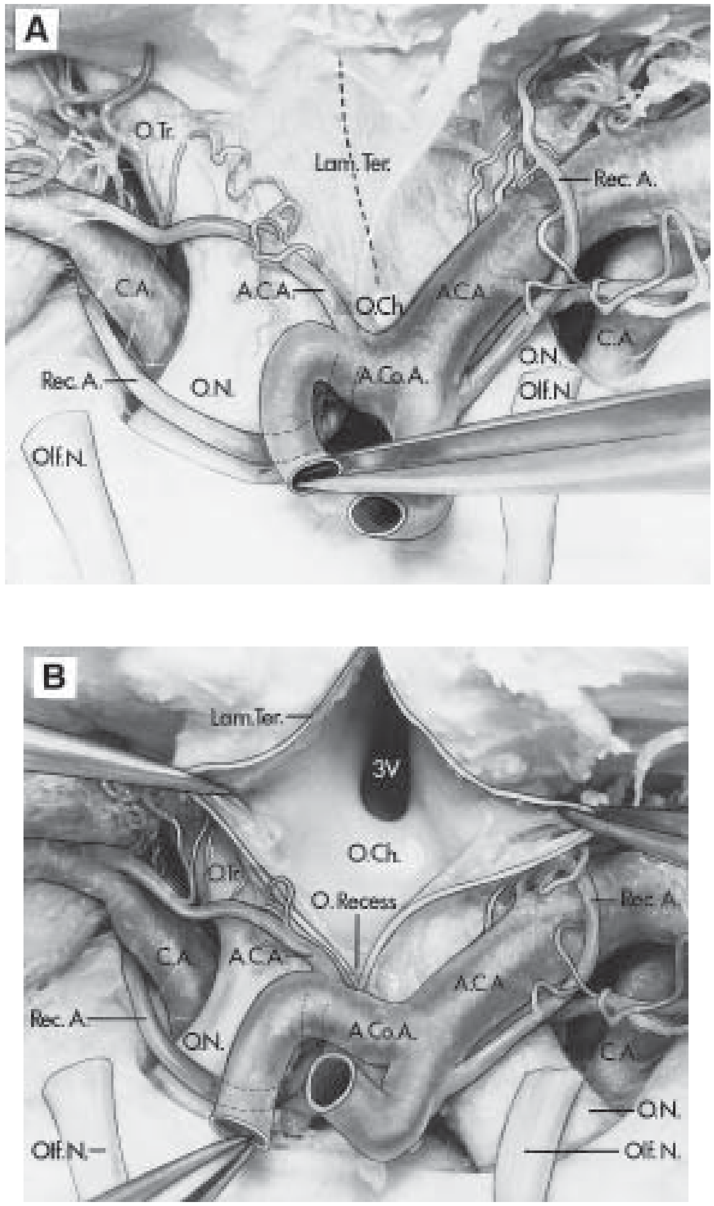


Figure 2-21 Anterior cerebral arteries and the lamina terminalis. **(A)** The anterior cerebral (A.C.A.), recurrent (Rec. A.), and anterior communicating arteries (A.Co.A.) have been retracted to expose the lamina terminalis (Lam. Ter.). Other structures in the exposure include the optic nerves (O.N.), chiasm (O.Ch.), and tracts (O.Tr.) and olfactory nerves (Olf. N.). The right anterior cerebral artery is hypoplastic. **(B)** The lamina terminalis has been opened along the dotted line shown in A to expose the cavity of the third ventricle (3V). The optic recess (O. Recess) extends downward between the lamina terminalis and the superior surface of the optic chiasm *(17)*.

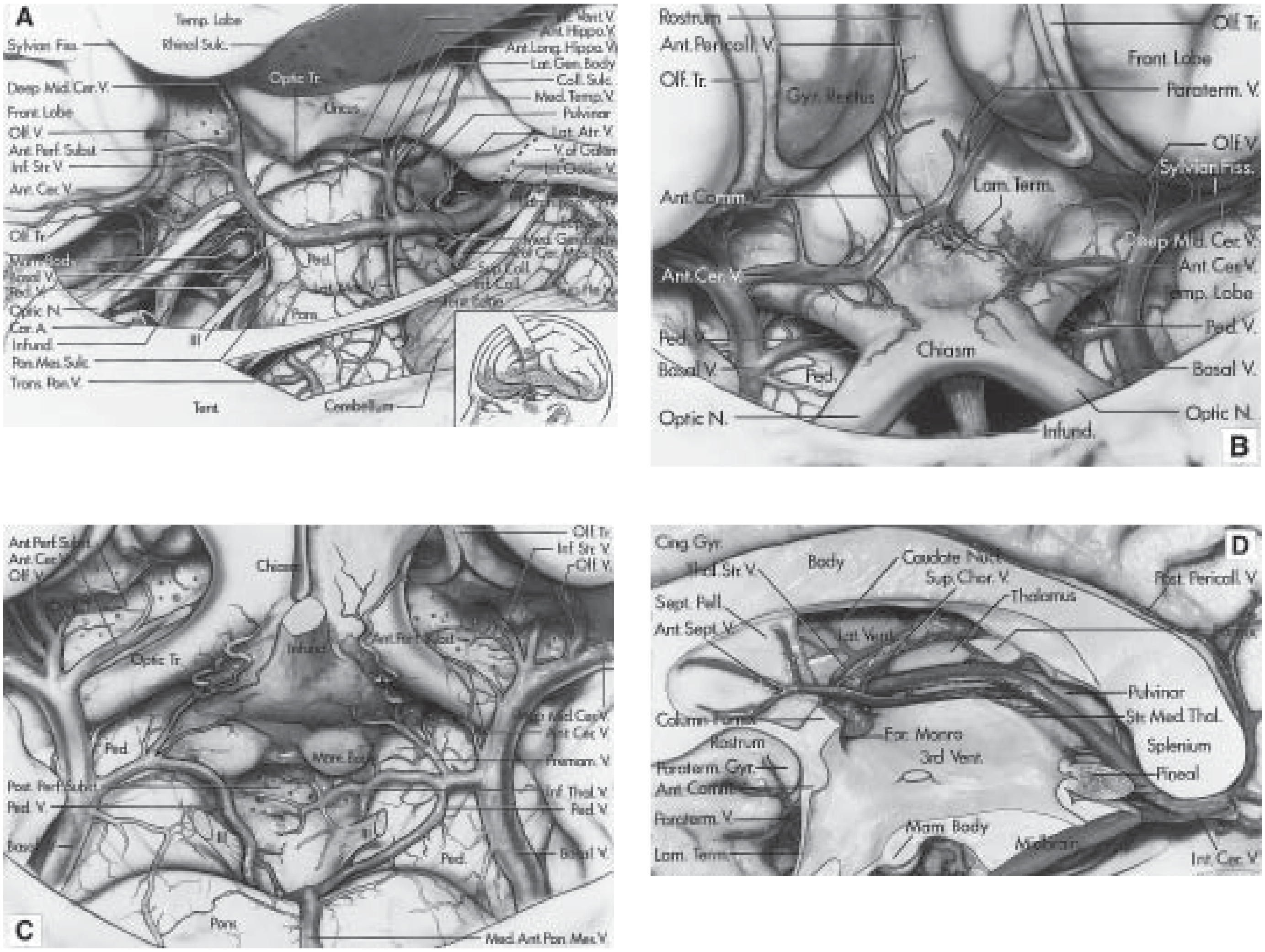


Figure 2-22 Veins in the suprasellar region. **(A)** Lateral view. Left side. The veins draining the suprasellar area converge on the anterior end of the basal vein (Basal V.). The temporal (Temp. Lobe) and frontal lobes (Front. Lobe) have been elevated, as shown in the insert. The basal vein arises below the anterior perforated substance (Ant. Perf. Subst.), passes around the cerebral peduncle (Ped.), and joins the vein of Galen (V. of Galen; dashed lines). The veins joining the anterior end of the basal vein include the olfactory veins (Olf. V.), which pass along the olfactory tract (Olf. Tr.); the inferior striate veins (Inf. Str. V.), which descend through the anterior perforated substance; the deep middle cerebral veins (Deep Mid. Cer. V.), which pass medially from the sylvian fissure (Sylvian Fiss.); and the anterior cerebral veins (Ant. Cer. V.), which pass across the optic chiasm. Other veins in the exposure include the peduncular (Ped. V.), lateral mesencephalic (Lat. Mes. V.), inferior ventricular (Inf. Vent. V.), anterior hippocampal (Ant. Hippo. V.), anterior longitudinal hippocampal (Ant. Long. Hippo. V.), medial temporal (Med. Temp. V.), lateral atrial (Lat. Atr. V.), internal occipital (Int. Occip. V.), transverse pontine (Trans. Pont.), superior vermian (Sup. Ve. V.) and superior hemispheric veins (Sup. He. V.), and the vein of the cerebellomesencephalic fissure (V. of Cer. Mes. Fiss.). Other structures in the exposure include the optic nerve (Optic N.) and tract (Optic. Tr.), carotid artery (Car. A.), lateral geniculate body (Lat. Gen. Body), infundibulum (Infund.), mamillary bodies (Mam. Body), tentorium (Tent.), tentorial edge (Tent. Edge), oculomotor nerve (III), parahippocampal (Parahippo. Gyr.), collateral (Coll. Sulc.), rhinal (Rhinal Sulc.) and pontomesencephalic sulci (Pon. Mes. Sulc.), lateral geniculate body (Lat. Gen. Body), and superior (Sup. Coll.) and inferior colliculi (Inf. Coll.). **(B)** Anterior view with the frontal lobe elevated. The anterior, deep middle cerebral, and olfactory veins join to form the basal vein. The anterior communicating (Ant. Comm. V.), paraterminal (Paraterm. V.), and anterior pericallosal veins (Ant. Pericall. V.) join the anterior cerebral veins in the region of the lamina terminalis (Lam. Ter.). The gyrus rectus (Gyr. Rectus) is also exposed. **(C)** Inferior view of the veins draining the floor of the third ventricle. The basal vein has its origin in the area below the anterior perforated substance. The peduncular veins cross the cerebral peduncle to join the basal veins. The premamillary veins (Premam. V.) drain the area around the infundibulum, and the inferior thalamic veins (Inf. Thal. V.) drain the region of the mamillary bodies and posterior perforated substance (Post. Perf. Subst.). The median anterior pontomesencephalic vein (Med. Pon. Mes. V.) courses in the midline on the midbrain and pons. **(D)** Midsagittal section showing the veins in the roof of the third ventricle (3rd Vent.). The brainstem has been sectioned at the level of the midbrain. Part of the septum pellucidum (Sept. Pell.) and body of the fornix has been removed to expose the right lateral ventricle (Lat. Vent.). The internal cerebral veins (Int. Cer. V.) course in the roof of the third ventricle. The thalamostriate (Thal. Str. V.), anterior septal (Ant. Sept. V.), posterior pericallosal (Post. Pericall. V.), and superior choroidal veins (Sup. Chor. V.) empty into the internal cerebral vein. Other structures in the exposure include the anterior commissure (Ant. Comm.), caudate nucleus (Caudate Nucl.), stria medullaris thalami (Str. Med. Thal.), paraterminal gyrus (Paraterm. Gyr.) and vein (Paraterm. V.), cingulate gyrus (Cing. Gyr.), and body of the corpus callosum (Body) *(20)*.

crosses the optic chiasm to reach the basal vein. The paired anterior cerebral veins are joined across the midline above the optic chiasm by the anterior communicating vein and receive the paraterminal veins from the paraterminal and parolfactory gyri and the anterior pericallosal veins from the rostrum and genu of the corpus callosum (Figure 22).

The veins on the surface of the brainstem that form the posterior wall of the anterior incisural space are divided into transversely and vertically oriented groups *(19,20)*. The transverse veins are the peduncular vein, which passes horizontally around the anterior surface of the cerebral peduncle and terminates in the basal vein, and the vein of the pontomesencephalic sulcus, which courses below the peduncular vein in the pontomesencephalic sulcus. The vertically oriented veins on the posterior wall of the anterior incisural space are the median anterior pontomesencephalic vein, which courses in the midline and connects the peduncular veins above with the pontine veins below, and the lateral anterior pontomesencephalic veins, which course on the anterolateral surface of the cerebral peduncle and the pons and join the basal vein superiorly and the vein of the pontomesencephalic sulcus below.

The internal cerebral veins course in the roof of the third ventricle and are only infrequently involved in pituitary adenomas (Figure 22). They originate just behind the foramen of Monro and course posteriorly within the velum interpositum. They join above or posterior to the pineal body to form the great vein.

REFERENCES

1. Pait TG, Zeal A, Harris FS, Paullus WS, Rhoton AL Jr. Microsurgical anatomy and dissection of the temporal bone. Surg Neurol 1977;8:363–391.
2. Rhoton AL Jr, Hardy DG, Chambers SM. Microsurgical anatomy and dissection of the sphenoid bone, cavernous sinus and sellar region. Surg Neurol 1979;12:63–104.
3. Rhoton AL Jr, Harris FS, Renn WH. Microsurgical anatomy of the sellar region and cavernous sinus. Clin Neurosurg 1977;24:54–85.
4. Rhoton AL Jr, Maniscalco J. Microsurgery of the sellar region. Neuroophthalmology 1977;9:106–127.
5. Bergland RM, Ray BS, Torack RM. Anatomical variations in the pituitary gland and adjacent structures in 225 human autopsy cases. J Neurosurg 1968;28:93–99.
6. Fujii K, Chambers SM, Rhoton AL Jr. Neurovascular relationships of the sphenoid sinus: A microsurgical study. J Neurosurg 1978; 50:31–39.
7. Hardy J. Transsphenoidal hypophysectomy. J Neurosurg 1971; 34:582–594.
8. Renn WH, Rhoton AL Jr. Microsurgical anatomy of the sellar region. J Neurosurg 1975;43:288–298.
9. Fujii K, Lenkey C, Rhoton AL Jr. Microsurgical anatomy of the choroidal arteries: Lateral and third ventricles. J Neurosurg 1980;52:165–188.
10. Inoue T, Rhoton AL Jr, Theele D, Barry ME. Surgical approaches to the cavernous sinus: A microsurgical study. Neurosurgery 1990;26:903–932.
11. Laws ER, Kern EB. Complications of transsphenoidal surgery. Clin Neurosurg 1976;23:401–416.
12. Harris FS, Rhoton AL Jr. Anatomy of the cavernous sinus: A microsurgical study. J Neurosurg 1976;45:169–180.
13. Gibo H, Lenkey C, Rhoton AL Jr. Microsurgical anatomy of the supraclinoid portion of the internal carotid artery. J Neurosurg 1981;55:560–574.
14. Rhoton AL Jr. Microsurgical anatomy of the region of the third ventricle. In: Apuzzo M, ed. Surgery of the Third Ventricle. Williams & Wilkins, Baltimore, 1987, pp. 92–166.
15. Gudmundsson K, Rhoton AL Jr, Rushton JG. Detailed anatomy of the intracranial portion of the trigeminal nerve. J Neurosurg 1971;35:592–600.
16. Parkinson D. Transcavernous repair of carotid cavernous fistula: A case report. J Neurosurg 1967;26:420–424.
17. Yamamoto I, Rhoton AL Jr, Peace DA. Microsurgery of the third ventricle: Part 1. Microsurgical anatomy. Neurosurgery 1981; 8:334–356.
18. Rhoton AL Jr, Yamamoto I, Peace DA. Microsurgery of the third ventricle: Part 2. Operative approaches. Neurosurgery 1981;8: 357–373.
19. Ono M, Ono M, Rhoton AL Jr, Barry M. Microsurgical anatomy of the region of the tentorial incisura. J Neurosurg 1984;60:365–399.
20. Ono M, Rhoton AL Jr, Peace DA, Rodriguez R. Microsurgical anatomy of the deep venous system of the brain. Neurosurgery 1984;15:621–657.
21. Saeki N, Rhoton AL Jr. Microsurgical anatomy of the upper basilar artery and the posterior circle of Willis. J Neurosurg 1977;46: 563–577.
22. Gibo H, Carver CC, Rhoton AL Jr, Lenkey C, Mitchell RJ. Microsurgical anatomy of the middle cerebral artery. J Neurosurg 1981;54:151–169.
23. Hardy DG, Peace DA, Rhoton AL Jr. Microsurgical anatomy of the superior cerebellar artery. Neurosurgery 1980;6:10–28.
24. Perlmutter D, Rhoton AL Jr. Microsurgical anatomy of the anterior cerebral-anterior communicating-recurrent artery complex. J Neurosurg 1976;45:259–271.
25. Zeal AA, Rhoton AL Jr. Microsurgical anatomy of the posterior cerebral artery. J Neurosurg 1978;48:534–551.
26. Rhoton AL Jr, Fujii K, Fradd B. Microsurgical anatomy of the anterior choroidal artery. Surg Neurol 1979;12:171–187.
27. Perlmutter D, Rhoton AL Jr. Microsurgical anatomy of the distal anterior cerebral artery. J Neurosurg 1978;49:204–228.
28. Rosner SS, Rhoton AL Jr, Ono M, Barry M. Microsurgical anatomy of the anterior perforating arteries. J Neurosurg 1984;61:468–485.

http://www.springer.com/978-0-89603-403-7

Diagnosis and Management of Pituitary Tumors
Thapar, K.; Kovacs, K.; Scheithauer, B.; Lloyd, R.V. (Eds.)
2001, 496 p. 454 illus., 15 illus. in color., Hardcover
ISBN: 978-0-89603-403-7
A product of Humana Press