Microsurgical anatomy of the sellar region

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Fifty adult sellae and surrounding structures were examined under magnification with special attention given to anatomical variants important to the transfrontal and transsphenoidal surgical approaches. The discovered variants considered disadvantageous to the transsphenoidal approach were as follows: 1) large anterior intercavernous sinuses extending anterior to the gland just posterior to the anterior sellar wall in 10%; 2) a thin diaphragm in 62%, or a diaphragm with a large opening in 56%; 3) carotid arteries exposed in the sphenoid sinus with no bone over them in 4%; 4) carotid arteries that approach within 4 mm of midline within the sella in 10%; 5) optic canals with bone defects exposing the optic nerves in the sphenoid sinus in 4%; 6) a thick sellar floor in 18%; 7) sphenoid sinuses with no major septum in 28% or a sinus with the major septum well off midline in 47%; and 8) a presellar type of sphenoid sinus with no obvious bulge of the sellar floor into the sphenoid sinus in 20%.

Variants considered disadvantageous to the transfrontal approach were found as follows: 1) a prefixed chiasm in 10% and a normal chiasm with 2 mm or less between the chiasm and tuberculum sellae in 14%; 2) an acute angle between the optic nerves as they entered the chiasm in 25%; 3) a prominent tuberculum sella protruding above a line connecting the optic nerves as they entered the optic canals in 44%; and 4) carotid arteries approaching within 4 mm of midline within or above the sella turcica in 12%.

KEY WORDS — sella turcica · pituitary gland · microsurgical anatomy · sphenoid sinus · optic chiasm

INCREASING use of surgical magnification for surgery of the sellar region has created a need for more detailed anatomical studies of the area. To define this anatomy better, we examined 50 adult sellae with special attention to the anatomical variants important to the transfrontal and transsphenoidal surgical approaches. Once aware of these variants, the surgeon can often recognize them on preoperative radiological studies. In addition, knowledge of potential variants such as exposure of optic nerves and carotid arteries in the sphenoid sinus may alter the surgeon’s technique, operative approach, and selection of instruments.

Methods

Fifty sellae were removed en bloc from embalmed adult cadavers and examined under 3 to 40 × magnification. Care was taken to remove the sella and surrounding structures as a single specimen. In some the vessels were injected with colored latex to define the vascular structures. Special attention was directed to the sphenoid sinus, and its septae,
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the sellar floor, optic nerves, canals and chiasm, the carotid, ophthalmic, and anterior cerebral arteries, and the venous connections around the sella.

**Results and Discussion**

**Optic Nerves and Chiasm**

The relationship of the optic chiasm to the tuberculum sellae and pituitary was determined by the criteria of Bergland, et al., namely, the normal chiasm overlies the diaphragma sellae and pituitary, the prefixed chiasm overlies the tuberculum sellae and the postfixed chiasm overlies the dorsum sellae (Fig. 1). Of the sellae we studied, 10% were prefixed, 15% postfixed, and 75% normal. These findings were similar to those of Bergland, that 9% were prefixed, 11% postfixed, and 80% normal.

The distance between the tuberculum sellae and the chiasm varies with the type of chiasm, and is critical in the transfrontal approach to the pituitary. In the presence of a prefixed chiasm the tuberculum sellae was found to project as much as 2 mm behind the anterior margin of the chiasm. This space between the tuberculum and the chiasm may also be very limited in some cases with a normal chiasm. The distance from the tuberculum to the anterior margin of the chiasm in normal specimens varied from 2 to 6 mm, with an average of 4 mm. In 14% of those with a normal chiasm, this distance was 2 mm or less. In those with a prefixed chiasm, the distance between the tuberculum and the anterior margin of the chiasm varied from 5 to 9 mm, mean 7 mm.

The cross-sectional width of the optic nerves just proximal to the optic canal was consistently greater than the height, thus making the nerves somewhat flat; width ranged from 3.5 to 6 mm, mean 5 mm, height from 2 to 5 mm, mean 3 mm. Optic nerve length from anterior chiasm to the optic canal entrance ranged from 8 to 19 mm, mean 12 mm. The length varied from side to side in the same specimen by 2 mm or greater in only 5 specimens (10% of the total specimens) (Fig. 2). The distance between the medial margins of the optic nerves just proximal to the optic canals ranged from 9 to 24 mm, mean 14 mm.

The angle formed by junction of the line along the medial margin of optic nerves as they approach the chiasm ranged from 50° to 80°. As this angle becomes more acute the area through which the surgeon can approach the pituitary in the transfrontal approach becomes smaller. Another finding which reduces surgical access to the sella is protrusion of the tuberculum above the line connecting the superior surface of the nerves as they enter the optic canals. The tuberculum protruded above this line in 44% of the specimens, with the greatest protrusion extending 3 mm.

The small transfrontal operative field created by a prefixed chiasm, a normal chiasm with a small area between the tuberculum and chiasm, a superiorly protruding tuberculum sellae, or an acute angle between the nerves is often enlarged by removing the tuberculum, or by using the transfrontal-transsphenoidal approach advocated by Rand.?
Optic Canals

As the optic nerves enter the optic canals they are covered by bone invested in dura. However, the bone covering around the nerve often does not begin for several millimeters distal to the dural sheath. This absence of bone over nerves covered by dura could lead to nerve injury during surgery, if coagulation was used along the dura above the optic canal on the assumption that bone separated dura from nerve. The length of nerve covered only by dura at the entrance into the optic canal varied from 0.5 to 8.0 mm, average 3 mm.

The optic canals bulge into the anterior superior part of the sphenoid sinus (Fig. 3). In 4% of the nerves, some areas were covered only by the optic sheath and sinus mucosa. Care must be taken to protect the nerves in the transsphenoidal approach if a defective bone covering exposes them in the sinus. Injury to nerves exposed in the sinus may explain some of the cases of unexpected visual loss following transsphenoidal surgery.

Diaphragma Sellae

The diaphragma sellae is defined in Gray's Anatomy as a "small, circular, horizontal fold of dura mater, which forms a roof for the sella turcica and almost completely covers the hypophysis; a small central opening in its center transmits the infundibulum." Close inspection in this study revealed that it is more often rectangular than circular and more often convex or concave rather than flat or horizontal. It often has a large rather than a small opening transmitting the infundibulum. Diaphragma width ranged from 6 to 15 mm, the mean being 11 mm; length ranged from 5 to 13 mm, the mean being 8 mm. The width of the diaphragma was greater than the length in 84%, and was equal to length in the other 16%. It was concave when viewed from above in 54% of the specimens, convex in 4%, and flat in 42%.

The diaphragma was usually thinner around the infundibulum and somewhat thicker at the periphery. It was at least as thick as one layer of dura in 38% and in these
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FIG. 4. Superior view of sellar region. Optic chiasm is reflected forward, and a congenitally absent diaphragm exposes the superior surface of pituitary gland. Arachnoid covers superior surface of gland, and the third cranial nerve is posterior to carotid arteries.

would furnish an adequate barrier during transsphenoidal hypophysectomy. In 62% of the specimens, the diaphragma was extremely thin over some portion of the pituitary gland.

A deficiency of the diaphragma sellae is assumed to be a precondition to formation of an empty sella by some authors. The diaphragmal opening was 5 mm or greater in 56% and in these cases it would not form a barrier during transsphenoidal pituitary surgery (Fig. 4). 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%.

Intercavernous Sinuses

A new anatomical observation made in this investigation is that the intercavernous venous connection posterior to the clivus, called the basilar sinus, which connects the posterior aspect of both cavernous sinuses, is usually the largest and most constant connection across the midline between the cavernous sinuses. It is a multiloculated cavity lying within the dura on the posterior aspect of the dorsum. It connects the cavernous sinuses and receives the superior and inferior petrosal sinuses. The basilar sinus was present in 82% of the specimens.

The intercavernous connections within the sella are usually named on the basis of their relationship to the pituitary gland; the anterior intercavernous sinus passes anterior to the hypophysis, and the posterior intercavernous sinus passes behind the gland. Actually, these intercavernous connections can occur at any site along the anterior, inferior, or posterior surface of the gland. The anterior sinus was usually larger than the posterior, but either or both may be absent. Anterior intercavernous sinuses (Figs. 5 to 9 and front cover) were present in 76% of the specimens, and posterior intercavernous sinuses in 32%. The anterior sinuses were not wholly contained by the diaphragm but extended in front of the gland in 10%. Large anterior venous sinuses make transsphenoidal pituitary surgery more difficult.

The distance between the posterior clinoid and the entrance of the third central nerve into the dura over the cavernous sinus varied from 3 to 11 mm, with the average 5 mm. The distance between the anterior clinoid and the entrance of the third central nerve into the cavernous sinus varied from 3 to 13 mm, mean 7 mm. The average distance between the anterior and posterior clinoid was 11 mm, range 7 to 19 mm.

Sella Turcica

A thin sellar floor markedly facilitates the transsphenoidal approach to the pituitary. The thickness of the bone of the sellar floor was 1 mm or less in 82% of our specimens.
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FIG. 5. Superior view of sellar region. Ophthalmic arteries arise from superior aspect of carotid artery and course laterally beneath the optic nerves to the optic foramen. The dura over the cavernous and anterior intercavernous sinuses has been removed to show the venous connection across the midline.

FIG. 6. Midline sagittal section of sellar region showing anterior and posterior intercavernous and basilar sinuses. The basilar sinus connecting the posterior aspect of both cavernous sinuses is the largest connection across the midline. An intermediate lobe cyst separates the anterior and posterior lobe of the pituitary gland. Anterior sellar wall bulging into sphenoid sinus is 1 mm thick.

FIG. 7. Midline sagittal section of sellar region showing optic nerve and chiasm, third cranial nerve (CN III), inferior part of hypothalamus, and pituitary stalk and gland. The anterior and inferior intercavernous sinuses are small. The basilar sinus, dorsal to the clivus, joining the posterior aspect of the two cavernous sinuses is the largest connection across the midline. Anterior sellar wall bulging into the sphenoid sinus is very thin.
Fig. 8. Schematic drawing of six sagittal sections of sellar region showing variation in intercavernous venous connections (blue) within dura (red). 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 connection 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 is frequently absent (lower right).

This correlates well with the figure of 72% found by Bergland, et al.\textsuperscript{1} In our specimens the floor was 0.5 mm or less in 40% (Fig. 10), and in several instances the floor was only a few microns thick, cracking even with careful removal of the pituitary gland or sphenoid sinus mucosa. The floor was greater than 1 mm thick in 18%; the thickest floor in our specimens was 4 mm.

The dimensions of the sella turcica were determined with the measurements of Taveras and Wood\textsuperscript{8} and the volume calculated by applying the simplified mathematical formula for the volume of an ellipsoid suggested by DiChiro and Nelson,\textsuperscript{4} namely, volume (cm\textsuperscript{3}) = 0.5 (length × width × depth in mm)/1000. The depth of the sella is the greatest distance between the floor and a perpendicular line connecting the tuberculum and dorsum sellae. The upper limit of normal depth according to Taveras and Wood\textsuperscript{8} is 13 mm. Camp\textsuperscript{2} found that the normal depth varied from 4 to 12 mm, mean 8 mm. We found that the depth ranged from 5 to 12 mm, mean 9 mm. Sellar length, defined as the greatest anteroposterior diameter of the pituitary fossa, may occur at the level of the tuberculum sellae or below, depending on the shape; according to Taveras and Wood\textsuperscript{8} the upper limit of normal is 17 mm. According to Camp\textsuperscript{2} normal sellar length ranges from 5 to 16 mm, mean 10.5 mm, in adults.
In this study, length ranged from 7 to 14 mm, mean 10 mm. Sella width, defined as the width of the horizontal plateau of the sella floor, varied from 10 to 15 mm as measured on x-ray films by Taveras and Wood, while DiChiro reported sellar widths of 9 to 18 mm in 100 normal subjects. The range in our study was 10 to 16 mm, the mean was 14 mm.

The mean sella volume in our study was 621 mm³ and the maximum 1056 mm³. DiChiro and Nelson found mean sella volume to be 594 mm³, with a maximum of 1094 mm³ in 173 normal adults.

**Pituitary Gland**

The shape of the pituitary gland varied markedly from one specimen to the next. Its width was equal to or greater than either its depth or length in all 50 specimens. The inferior surface of the gland usually conformed to the shape of the sella floor. The pituitary gland has no bone boundary on its lateral and superior margins. If there was a large opening in the diaphragm the gland tended 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. One unusual gland had a round extension that filled a deep secondary cup that protruded inferiorly from the floor of the sella into the sphenoid sinus.

Variations in the shape of the gland create some problems in accomplishing complete hypophysectomy. When the carotid arteries indent the lateral surface of the gland it loses its rounded shape and conforms to the wall of the artery, often developing tongue-like protrusions above or below the artery. In addition, intrasellar tumors are subjected to the same forces, which prevent them from being spherical, and the increased pressure within the tumor tends to increase the degree to which extensions of tumor insinuate into surrounding crevasses and tissue planes. Separation of these extensions from the main mass of gland or tumor may explain cases in which
functioning pituitary gland remains after hypophysectomy, and others in which the serum growth hormone becomes elevated long after it has fallen to zero immediately following eosinophilic adenoma removal.

**Sphenoid Sinuses**

The sphenoid sinuses are described in Gray's Anatomy as paired cavities lying side by side in the body of the sphenoid bone, separated by a bone septum which is commonly deflected to one side or the other. We found the cavities varied markedly in size and shape, were seldom symmetrical from side to side, and were often subdivided by irregular minor septae (Figs. 11 and 12). The position of the major bone septum that separates the paired sinuses can usually be seen on tomograms and, if located near the midline, can be of considerable aid in directing the transsphenoidal approach to the hypophysis. The most common type of sphenoid sinuses encountered in our study had multiple smaller cavities in the larger paired sinuses with the large sinuses usually separated by a septum oriented along an anteroposterior axis. The smaller cavities were separated by septae oriented in all directions. A single major septum separated the sinus into two large cavities in 68% of the specimens, and 4% had two major septae separating the sinus into three large cavities. The major septae were off midline as they crossed the floor of the sella in 46% of instances. No major septae separated the two sides in 28%; no minor cavities or septae were found within paired cavities in 18%.
Anteroposterior tomograms of the sellae are essential to define the relation of the septae to the floor of the sella for the transsphenoidal approach. In one case at surgery, entry into an asymmetric air cell like that formed by the bifurcation of the major septum in Fig. 3, revealed the carotid artery exposed in the opening. This was recognized and the approach modified to a more appropriate midline location for hypophysectomy. Major septae were found a maximum of 8 mm to either side of the midline.

Hamberger, et al., 5 classified the sphenoid sinuses into three main anatomical groups: conchal, preseptal, and sellar types, depending on the extent to which the sphenoid bone is pneumatized. In the conchal type the sinus does not extend into the body of the sphenoid bone and the thickness of the bone wall between the sella and the sinus is at least 10 mm. The preseptal type of sphenoid sinus does not penetrate beyond a plane perpendicular to the tuberculum sellae. The sella has a thin floor and usually bulges into the sellar type of sinus. No conchal types were encountered in our study of adults; this type of sella is more common in children. The presellar type was found in 20% and the sellar type in 80% of our specimens. Hamberger, et al., 5 found a presellar type in 11% and a sellar type in 86%.

The sellar floor and optic canals are not the only structures that bulge into the sphenoid sinus. The carotid arteries also bulge into the superolateral wall of the posterior part of the sinus; we found 71% of the carotid arteries bulging into the sphenoid sinus. The arterial bulges were usually covered by bone; however, 4% had no bone separating the artery from the sinus mucosa (Figs. 10 and 12), and 66% had less than 1 mm thickness of bone covering the carotid arteries. The bone was often only a few microns thick and would not protect the artery during transsphenoidal hypophysectomy. In 30% of cases a 1 mm or greater thickness of bone protected the artery from the sphenoid sinus. The exposure of optic nerves and carotid arteries in the sphenoid sinus makes it important that dissection in this area be done with great care.

Arterial Relationships

Ophthalmic Arteries. In this study the ophthalmic artery arose from the carotid artery above the cavernous sinus in 89%, and within the cavernous sinus in 8%. It was absent in 3%. The ophthalmic arteries that exited from the carotid artery above the cavernous sinus can be divided further: 72% coursed along the medial third of the superior surface of the carotid artery, 13% above the central third, and 4% along the lateral third (Figs. 1 center, 4, and 5). Two of the arteries that exited from the carotid artery in the cavernous sinus entered the floor of the optic canal through a bone foramen.

The diameter of the ophthalmic arteries as they exited from the carotid artery varied from 0.5 to 3 mm, mean 2 mm. The ophthalmic artery length from the internal carotid artery to its entrance into the optic canal under the optic nerve was determined. In 14% the ophthalmic artery exited from the carotid artery and immediately entered the optic canal; in the remaining 86%, this maximal length was 7 mm, mean 3 mm.

Since the artery may be absent or may arise in the cavernous sinus and never reach the subarachnoid space before entering the optic foramen, it is important that it be defined by angiography where its identification at surgery may be important in treating such disorders as cavernous or orbital arteriovenous fistulas.

Carotid Arteries. The proximity of the carotid arteries to the midline is extremely important in pituitary surgery. The shortest distance between the two carotid arteries was determined in the sphenoid sinus, cavernous sinus lateral to the sella, and in the supraclinoid area. The shortest distance between the two carotid arteries was found in the supraclinoid area in 82% of the cases, in...
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Fig. 13. Superior view of sellar region showing optic nerves, carotid arteries, and third cranial nerves. Carotid arteries bulged into the pituitary fossa.

Fig. 14. Superior view of sellar region. Long, tortuous anterior cerebral arteries above the optic chiasm. The A-1 segment of the right anterior cerebral artery loops in a complete circle between its origin from the carotid artery and its junction with its mate from the opposite side at the anterior communicating artery. Tortuous left anterior cerebral artery rests against the tuberculum sellae covering the prechiasmatic space.

the cavernous sinus in 14%, and in the sphenoid sinus in 4%. The shortest distance between the carotid arteries varied from 4 to 18 mm, mean 12 mm. In some the carotid arteries approached within 4 mm of each other within the sella turcica and compressed the pituitary laterally (Fig. 13).

Anterior Cerebral Artery. The relationships of the anterior cerebral-anterior communicating artery complex to the optic nerves and chiasm were determined. In some, the A-1 segments of the anterior cerebral artery exited from the carotid artery relatively proximal, were short and straight, and appeared to be stretched across the chiasm (Fig. 2). Other A-1 segments were longer, exiting from the carotid artery further distal (Fig. 1 center), and still others were even longer and more tortuous, making a complete circle between their origin from the carotid artery and their junction with their mate of the opposite side at the anterior communicating artery (Fig. 14). Some of the tortuous arteries extended as far anterior as the tuberculum and completely covered the prechiasmatic space.
Summary

Variants considered disadvantageous to the transsphenoidal approach were:

1. Large anterior intercavernous sinuses extending anterior to the gland.
2. A thin diaphragm sellae or a diaphragm with a large opening.
3. A thick sellar floor.
4. Sphenoid sinuses with no major septum or a sinus with the major septum off the midline.
5. A presellar type of sphenoid sinus with no obvious bulge of the sellar floor into the sphenoid sinus.
6. Carotid arteries exposed in the sphenoid sinus with no bone over them.
7. Carotid arteries that approach within 4 mm of midline within the sella.
8. Optic canals with bone defects exposing the optic nerves in the sphenoid sinus.

Variants considered disadvantageous to the transfrontal approach were:

1. A prefixed chiasm and a normal chiasm with 2 mm or less between the chiasm and tuberculum sellae.
2. An acute angle between the optic nerves as they entered the chiasm.
3. A prominent tuberculum sellae protruding above a line connecting the optic nerves as they entered the optic canals.
4. Carotid arteries approaching within 4 mm of midline within or above the sella turcica.

References


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