Anatomical Variations in the Pituitary Gland and Adjacent Structures in 225 Human Autopsy Cases*

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Observations in over 1,000 intracranial operations for tumors of the pituitary or for its palliative ablation by various members of the Neurosurgical Department at The New York Hospital-Cornell Medical Center have produced evidence of several hitherto unrecognized variations both in the gland and in the surrounding anatomy. To define these anatomical variations, the pituitary gland and adjacent structures were removed en bloc with a motor saw from 225 fresh autopsy cases, measured in detail, drawn, photographed, and embedded in plastic. None of these cases had had a recognized pituitary disease or operation. Attention was directed to the optic chiasm, the arachnoid cisterns, the diaphragm of the sella, the cavernous and intercanalveous sinuses, the carotid siphon, the surrounding bones, and the size and shape of the pituitary itself.

Optic Chiasm

Schaeffer 12 first described variations in the chiasm and called attention to its "prefixed" and "post-fixed" positions. The chiasm normally lies directly above the central portion of the diaphragm and the pituitary (Fig. 1). The so-called prefixed chiasm overlies the tuberculum sellae (Fig. 2) whereas the post-fixed chiasm overlies the dorsum sellae (Fig. 3). These designations are rather dependent upon the length of the tuberculum sellae, which averages 7 mm but may vary from 3 to 12 mm. In this study, the length of the tuberculum was related to the length of the prechiasmal space. In 9% of the specimens, the tuberculum equalled or exceeded the length of the prechiasmal space, and these chiasms were judged to be prefixed. In 11% of the specimens, the tuberculum was shorter than the length of the prechiasmal space by 6 mm or more, and these chiasms were judged to be post-fixed. The remainder, or 80%, were regarded as normal.

Diaphragma Sellae

The prechiasmal space varied considerably in width as well as in length. The distance between the optic nerves as they enter the optic foramina averaged 13 mm, varying from 8 to 20 mm; the width of the prechiasmal space varied accordingly (Fig. 4).

The width of the chiasm itself did not vary significantly and averaged 10 mm. In 4% of the specimens, the optic nerves were noticeably distorted by the intradural portion of the carotid artery.

Despite frequent anomalies of the diaphragm described by several workers, 1,12,13 the structure is commonly assumed to provide a dense connective tissue covering for the sella turcica and to possess a small opening for the penetration of the pituitary stalk. Indeed, most trans-sphenoidal procedures are designed on the assumption that the diaphragm will serve as a barrier between the sella turcica and the intracranial space.

In 39% of the diaphragms in this study, the openings for the stalk were greater than 5 mm in diameter (Figs. 5 and 6); 10% of the diaphragms were considered too thin to serve as reliable barriers against easy penetration during trans-sphenoidal procedures (Fig. 7).

The anterior and posterior attachments were found to vary considerably. Although the diaphragm is presumed (from lateral x-ray studies) to extend from the superior aspect of the posterior clinoid processes to the superior margin of the tuberculum sellae, often the attachment was found several millimeters below these points. Corresponding to the variations in the point of attachment,
the diaphragm can be tilted either anteriorly or posteriorly (Fig. 8).

**Arachnoid Cisterns**

Wislocki reported that it is not embryologically feasible for the arachnoid to surround the pituitary; yet roentgenography has occasionally demonstrated an extension of the subarachnoid space into the sella turcica.

The arachnoid may balloon into the sella above a diaphragm that has a low attachment, but more often it protrudes through the large opening frequently present in the diaphragm. The incidence of a subarachnoid space that lies within the sella turcica, as would be outlined in a lateral x-ray, exceeds 20%. This correlates well with the incidence of cerebrospinal fluid rhinorrhea following stereotaxic pituitary procedures.

**Cavernous Sinus**

Although Parkinson described the anatomical details of the cavernous sinus, he gave little attention to variations. Bedford described most of the pertinent variations and stressed that the sinus did not contain bridging bands. Although it is difficult to quantify the size and shape of the cavernous sinus, our studies indicate that there is considerable variation. In some specimens the sinus is large, while in others it is almost obliterated by the traversing nerves, arteries, and contained pituitary. Contrary to Bedford's description, nearly all specimens had several bridging connective tissue bands that often extended from the carotid to the pituitary capsule (Fig. 9).

The venous channels connecting the right and left cavernous sinuses have been called the intercavernous or circular sinuses (Fig. 10). Most anatomy texts describe these as small spaces within the substance of the diaphragma sellae, but in this study the intercavernous sinuses were frequently large and not wholly contained within the diaphragm. In 85% of the specimens, an anterior intercavernous sinus was present; the largest was 8 mm deep (Fig. 11). Less often, vascular connections were found beneath or behind the pituitary yet within the sella turcica (Fig. 12).

**Carotid Arteries**

Since the advent of arteriography, study of the parapituitary carotid siphons has become commonplace. Bull has outlined the variations in these structures and noted the variable distances between them in the parapituitary area.

In our studies, the distance between the carotid siphons averaged 14 mm but was as great as 23 mm (Fig. 13). The carotid arteries usually were not in contact with the pituitary, but as they became more tortuous the distance between them decreased, and the gland sometimes became compressed on either or both sides. Figure 14 shows such a tortuosity of the siphons, in which the distance between the carotids is 4 mm and the pituitary is correspondingly compressed. In 22% of the specimens, the gland was distorted laterally by the carotids (Fig. 15).

**Surrounding Bones**

Mahmoud did extensive studies of the bones that join to form the sella turcica, cataloging variations and correlating the growth of pituitary tumors with the consistency of the surrounding bone. Hamburger correlated the variations in the bony floor of the sella with the ease of trans-sphenoidal hypophysectomy and noted that 87% of the cases had thin bone that was readily removed.

In 72% of the specimens in this study, the anterior floor of the sella was 1 mm or less in thickness (Fig. 16). Thicker spongiosum bone was more commonly seen toward the posterior sellar floor, and the bones forming the clivus were nearly always spongiosum. Although the floor of the sella was uniformly thick (up to 20 mm) in children (Fig. 17), the sphenoid sinus enlarged with age and the floor of the sella became thinner.

In 6% of the specimens, a bony bridge extended from the posterior to the anterior clinoids (Fig. 19). These bridges were generally bilateral and of variable diameter, the largest being 3 mm. An additional strut often extended from the middle clinoid to the anterior clinoid, immediately behind the carotid siphon, and formed a sturdy foramen for the carotid within the cavernous sinus. It must be stressed that this additional bone formation was lateral to the pituitary, not above it.

**Pituitary Gland**

The weight of the normal pituitary as recorded by A. T. Rasmussen may vary from 350 to 800 mg in males and from 450 to 900 mg in females. During pregnancy these weights may double, and related visual field
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Fig. 1. A normal chiasm. The prechiasmal space is 8 mm long, and the length of the tuberculum sellae is 5 mm.

Fig. 2. A prefixed chiasm. The prechiasmal space is only 3 mm long, and the chiasm overlies the tuberculum sellae (as in 9% of specimens).

Fig. 3. A post-fixed chiasm. The prechiasmal space is 12 mm long, and the tuberculum sellae is 6 mm long. The chiasm overlies the dorsum sellae (as in 11% of specimens).

Fig. 4. In the upper specimen, the optic nerves are 12 mm apart as they enter the optic foramina. In the lower specimen, this distance is 20 mm and the prechiasmal space is accordingly wider.

Fig. 5. The chiasm has been removed. The diaphragma sellae does not form a complete cover for the sella turcica, and the opening for the pituitary stalk measures 7 mm in diameter.

Fig. 6. The chiasm has been removed. The opening in the diaphragm is 9 mm in diameter (it exceeded 5 mm in 39% of specimens). The pituitary portal vessels extend from the stalk to the pars distalis.
Fig. 7. The chiasm has been removed. The diaphragm is complete but thin enough to allow visualization of the pituitary and the portal system (as in 10% of specimens).

Fig. 8. Midline sagittal section. The diaphragm does not extend from the top of the dorsum sellae to the edge of the tuberculum sellae as might be expected on a lateral x-ray film.

Fig. 9. The dorsum sellae and posterior dural investments have been removed to expose the cavernous sinus. The sinus is nearly obliterated by the contained nerves and vessels. Trabeculae extend from the pituitary capsule to the carotid arteries.

Fig. 10. The intercavernous sinuses have been opened and are visible as circular channels connecting the right and left cavernous sinuses.

Fig. 11. Right lateral view exposing the mesial wall of the cavernous sinus. A large anterior intercavernous sinus is seen in front of the pituitary and not wholly contained by the diaphragm.

Fig. 12. Right lateral view exposing the mesial wall of the cavernous sinus. A large inferior intercavernous sinus is seen beneath the pituitary, which is traversed by numerous trabeculae.
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Fig. 13. The dorsum sellae and posterior dural investments have been removed, exposing a large cavernous sinus. The floor of the sella turcica is several mm wider than the pituitary. The carotid siphons are 21 mm apart.

Fig. 14. The dorsum sellae, dura, pituitary, and cranial nerves have been removed to visualize the tortuous carotid arteries. The arteries are only 4 mm apart, and the pituitary is correspondingly compressed.

Fig. 15. The dorsum sellae and the dural covering of the cavernous sinus have been removed. The lateral margins of the pituitary have been compressed by the carotid arteries (as in 22% of the specimens).

Fig. 16. Midline sagittal section. The anterior floor of the sella turcica is less than 1 mm thick (as in 72% of the specimens).

Fig. 17. Midline sagittal section. The floor of the sella is composed of thick spongiosum bone, as seen in this specimen from a 10-year-old child.

Fig. 18. Midline sagittal section. The sella turcica is only partially filled by the pituitary gland. A large anterior intercavernous sinus is visible.
changes have been reported. With multiparity, the pituitary weight is increased progressively. These data emphasize the difficulty of assuming such a thing as a “normalized” pituitary.

The shape of the gland was nearly as variable as its size. In our specimens the gland was generally wider than it was long, but frequently it was found to be narrow, flat, tall, round, or asymmetrical. As noted previously, 22% of the glands were compressed laterally by the carotid arteries.

The anterior, inferior, and posterior contours of the pituitary correlated fairly well with the corresponding portions of the sella turcica, and for these measurements a lateral x-ray film provided a reliable estimate. However, the lateral margins of the gland were bounded by soft tissues of the cavernous sinus, and the width of the pituitary could not be accurately established by routine x-ray. The width of the gland has been correlated with the width of the dorsum sellae (Joplin) and with the width of the floor of the sella (di Chiro). However, the lateral margins of the pituitary have no consistent bony correlates, and visualization of the cavernous sinus as proposed by Hanafee is necessary to establish the width of the gland.

Neither the superior contour nor the height of the pituitary can be determined by routine x-ray. Although the pituitary is commonly assumed to fill the sella turcica, in 23% of specimens the gland was at least 2 mm shorter than the depth of the sella (Fig. 18). In some specimens the height of the gland was less than one-half the depth of the sella. The subarachnoid cisterns ballooned into the sella turcica in those specimens in which the sella was not completely filled by the pituitary gland. Detailed air studies are necessary in order to delineate the true height of the pituitary.

The pars tuberalis and pituitary portal system could be observed on many gross specimens, but no statement is possible concerning variations. The pars distalis and pars nervosa were easily distinguished in gross specimens; the line of demarcation between the two was quite variable. In some specimens, the pars distalis was wrapped around the pars nervosa, while in others the pars nervosa protruded posteriorly without any encompassing pars distalis. Frequently, the pars nervosa lay in a shallow depression on the anterior surface of the dorsum sellae.
Conclusions

The common anatomical variations of the pituitary and its adjacent structures explain many of the hazards and complications attending the various hypophyseal ablative procedures and some of the changes noted in the pathological conditions of the gland. Routine roentgenograms employed in stereotaxy can neither define the size, shape, or position of the pituitary, nor accurately predict variations in the position of the important adjacent structures. Although more refined x-ray procedures might uncover many of these abnormalities, the additional stress involved is precisely what stereotaxic operations are designed to avoid.

The advantages of adequate surgical exposure are nowhere more obvious than in surgery of the pituitary. The intracranial approach facilitates recognition and management of the anatomical variations about the sella and permits more certain removal of the normal gland or of pituitary tumors. In addition, the complications that sometimes compromise the effectiveness of the less direct procedures can be avoided.

References

3. Busch, W. Die Morphologie der Sella turcica

*Editor's Note: The details of this technique are fully described in a special article by Dr. Bronson Ray which appears on pp. 180-186 of this issue of the Journal of Neurosurgery.