Normal Pituitary Gland:
1. Macroscopic Anatomy–CT Correlation

To improve the radiologic recognition of pituitary microadenomas that have subtle or no mass effect, the appearance of the normal pituitary gland on computed tomographic (CT) images was studied. Thirteen autopsy specimens of the pituitary gland and sella turcica were examined by coronal CT and histologically sectioned in similar coronal planes. The CT and histologic findings were correlated, then compared with the coronal CT images of 30 normal pituitary glands in vivo, most of which were contrast-enhanced. The normal pituitary gland had a nonhomogeneous CT appearance with a variety of frequently predictable patterns. This heterogeneity was in part the result of gross anatomic structural interrelations between the anterior lobe, pars intermedia, and posterior lobe.

The normal pituitary gland may have a heterogeneous appearance on computed tomographic (CT) examination, consisting of intermingled CT-lucent and CT-dense areas. Since microadenomas (adenomas < 10 mm in diameter) may present as nonhomogeneous, lucent or dense areas within the gland [1] and may possess subtle or no mass effect, confusion may arise between normal nonhomogeneous areas and microadenomas. In order to recognize microadenomas, it is therefore essential to have a clear understanding of the normal appearance of the pituitary gland on CT. For this purpose, we examined autopsy specimens of normal pituitary glands and sellae turcicae both by coronal CT and by histologic analysis of coronal sections. The CT and histologic findings were correlated, then compared with the contrast-enhanced coronal CT images of normal pituitary glands in vivo.

This paper is concerned primarily with defining the gross anatomic interrelations of the anterior lobe, pars intermedia, and posterior lobe, and with determining how these interrelations can contribute to a normal heterogeneous appearance on coronal CT. Part 2 (pp. 937–944, this issue) deals primarily with histologic sources of variation in CT appearance within the anterior and the posterior lobes. The effects of contrast enhancement on these areas is also discussed.

Materials, Subjects, and Methods
Thirteen sphenoid bones containing pituitary glands were removed en bloc at autopsy and fixed in formalin. The fixed specimens were then suspended in a water bath and examined by CT in the coronal and axial planes. On six specimens, 1.5-mm-thick contiguous coronal CT sections were made. On the other seven, 1.5-mm-thick sequential coronal CT sections overlapping by 1 mm were made. In addition, contiguous 1.5-mm-thick axial CT sections were made on all specimens.

Each sphenoid bone specimen with its pituitary gland was then sectioned in the coronal plane at 2 mm intervals and stained with H and E, trichromatic PAS/hematoxylin-orange G, Masson trichrome, and Wilder reticulum. Additional histologic sections were made as needed for the CT-anatomic correlation.

For comparison with the specimens, contrast-enhanced CT images of normal pituitaries
Fig. 1.—Measurement of degree of intrasellar cisternal herniation on coronal section. A, Level of superior border of sella turcica is represented by line (dotted line) drawn between points of juncture of cavernous sinuses bilaterally with diaphragma sellae (arrows). Percentage of cisternal herniation = a / b x 100. B, When points of juncture are not discernible on CT, superior border of sella is estimated to correspond to line (dotted line) drawn between tips of anterior clinoid processes (arrows).

Fig. 2.—Diagram of pituitary gland as seen from above. Anterior lobe (long arrow), pars intermedia (short arrows), and posterior lobe (arrowheads).

Fig. 3.—A, Schematic coronal section (arrows) through anterior lobe anterior to pars intermedia. B, Coronal histologic section (H and E stain). Strongly (large arrows) and weakly (small arrows) staining areas indicate heterogeneous tissue composition. C, Closely corresponding CT section of specimen. Nonhomogeneous appearance with intermingled CT-dense (large arrows) and CT-lucent (small arrows) areas. D, Contrast-enhanced coronal CT scan through anterior lobe in normal patient also demonstrates CT-dense (large arrows) and CT-lucent (small arrows) areas.

in vivo were obtained. Thirty patients who were being evaluated for extrasellar pathology, usually orbital lesions, were examined by coronal CT. Four without contrast enhancement and 26 after the administration of 150 ml 60% iothalamate meglumine over 5 min. Scans were obtained during the first 20 min postinfusion. The length of the interval between contrast infusion and pituitary scanning depended on the CT requirements of each patient’s underlying pathologic condition; in most cases, the area of primary clinical interest was scanned first and the pituitary gland was scanned immediately thereafter. Four patients were examined with contiguous 1.5-mm-thick coronal slices, 25 patients with 5-mm-thick coronal slices overlapping by 3 mm, and one patient by both methods.

Patient and specimen examinations were performed on the GE
8800 scanner at 120 kV and 614.4–960 mAs. Filming with a magnification factor of 2.7 produced a 1:1 size correlation between CT slices and histologic sections. Window widths of 150, 250, and 300 and window levels ranging from 16 to 69 were used. CT density determinations were made on CT-lucent and CT-dense areas by averaging multiple 4-pixel values. The height of the pituitary glands was measured at the midline in the region of the anterior lobe. This lobe was selected because most mass-producing abnormalities of pituitary glands originate in the anterior lobe.

Intrasellar cisternal herniation was defined as the invagination of the suprasellar cistern into the sella turcica. The superior border of the sella turcica is level with a line drawn between the points of juncture of the cavernous sinuses bilaterally with the diaphragma sellae (fig. 1A). When these points of juncture were not obvious on coronal CT, they were estimated to correspond with the tips of the anterior clinoids (fig. 1B). The degree of cisternal herniation was calculated by dividing the distance between the superior border of the sella and the superior surface of the anterior lobe in the midline by the total height of the sella in that region (fig. 1). Grade I cisternal herniation corresponded to a 25% herniation, grade II to 50%, grade III to 75%, and grade IV to 100%.

Results

Anatomy

On gross examination, the anterior lobe of the pituitary gland is partly wrapped around the posterior lobe. The pars intermedia lies between the two lobes (fig. 2).

On coronal CT sections through the anterior lobe, the pituitary gland often has a heterogeneous appearance produced by the mixture of CT-lucent and CT-dense areas (fig. 3).

On coronal CT sections obtained more posteriorly in the gland, the anterior aspect of the pars intermedia is centrally located (fig. 4A). Colloid cysts are often abundant in this region (fig. 4B) [2]; their presence defines the location of the pars within the gland. When colloid cysts are infrequent or absent, the pars intermedia is only a very thin structure and usually is not discernible on CT. The cysts appear on CT either as small, round, midline lucent areas or as elongated midline lucent areas extending from the inferior to the superior border of the gland (figs. 4C and 4D). It is important not to mistake these normal lucent areas for lucent pituitary microadenomas.

On coronal CT sections located still more posteriorly in the gland, the central region is occupied by the anterior aspect of the posterior lobe (fig. 5A). This area is often homogeneous and dense on CT (figs. 5C and 5D). Immediately adjacent to the posterior lobe on either side is the diverging pars intermedia. When colloid cysts are large and/or abundant in the pars (fig. 5B), the CT appearance usually is that of two elongated lucent areas that extend obliquely from the inferior border of the pituitary gland.
toward its superior border in the midline, producing a tent-like configuration (figs. 5C and 5D). Lateral to the pars on either side of the gland are the posterior parts of the anterior lobe, which are often relatively homogeneous and dense on CT (fig. 5C). This CT section may include the base of the pituitary infundibulum, which frequently causes the surface of the gland to have a slight central superior convexity (fig. 5D).

On the furthest posterior coronal CT sections in the gland, only the posterior lobe is imaged (fig. 6A). In this region, the posterior lobe is nonhomogeneous in most cases, frequently having a "cystic" appearance on CT (figs. 6C and 6D), although true cysts are not present. The most posterior part of the posterior lobe is often embedded in a convexly cupped dorsum sellae (figs. 6B, 7A, and 7B). The posterior lobe may also be embedded in a convexly cupped posterior-inferior sellar floor (fig. 7C).

This description of contiguous coronal CT sections is, of course, subject to minor alterations as a result of individual variations in anatomy or technique. For example, when the pars intermedia has a more transverse orientation within the gland (fig. 8A), the relatively lucent inferolateral regions on coronal CT (fig. 8B) are thought to represent the transversely sectioned pars intermedia; the more dense central region represents the anterior part of the posterior lobe. In another possible variation the part of the posterior lobe that is partly surrounded by the anterior lobe fails to extend to the sellar floor; its inferior surface rests instead on anterior lobe tissue (fig. 9). In these instances, the anterior tip of the posterior lobe may be virtually enveloped by the anterior lobe, with the pars intermedia interposed between the two lobes. A similar anatomic orientation occurs if a CT section is angled slightly anteroinferiorly as the result of suboptimal head position or suboptimal gantry angulation. Another variation in anatomic CT appearance occurs when the posterior lobe is positioned slightly eccentrically within the gland (fig. 10). Although in these instances there may be more anterior lobe tissue on one side of the posterior lobe than on the other, the CT patterns are essentially the same as previously described. However, as a result of this anatomic variation, the point of insertion of the infundibulum into the posterior lobe will be slightly off the patient's midline, and canting of the infundibulum may result.

**Gland Height**

Our measurements of the midline height of the anterior lobe of normal pituitary glands demonstrated a slightly greater mean gland height for females than for males: 4.2 mm ± 1.4 mm as compared with 3.5 ± 0.9 mm, respectively, in our patient population; 5.1 ± 1.0 mm as compared
Fig. 6.—A, Schematic coronal section (arrowheads) through posterior lobe. B, Coronal histologic section (H and E stain). Normal posterior lobe tissue (arrowheads) embedded in dorsum sellae. C, Closely corresponding CT section of specimen. Posterior lobe (arrowheads) contains intermingled CT-lucent and CT-dense areas. D, Contrast-enhanced coronal CT scan through same region in normal patient also demonstrates posterior lobe (arrowheads) containing CT-lucent and CT-dense areas.

Fig. 7.—Normal bone changes adjacent to posterior lobe. Autopsy specimens. A, Axial section shows dorsum sellae (long arrows) with anterior cupping partly surrounding normal posterior lobe (arrowheads). Anterior lobe (short arrows) is also visualized. B, Coronal section of same convexly cupped dorsum sellae (arrows) and normal posterior lobe (arrowheads). C, Coronal section of another specimen demonstrates cupping floor of sella turcica posteriorly, immediately adjacent to dorsum. Normal posterior lobe tissue (arrowhead).

with $4.5 \pm 0.9$ mm, respectively, for the autopsy specimens. The mean gland heights also appear to vary with age. For patients under 11 years of age, the mean gland height was $3.3 \pm 0.4$ mm; for ages 12–60 years, it was $4.2 \pm 1.5$; for patients over 60 years of age, it was $3.9 \pm 1.0$. For autopsy specimens representing ages 12–60 years, the mean gland height was $5.2 \pm 1.1$; in the age group over 60 years, it was $4.5 \pm 0.7$ mm. Thus, with the exception of the prepubertal age group, the mean gland height appears to decline with age.
Fig. 8.—Variation in pars intermedia. A, Schematic coronal section through mid part of gland in which pars intermedia (arrows) has transverse orientation. B, Contrast-enhanced coronal CT scan shows transversely sectioned CT-lucent pars intermedia (arrows) on both sides of centrally positioned posterior lobe (arrowheads).

Fig. 9.—Coronal histologic section of specimen in which posterior lobe (arrowheads) is almost entirely surrounded by anterior lobe (large arrows) represents variation in normal anatomy or in angulation of the section. Small colloid cysts (small arrows) in pars intermedia.

Fig. 10.—Eccentric position of posterior lobe. A, Axial CT section of autopsy specimen. Slightly eccentric posterior lobe (arrowheads) immediately posterior to and partly surrounded by anterior lobe (arrows). B, Coronal CT section through eccentric posterior lobe (arrowheads) embedded in dorsum sellae. Incomplete lateral extension of dorsum sellae on opposite side (curved arrow). C, More anterior coronal section. Site for infundibular insertion (arrow) is slightly off midline.

Surface Configuration and Cisternal Herniation

The superior surface of the anterior lobe was flat in 16 (53%) of our patients and eight (62%) of our autopsy specimens. It was concave in 13 (43%) of our patients and in five (39%) of our autopsy specimens. In one patient the surface of the anterior lobe had a superior biconvexity and a central depression. This scalloped configuration was seen more typically, however, on sections through the anterior pars intermedia, where the pars itself created the central depression (fig. 11).

Cisternal herniation, as defined earlier, was present in 15 (50%) of the normal patients and five (39%) of the autopsy specimens. It was present in all patients whose anterior lobe had a concave superior surface. It was also present in one patient whose anterior lobe had a flat superior surface and in the patient whose anterior lobe had a biconvexly scalloped superior surface; the former was a 9-year-old girl and the latter a 12-year-old boy.

Fig. 11.—Biconvexly scalloped superior surface of gland (arrowheads), when present, is usually seen on CT sections through anterior pars intermedia (arrows).
Of the 20 combined patients and autopsy specimens having cisternal herniation, 17 were over 34 years of age. The other three included the girl whose anterior lobe had a flat superior surface and the boy whose anterior lobe had a biconvexly scalloped superior surface. The third patient was a 28-year-old woman whose anterior lobe had a slightly concave superior surface, possibly related to significant bony sellar asymmetry.

The superior surface of the normal posterior lobe usually was flat or only slightly concave. The posterior lobe was frequently embedded in bone posteriorly, where the superior surface usually was convex. The superior surfaces of the posterior lobes of glands with cisternal herniation usually were concave but had a lesser degree of concavity than their anterior lobes.

Bone Changes

Bone changes ranged from perpendicular or slanting linear bony defects <1 mm wide, often occurring bilaterally, to defects up to several mm wide (fig. 12). Focal areas of cupping posteriorly into the dorsum sellae were frequently present and contained normal posterior lobe tissue (figs. 7A and 7B). A focal area of cupping inferiorly into the sellar floor was present in one autopsy specimen and also contained normal posterior lobe tissue (fig. 7C).

Discussion

We have found contiguous 1.5-mm-thick coronal sections through the contrast-enhanced pituitary gland to be the most informative for the CT evaluation of the gland. The use of these thin CT slices entails less masking effect from partial-volume averaging, thus permitting a more complete evaluation. Although potential interference from background mottle is always a consideration in evaluating small areas with thin sections, this did not appear to cause appreciable structural distortion in our subjects. The standard deviations in the CT densities of the water baths of our autopsy specimens and in the CT densities of the cerebrospinal fluid (CSF) in the frontal horns of our patients were indicators of the degree of mottle. The standard deviations of the water bath densities ranged from 3.75 to 4.11 H (Hounsfield units); the standard deviations of frontal horn CSF densities ranged from 3.76 to 5.73 H. The difference in CT density between adjacent lucent and dense areas in both our autopsy and patient populations was usually appreciably greater than 2x the standard deviation for that particular specimen or patient. This indicates little likelihood that subjects' CT-lucent and CT-dense appearances were appreciably affected by background mottle. Moreover, the CT patterns seen in different individual pituitary glands showed similarities in corresponding locations from gland to gland.

Maximum hyperextension of the head is necessary in coronal scanning of the pituitary gland in order to avoid artifacts from teeth. This can be achieved most reliably by scanning with the patient in the prone position. However, strict midline centering with absence of even the slightest head rotation (critical for an accurate evaluation based on normal coronal anatomy) can be achieved most reliably with the patient supine. Although both the prone and the supine positions have advantages, the prone position is recommended in older patients and in those with relatively short necks, where hyperextension is difficult. In either the prone or the supine position, complete immobilization is necessary. Head movement not only is a source of unwanted motion artifacts but also removes parts of the gland from the scanning plane, resulting in failure to visualize the gland completely.

In addition to the coronal sections, contiguous 1.5 mm axial sections angled -10° to -20° to the orbitomeatal line may be obtained; the purpose of the angulation is to avoid petrous ridge artifacts [3]. In most cases, the axial scans are not necessary for interpretation. However, if artifacts from teeth cannot be avoided on the direct coronal scans, the axial scans are essential. Coronal reconstruction of these axial scans is strongly recommended.

Although we do not routinely obtain unenhanced scans, such scans may be helpful in evaluating patients with suspected acidophilic microadenomas. Before contrast enhancement, acidophilic microadenomas may appear hyperdense relative to adjacent tissue [1, 4]. Because of this potential relative hyperdensity, unenhanced scans may aid in the detection of these tumors and in determining their extent within the gland.

Microadenomas may present as lucent, nonhomogeneous or dense areas, with or without mass effect. Mass effect is defined as the presence of a superior convexity to the surface of the gland, inferior bone erosion, an increase in glandular height [5], and/or infundibular displacement [1]. Care must be taken not to misdiagnose a lucent colloid-cyst-containing pars intermedia as a small microadenoma. When the pars contains large and/or numerous colloid cysts it may resemble a lucent microadenoma, especially on CT sections taken through its most anterior part, where a single central lucency may occur (figs. 4C and 4D). When contiguous 1.5 mm sections are made, however, this central lucency should not present a diagnostic problem, since the immediately adjacent posterior section will usually demonstrate a dense, centrally located posterior lobe with the diverging lucent pars intermedia on either side. This pinpoints the location of the previous CT section within the gland. The more posterior diverging pars, when lucent, can be differentiated from an abnormal finding by its typical elongated configuration and by its characteristic tendency to slant toward the midline as it courses from the inferior to the superior border of the gland (figs. 5C and 5D). If present bilaterally, these lucent areas tend to form a tentlike configuration (figs. 5C and 5D). In addition, the sides of these pars intermedia lucencies are often parallel, which would be unexpected in an expanding mass lesion.

On the same CT section on which the diverging pars intermedia appears, there is another potential source of diagnostic error: The central, often dense and homogeneous posterior lobe, especially when flanked on either side by a lucent pars intermedia, may have the appearance of an enhancing mass lesion. This is true particularly if the infundibulum inserts into the superior surface of the posterior lobe in this section, resulting in a midline superior convexity (fig. 5D).
A convex configuration of the superior surface of the gland may also result from the faint visualization of the tuberculum sellae on the most anterior section through the gland, owing to partial-volume averaging (figs. 13A and 13B). Comparison of the involved CT section with its anterior and posterior contiguous sections (fig. 13C) will help to clarify whether the source of this convexity is the extraglandular tuberculum sellae or an abnormal intraglandular mass.

While evidence of infundibular displacement is generally used to support the presence of a mass [1], some investigators have found that slight displacement or canting does not necessarily indicate abnormality [5]. Our results support these findings and suggest that slight canting, at least in some instances, may reflect a slightly eccentrically positioned posterior lobe into whose anteromedial portion the infundibulum inserts (fig. 10).

Caution must be exercised to avoid mistaking tortuous anterior cerebral arteries for a displaced infundibulum. This potential error can be avoided by carefully following the course of the infundibulum from the surface of the gland to the infundibular recess of the third ventricle. Its course may extend over several CT sections. Also, since the infundibulum generally does not appear on the anterior sections of the pituitary gland, where the anterior cerebral arteries characteristically reside, it is helpful to determine the location of the involved CT section within the gland.

Care must be taken when invoking bone changes as an indicator of mass effect. As in all phases of CT bone scanning, changes in window level can produce areas of apparent thinning, simulating bone erosion (fig. 12). Such areas in the floor of the sella, particularly when symmetric, should be ignored. Only when bone changes are associated with abnormal-appearing areas within the gland are they significant.

Increased gland height is a reliable indicator of mass effect. In our normal male population, the mean gland height...
was less than in our normal female population. Similar findings have been reported by others [5, 6]. As also noted by these investigators [5, 6], the mean gland height in our autopsy specimens was greater than that of our patients. The reasons for this are unclear.

Our results suggest a decreased mean gland height in two populations, namely, in the prepubertal age group and in the group over 60 years of age. Decreased gland height in the prepubertal age group is probably related to the lesser degree of pituitary function in that population. Possible etiologies for the decreased mean gland height in the group of subjects over 60 years of age include regression of pituitary tissue from decreasing function; progressive compression of the pituitary gland from prolonged and persistent CSF pressure over time; and ischemic changes in the anterior lobe. The anterior lobe is more subject to ischemic changes than the posterior lobe, perhaps because the anterior lobe receives its arterial blood supply indirectly from the superior hypophyseal arteries via portal sinuses, whereas the posterior lobe receives its blood supply directly from the inferior hypophyseal arteries [7]. Our findings of a concave configuration of the superior surface of the anterior lobe in patients above the age of 34 years with cisternal herniation and, conversely, the absence of a concave configuration of the superior surface of the pituitary gland in a 9-year-old girl with cisternal herniation support any of the above proposed etiologies for decreasing mean gland height with age.

In summary, we emphasize that the normal pituitary gland often has a heterogeneous appearance on coronal CT. By relating the gross CT anatomy of the pituitary gland to its coronal histologic sections, we can identify sources of CT-density variation within the gland and the range of normal patterns that may occur. Understanding these normal patterns can prevent an incorrect diagnosis of normal glandular tissue as a microadenoma. It can also aid in the correct diagnosis of a microadenoma when the "normal" patterns appear to be distorted.

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REFERENCES