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Normal Pituitary Stalk Size in Children: CT Study

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A retrospective study was undertaken of 1005 normal contrast-enhanced head computed tomographic (CT) scans in children to determine normal standards for pituitary stalk diameter, basilar artery diameter, and their ratio for age and gender. The pituitary stalk enlarges with age, and girls have larger stalks than do boys after age 8. The pituitary stalk-to-basilar artery ratio is easily estimated visually. Ratios greater than or equal to 1 are unusual in normal children. A ratio greater than or equal to 1 should prompt direct measurement of the stalk and comparison with age-matched normal values. If the stalk measurement is greater than 2 SD above the age-matched mean, it is presumably abnormal and deserves further evaluation for numerous possible pathologic conditions including histiocytosis X, pituitary adenoma, hypothalamic lesions, Rathke cleft cysts, metastases, sarcoidosis, hypothyroidism, and infection.

The normal pituitary stalk (PS) is a readily recognized structure on routine contrast-enhanced head computed tomography (CT). In the pediatric population, with relatively frequent endocrine problems and central nervous system (CNS) neoplasia, early recognition of an abnormal stalk is especially important. Unfortunately, no data are available in children that define normal stalk dimensions, although normal values were recently published for adults [1].

This lack of data was important for one of our early CT patients (fig. 1). A 16-year-old girl presented with growth failure. At that time, the scan was interpreted by several observers as normal. Unfortunately, 3 years later, the patient returned with headaches and blurred vision. A follow-up scan demonstrated a large suprasellar dysgerminoma. Could this apparent false-negative scan have been avoided?

We and others [2-6] have noted that there are variations in the size of the PS and pituitary gland with age. In particular, normal adolescent girls seem to have larger stalks and glands than do boys. To help us better distinguish a normal stalk from abnormal enlargement, we hypothesized that the normal PS diameter rarely equals and should not exceed the diameter of the basilar artery (BA). In other words, the ratio of the PS diameter to the BA diameter should be less than or equal to 1 (fig. 2). To test this hypothesis and to develop standards for the diameter of the PS and BA, as well as their ratio, for age and gender, we undertook this retrospective study.

Materials and Methods

We reviewed all contrast-enhanced head CT scans interpreted as normal from November 1981 through February 1984. Several scans from the same patient were included if separated by at least 1 year.

All scans were obtained on a GE 8800 scanner using a 9.6 sec scan time in the dynamic scanning mode with table incrementation. The scans were begun during a bolus injection of 2 ml/kg of Hypaque meglumine 60% (Winthrop). Using a six power hand lens micrometer (Edscorp, Edmund Scientific), the transverse diameter of the PS and BA were measured from examination of hard-copy films. Ideally, the PS diameter measurement was made through the

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midstalk in the suprasellar cistern. However, slight changes in scan angle and level, particularly in young children, could easily result in the inclusion of the dorsum sellae on the scan, even if the stalk was well demonstrated. Therefore, notation was made of cases where the measurements were thought to be high near the tuber cinereum or low near the dorsum sellae, but inclusion of the posterior clinoids did not disqualify the scan from the study (fig. 3). No estimate of the position of the optic chiasm (pre- or postfixed) was made. While this position may change the angle of the PS in the anterior or posterior direction, such angulation should not influence its transverse measurement. Since the BA can appear wide if it is coursing obliquely on the scan, it was measured in a plane perpendicular to its course to provide a more accurate cross-sectional measurement (fig. 4). The BA measurement was usually made on the same slice as the stalk measurement, but occasionally it was made on a lower slice. Finally, the 5 cm index grid that appears on each scan was measured as a reference standard for conversion of these measurements to millimeters. All measurements in this study were made at routine window

and level settings—usually at a level of about 40 and a window of 80–150 H.

Initially, a small population of scans was measured with both the hand micrometer on film and with the electronic cursor on the CT console. The cursor measurement is limited by pixel size, which ranges from 0.6 to 0.8 mm on routine scans. The micrometer measurement is visually limited by the magnification of the individual pixel element, but should be equal, or perhaps even greater, in accuracy. Since no difference in the measurements was observed, only micrometer measurements were used for this study.

The data were then tabulated and analyzed by computer. The absolute PS and BA diameters as well as the ratio of the PS diameter to the BA diameter were calculated. This was done for two populations. The first consisted of the total group of 1005 scans including all slice thicknesses and levels as well as poorly demonstrated stalks. The second was a "pure" group consisting of 659 10-mm-thick midstalk-level scans. Curves for the PS diameter, BA diameter, and PS diameter to BA diameter ratio for both groups were then calculated. Intergroup comparisons were made using the Student paired *t* test, analysis of variance techniques, and multiple comparisons using the Duncan method.

Results

The overall population statistics are presented in tables 1–4. There were 1005 normal scans in 990 patients aged newborn to 18 years. Of these, 53% were boys and 47% were girls. Of the 1005 scans, 910 were made with 10 mm slice thickness.

There was adequate demonstration of the PS on 87% of the scans, poor demonstration in 6%, and the stalks were not measurable in 7%. The poor or nondemonstrated stalks usually resulted from suboptimal 10 mm slice location in a patient population that was not, in general, scanned with specific attention to the pituitary. In the group of adequately demonstrated stalks, the scanning plane was through the midstalk in 86%. In 11%, the scan was believed to be high

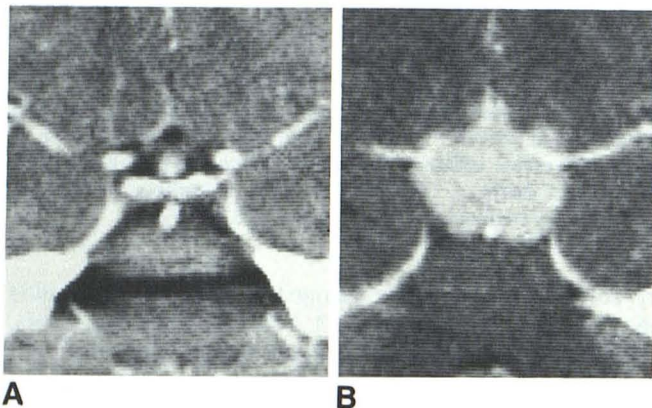


Fig. 1.—16-year-old girl with growth failure. **A**, Is this PS abnormal (PS/BA > 1.0)? **B**, 3 years later after 2 weeks of headache and blurred vision. Large, enhancing suprasellar mass (dysgerminoma).

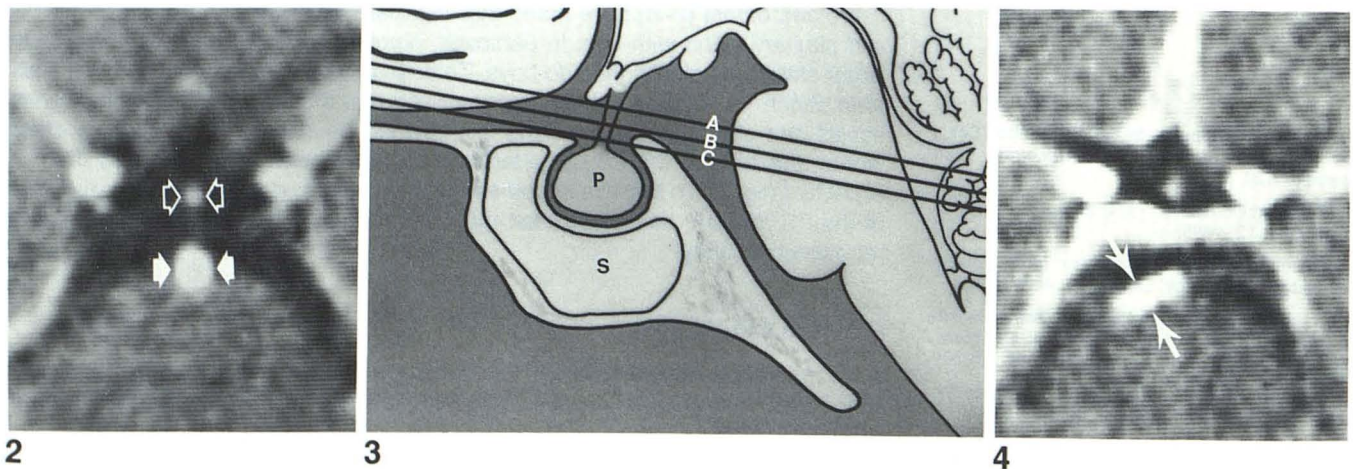


Fig. 2.—Normal PS with PS/BA ratio less than 1.0. PS diameter (open arrows); BA diameter (closed arrows).

Fig. 3.—Idealized (B), high (A), and low (C) scanning planes through pituitary

stalk. P = pituitary gland; S = sphenoid sinus.

Fig. 4.—Plane of measurement of obliquely coursing BA (arrows).

TABLE 1: Pituitary Measurements in Total Population of Normal Boys Aged 0–19 Years

| Age (months) | Minimum No. (n = 1005) | Mean Diameter in mm (SD) | | Mean Stalk/Basilar Ratio (SD) |
|--------------|------------------------|--------------------------|----------------|-------------------------------|
| | | Pituitary Stalk | Basilar Artery | |
| 0–6 | 15 | 1.9 (0.31) | 2.7 (0.65) | 0.73 (0.18) |
| 7–12 | 13 | 2.0 (0.39) | 3.4 (0.52) | 0.59 (0.12) |
| 13–24 | 49 | 2.0 (0.32) | 3.5 (0.56) | 0.57 (0.12) |
| 25–36 | 33 | 1.9 (0.35) | 3.8 (0.55) | 0.51 (0.11) |
| 37–48 | 31 | 2.1 (0.50) | 3.7 (0.50) | 0.58 (0.14) |
| 49–60 | 26 | 2.1 (0.39) | 3.8 (0.58) | 0.56 (0.15) |
| 61–72 | 26 | 2.2 (0.39) | 3.9 (0.45) | 0.56 (0.13) |
| 73–84 | 34 | 2.2 (0.32) | 3.7 (0.44) | 0.59 (0.11) |
| 85–96 | 37 | 2.2 (0.41) | 3.8 (0.50) | 0.58 (0.14) |
| 97–108 | 45 | 2.3 (0.38) | 3.9 (0.58) | 0.59 (0.13) |
| 109–120 | 30 | 2.4 (0.46) | 3.9 (0.55) | 0.65 (0.24) |
| 121–132 | 30 | 2.4 (0.56) | 3.9 (0.54) | 0.65 (0.21) |
| 133–144 | 24 | 2.5 (0.61) | 3.9 (0.55) | 0.65 (0.18) |
| 145–156 | 27 | 2.5 (0.46) | 3.6 (0.60) | 0.67 (0.15) |
| 157–168 | 16 | 2.4 (0.57) | 3.7 (0.46) | 0.64 (0.13) |
| 169–180 | 16 | 2.5 (0.53) | 3.4 (0.54) | 0.72 (0.13) |
| 181–192 | 15 | 2.9 (0.72) | 3.5 (0.55) | 0.83 (0.20) |
| 193–204 | 15 | 2.5 (0.54) | 3.6 (0.40) | 0.72 (0.17) |
| 205–216 | 3 | 2.3 (0.50) | 3.6 (0.05) | 0.64 (0.13) |
| 217–228 | 3 | 2.6 (0.66) | 3.2 (0.25) | 0.79 (0.23) |

TABLE 2: Pituitary Measurements in “Pure” Population of Normal Boys Aged 0–19 Years

| Age (months) | Minimum No. (n = 659) | Mean Diameter in mm (SD) | | Mean Stalk/Basilar Ratio (SD) |
|--------------|-----------------------|--------------------------|----------------|-------------------------------|
| | | Pituitary Stalk | Basilar Artery | |
| 0–6 | 11 | 1.9 (0.34) | 2.7 (0.74) | 0.73 (0.20) |
| 7–12 | 12 | 1.9 (0.35) | 3.4 (0.54) | 0.57 (0.10) |
| 13–24 | 37 | 2.0 (0.31) | 3.6 (0.43) | 0.55 (0.10) |
| 25–36 | 22 | 1.9 (0.37) | 3.9 (0.57) | 0.50 (0.11) |
| 37–48 | 23 | 2.1 (0.47) | 3.8 (0.40) | 0.57 (0.12) |
| 49–60 | 23 | 2.1 (0.36) | 3.9 (0.53) | 0.52 (0.09) |
| 61–72 | 23 | 2.1 (0.36) | 3.9 (0.46) | 0.56 (0.12) |
| 73–84 | 29 | 2.2 (0.31) | 3.7 (0.46) | 0.60 (0.12) |
| 85–96 | 27 | 2.1 (0.31) | 3.8 (0.46) | 0.56 (0.11) |
| 97–108 | 35 | 2.2 (0.37) | 3.9 (0.56) | 0.57 (0.12) |
| 109–120 | 25 | 2.4 (0.42) | 3.9 (0.40) | 0.62 (0.11) |
| 121–132 | 22 | 2.4 (0.47) | 3.9 (0.51) | 0.62 (0.16) |
| 133–144 | 14 | 2.6 (0.46) | 4.1 (0.56) | 0.64 (0.15) |
| 145–156 | 20 | 2.3 (0.38) | 3.7 (0.65) | 0.62 (0.12) |
| 157–168 | 9 | 2.4 (0.55) | 3.8 (0.54) | 0.62 (0.10) |
| 169–180 | 11 | 2.4 (0.34) | 3.5 (0.51) | 0.68 (0.10) |
| 181–192 | 4 | 2.8 (0.74) | 3.8 (0.46) | 0.72 (0.20) |
| 193–204 | 5 | 2.3 (0.49) | 3.8 (0.46) | 0.61 (0.13) |
| 205–216 | 3 | 2.3 (0.50) | 3.6 (0.05) | 0.64 (0.13) |
| 217–228 | 1 | 1.8 | 3.2 (0.23) | 0.54 |

near the hypothalamus. In 3%, it was low in the sella turcica near the pituitary gland.

The BA was adequately demonstrated in 96% of the scans. It was poorly demonstrated or not measurable in only 4%. This was usually because of a poor contrast bolus or failure to resolve the BA closely applied to the clivus at the window and level settings photographed.

Comparison of the 5 and 10 mm slice thickness groups showed no significant difference between the mean PS diameter, the mean BA diameter, and the PS diameter/BA

TABLE 3: Pituitary Measurements in Total Population of Normal Girls Aged 0–19 Years

| Age (months) | Minimum No. (n = 1005) | Mean Diameter in mm (SD) | | Mean Stalk/Basilar Ratio (SD) |
|--------------|------------------------|--------------------------|----------------|-------------------------------|
| | | Pituitary Stalk | Basilar Artery | |
| 0–6 | 12 | 2.0 (0.43) | 2.6 (0.42) | 0.76 (0.09) |
| 7–12 | 12 | 1.8 (0.31) | 3.3 (0.41) | 0.57 (0.12) |
| 13–24 | 49 | 2.1 (0.43) | 3.5 (0.60) | 0.61 (0.13) |
| 25–36 | 36 | 2.0 (0.32) | 3.6 (0.67) | 0.58 (0.14) |
| 37–48 | 35 | 2.0 (0.44) | 3.6 (0.47) | 0.58 (0.12) |
| 49–60 | 25 | 2.1 (0.41) | 3.5 (0.57) | 0.61 (0.18) |
| 61–72 | 33 | 2.2 (0.47) | 3.7 (0.50) | 0.60 (0.18) |
| 73–84 | 31 | 2.2 (0.45) | 3.7 (0.58) | 0.61 (0.12) |
| 85–96 | 29 | 2.3 (0.63) | 3.6 (0.46) | 0.63 (0.14) |
| 97–108 | 30 | 2.4 (0.50) | 3.9 (0.48) | 0.61 (0.16) |
| 109–120 | 14 | 2.6 (0.66) | 3.4 (0.45) | 0.75 (0.18) |
| 121–132 | 18 | 2.4 (0.38) | 3.7 (0.50) | 0.64 (0.14) |
| 133–144 | 24 | 2.7 (0.50) | 3.6 (0.54) | 0.74 (0.15) |
| 145–156 | 24 | 2.8 (0.54) | 3.6 (0.34) | 0.78 (0.19) |
| 157–168 | 14 | 2.6 (0.55) | 3.7 (0.46) | 0.70 (0.10) |
| 169–180 | 13 | 2.6 (0.75) | 3.3 (0.51) | 0.78 (0.23) |
| 181–192 | 19 | 2.7 (0.57) | 3.5 (0.60) | 0.78 (0.20) |
| 193–204 | 5 | 2.8 (0.52) | 3.3 (0.57) | 0.82 (0.11) |
| 205–216 | 9 | 2.8 (0.58) | 3.5 (0.57) | 0.81 (0.16) |
| 217–228 | 5 | 2.6 (0.60) | 3.2 (0.35) | 0.84 (0.19) |

TABLE 4: Pituitary Measurements in “Pure” Population of Normal Girls Aged 0–19 Years

| Age (months) | Minimum No. (n = 659) | Mean Diameter in mm (SD) | | Mean Stalk/Basilar Ratio (SD) |
|--------------|-----------------------|--------------------------|----------------|-------------------------------|
| | | Pituitary Stalk | Basilar Artery | |
| 0–6 | 8 | 1.9 (0.41) | 2.5 (0.47) | 0.74 (0.09) |
| 7–12 | 9 | 1.8 (0.34) | 3.3 (0.47) | 0.57 (0.13) |
| 13–24 | 37 | 2.1 (0.42) | 3.5 (0.56) | 0.59 (0.11) |
| 25–36 | 30 | 2.0 (0.31) | 3.6 (0.66) | 0.57 (0.15) |
| 37–48 | 28 | 2.0 (0.40) | 3.5 (0.44) | 0.58 (0.11) |
| 49–60 | 17 | 2.0 (0.31) | 3.6 (0.63) | 0.60 (0.16) |
| 61–72 | 22 | 2.2 (0.48) | 3.7 (0.47) | 0.60 (0.18) |
| 73–84 | 24 | 2.2 (0.33) | 3.5 (0.52) | 0.62 (0.09) |
| 85–96 | 19 | 2.2 (0.52) | 3.7 (0.51) | 0.61 (0.10) |
| 97–108 | 20 | 2.2 (0.45) | 3.9 (0.53) | 0.57 (0.15) |
| 109–120 | 9 | 2.4 (0.57) | 3.5 (0.53) | 0.69 (0.13) |
| 121–132 | 11 | 2.2 (0.28) | 3.6 (0.50) | 0.60 (0.09) |
| 133–144 | 15 | 2.5 (0.39) | 3.7 (0.51) | 0.68 (0.08) |
| 145–156 | 13 | 2.8 (0.50) | 3.5 (0.30) | 0.80 (0.17) |
| 157–168 | 10 | 2.6 (0.49) | 3.7 (0.49) | 0.70 (0.10) |
| 169–180 | 5 | 2.5 (0.63) | 3.2 (0.69) | 0.73 (0.10) |
| 181–192 | 10 | 2.7 (0.68) | 3.6 (0.71) | 0.74 (0.21) |
| 193–204 | 1 | 2.7 | 3.4 (0.54) | 0.64 |
| 205–216 | 4 | 3.0 (0.82) | 3.8 (0.59) | 0.79 (0.21) |
| 217–228 | 3 | 2.4 (0.32) | 3.1 (0.47) | 0.79 (0.18) |

diameter ratio. Therefore, we believe that our results are applicable to both 5 and 10 mm slice thicknesses.

Group Means

For the total population of 1005 scans, the mean PS diameter was 2.3 ± 0.5 mm, the mean BA diameter 3.6 ± 0.6 mm, and the mean PS diameter to BA diameter ratio 0.63 ± 0.17 . These values are not statistically different than those of the “pure” 10 mm group ($n = 659$): PS diameter = 2.2 ± 0.4

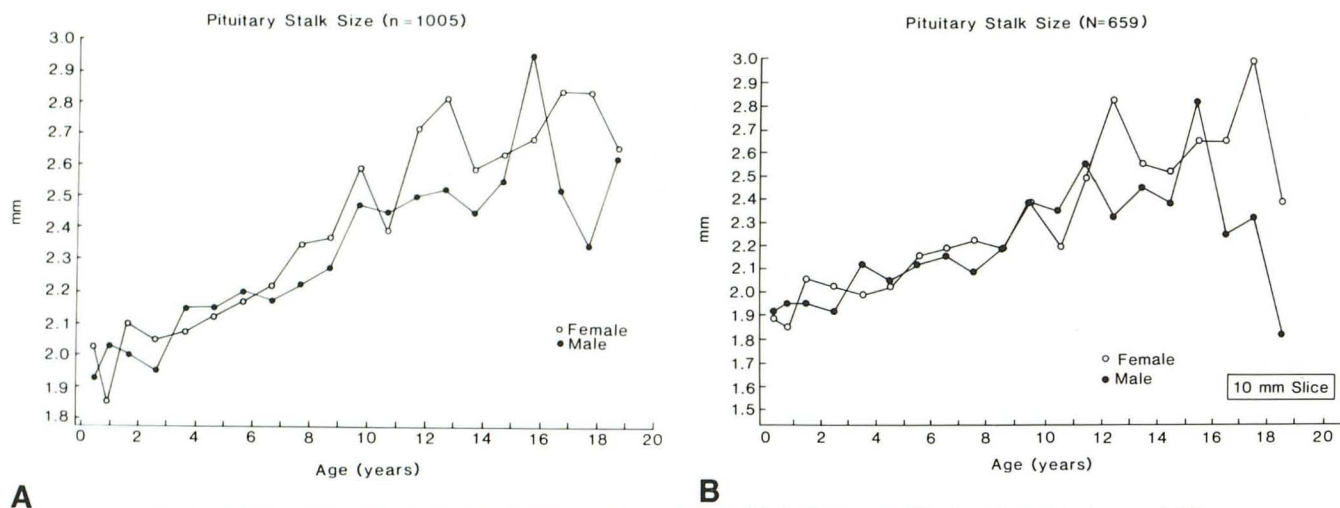


Fig. 5.—PS size. In both total population (A) and "pure" population (B), PS size increases with advancing age for boys and girls.

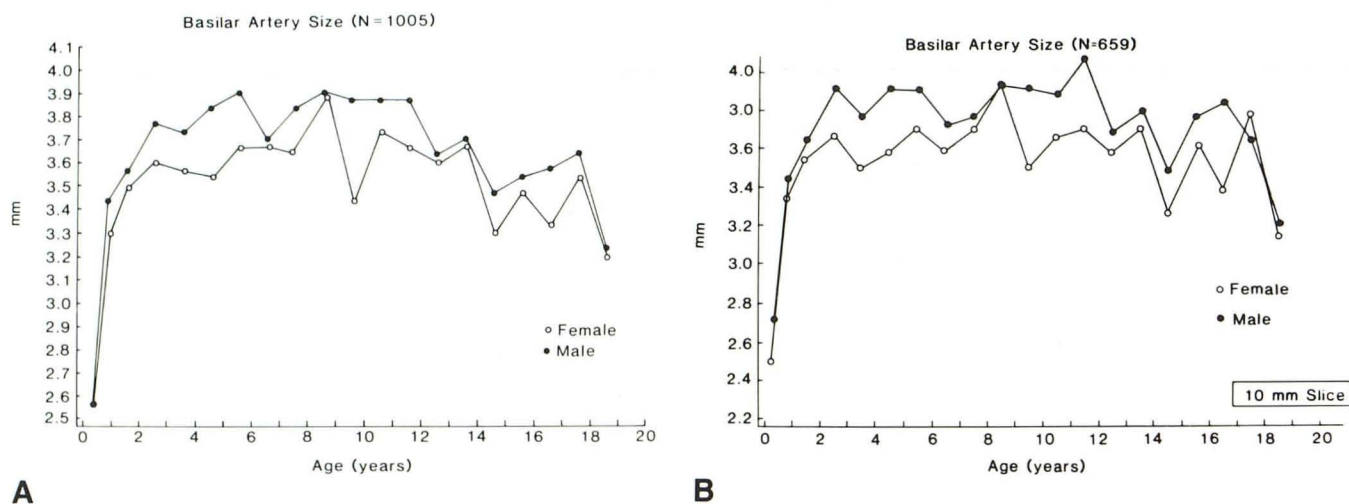


Fig. 6.—BA size. In both total population (A) and "pure" population (B) basilar artery is slightly greater in boys than in girls.

mm, BA diameter = 3.7 ± 0.6 mm, and PS/BA ratio = 0.60 ± 0.14 . Nevertheless, we analyzed the data for the two groups separately and noted some differences.

PS Size

There was a significant correlation between the PS diameter and age throughout childhood ($p < 0.001$), with a general increase with advancing age for both boys and girls (fig. 5). There was no significant difference in the PS diameter between boys and girls younger than 8 ($p = 0.65$). However, between 8 and 18 years, girls had a larger mean PS diameter (2.6 mm) than boys (2.45 mm) ($p = 0.02$). In girls, a relatively

rapid increase in PS diameter began after age 8. In boys, the increase was delayed to 12 years of age with a sharp and unexplained peak noted at age 15. This difference was present in both the total and "pure" 10 mm population groups.

BA Size

The mean BA size was slightly but significantly greater in boys than in girls throughout childhood ($p < 0.01$) (fig. 6). This was true for both the total and "pure" 10 mm groups. A rapid increase in the BA size occurred from birth to 1 year of age in both genders, causing a rapid decrease in the PS to BA ratio.

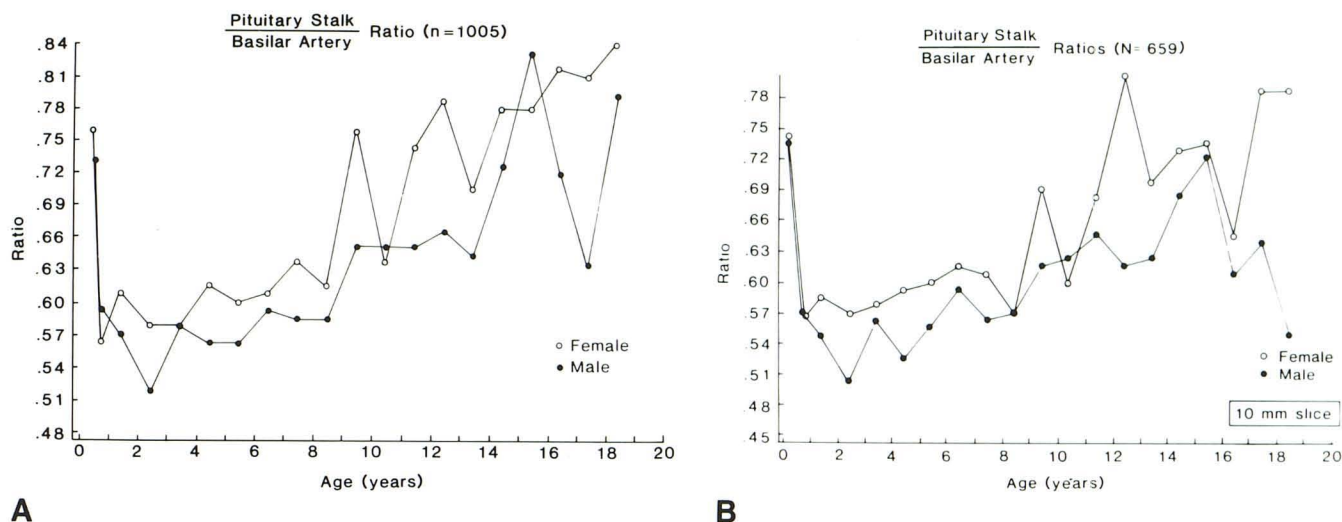


Fig. 7.—PS to BA ratio. In both total population (A) and "pure" population (B) ratio increases with age and is slightly larger in girls than in boys.

PS/BA Ratio

The PS diameter to BA diameter ratio correlated with both age ($p = 0.0001$) and gender ($p < 0.02$). The ratio was larger in girls than in boys throughout childhood, although the differences were greater after age 8 (fig. 7). Wide oscillations in the curves during adolescence may reflect the sample size and the variable age of onset of puberty among individuals of the same gender. The "pure" 10 mm group showed an increased ratio in children less than 1 year of age. Nevertheless, their PS diameter was not unusually large, nor was their BA diameter unusually small. The 10 mm population also demonstrated an apparent decline in stalk size and ratio in 17- and 18-year-old boys, although the sample size in this age group was quite small ($n = 3$).

Ratios > 1.0

In 45 cases, the PS diameter to BA diameter ratio was greater than or equal to 1 in the "normal" population. Of these 45 cases, only 18 had ratios greater than 1, and 14 of these were in the older age group. It is important to remember that certain factors may artifactually increase this ratio. The PS diameter will be large if the stalk size is at the upper limits of normal or if it is measured at a scan level too high or too low. On the other hand, the BA diameter will be small if it is an anatomic variant or if there is a poor contrast bolus. All of these will result in an increased ratio even if the absolute stalk size is within normal limits.

To eliminate such artifactually "elevated" ratios, we further selected those cases with PS to BA diameter ratios greater than or equal to 1 and with PS diameters greater than 2 SD above age-matched group means. From our total population of 1005 scans and our subgroup of 45 scans with ratios greater than or equal to 1, only 12 scans (1%) remained. Most of these patients were 8–18 years old, ages when relatively large PSs and PS to BA ratios are more common. Our total

population was selected from scans prospectively interpreted as normal. While in retrospect most of these 12 scans seem suspicious and would now prompt further evaluation, none of the patients are known to be abnormal at this time. Thus, the application of these two measurements has resulted in a very small subset of patients whose scans deserve careful consideration before being declared normal, especially in patients under 8 years of age.

Discussion

We have developed standards for PS diameter and BA diameter, as well as their ratio, for both age and gender. There is a predictable relation between boys and girls throughout childhood. In general, the data curves are more variable in adolescents, especially after the expected onset of puberty. Overall, girls do have larger stalks than boys, but only during adolescence. This increase in size of the PS and pituitary gland is hypothesized to relate to the endocrine events of puberty [4].

Many pathologic states have been shown to produce enlargement of the PS and/or pituitary gland [7, 8] including diabetes insipidus due to histiocytosis X [9] and other causes [9–11]; pituitary adenoma [12, 13]; hypothalamic lesions including glioma and neuroepithelial tumors (dermoid, teratoma, dysgerminoma, and hamartoma) [14, 15]; Rathke cleft cyst [16]; metastases [17]; sarcoidosis [18, 19]; hypothyroidism [20–22]; and infection [23]. Discussion of the pathologic causes of PS enlargement in children is beyond the scope of this report.

Peyster et al. [1] recently reported a similar approach to screening for abnormal PS size. They recommended direct measurement of the PS if its size was larger than the BA by visual inspection. Their data were not grouped for age or gender. The sample size for children was very small and the youngest patient was 9 years of age. Therefore, it is not

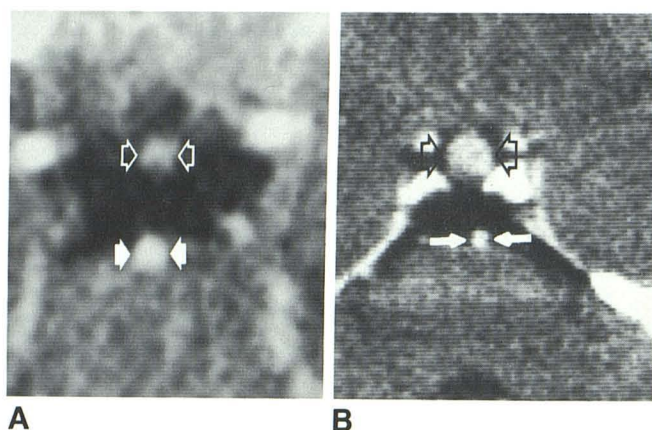


Fig. 8.—Recognition of abnormal PS using PS/BA ratio. A, PS/BA ratio = 1.0 (measure PS diameter). B, PS/BA ratio > 1.0 (PS diameter > 2 SD above age-matched mean). PS diameter (open arrows); BA diameter (closed arrows).

surprising that they did not make the observations that we report here. However, their mean PS and BA values correlate well with those of our older patients.

The PS to BA ratio is an easily applied visual screening tool that enables ready recognition of the possibly abnormal stalk. If the ratio appears close to 1.0, further evaluation should include direct measurement of the stalk diameter (fig. 8A). We have reported values for 10 mm slice thickness and have shown no difference with 5 mm slice thickness. However, if the scanning plane is not ideal, additional thin slices may be of benefit. If the direct measurement of the PS diameter falls within 2 SD of our standards, it is likely normal; 99% of normal children will fall within this range. However, stalks greater than 2 SD should be viewed with suspicion, and further clinical evaluation and a follow-up scan are recommended (fig. 8B).

Coronal imaging is the scanning plane of choice for investigating the pituitary gland. However, the stalk is a vertically oriented structure; thus, coronal imaging is not ideal for its evaluation and measurement. Although the PS may be demonstrated on coronal images, we believe that its measurement and comparison with BA size are best made in the axial plane.

On reevaluation of our index case (fig. 1), it is obvious that the PS to BA ratio is greater than 1. With our present knowledge, careful measurement of the PS and early follow-up would have been performed. Such measurements should have permitted earlier diagnosis of this tumor. In fact, our failure to properly diagnose this lesion prompted this study. It is hoped that application of our standards may prevent another unfortunate false-negative.

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