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PITUITARY DIMENSIONS AND VOLUME MEASUREMENTS IN PREGNANCY AND *POST PARTUM*

MR assessment

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Abstract

Purpose: Our purpose was to clarify and further characterize the changes in height, length, width, volume, and shape in the normal pituitary gland and in width in the infundibulum during pregnancy and the first 6 months *post partum.*

Material and Methods: Cranial MR imaging was performed in 78 women who were pregnant in the second or third trimester or who were *post partum*, and in 18 age-matched control subjects who were not pregnant. Volume measurements were performed in 2 ways; volume 1=1/2×height×length×width; and volume 2=area (measured by trackball)×slice thickness.

Results: Gland volume, height, width, length, and convexity, and infundibular width increased during pregnancy. The highest values were seen during the 3 days immediately *post partum.* When compared with volunteers, volumes 1 and 2 showed the largest increase (120%) among the parameters. Gland height showed the best correlation ($r=0.94$, $p<0.00001$) with gestational age. The mean height of the gland was 8.76 mm in the third trimester. None of the pregnant women had a gland height of above 10 mm during pregnancy. Only 2 subjects had gland heights of 10.04 and 10.2 mm during the 0–3 days *post partum.* After this first *post-partum* period of 3 days, the gland size, shape, and volume and the infundibular width returned to normal within 6 months.

Conclusion: The pituitary gland enlarges in three dimensions throughout pregnancy. During pregnancy, the volume of the gland shows the highest percentage of increase compared to its length, height, and width. The maximum height of the gland does not exceed 10 mm during pregnancy but it may exceed 10 mm during the 3 days immediately *post partum.*

Key words: Pregnancy, pituitary; MR measurements.

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MR imaging has proved to be an accurate modality for evaluating the pituitary gland (2, 7, 8, 11, 14). Previous *in vivo* imaging studies have demonstrated that the size and shape of the gland increase during pregnancy, adolescence, precocious puberty, and the first year of life (4, 6, 9, 12). To our knowledge, there is only one *in vivo* imaging study that attempts to define the volume of the normal pituitary gland during pregnancy but there is no study that defines the volume of the normal pituitary gland in the *post-partum* period (9). We studied the changes in height, length, width, volume, and shape in the normal pituitary gland and in the width of the infundibulum during pregnancy and the first 6 months *post partum.*

Material and Methods

Ninety-six women (aged 20–38 years, mean 26.5 years) with no evidence of pituitary disorders took part in the study. One woman in the second trimester and one in the third trimester had parasellar men-

ingioma found incidentally at MR examination and were excluded from the study. The subjects were divided into 5 groups: group I (n=10): pregnant in the second trimester with a gestational age of 13–24 weeks (mean 18.5±2 weeks); group II (n=14), pregnant in the third trimester with a gestational age of 25–39 weeks, mean 30.2±3 weeks); group III (n=32), 0–3 days *post partum*; group IV (n=10) 4 days to 2 months *post partum*; group V (n=12), 2–6 months *post partum*. Group VI (n=18) were control subjects who were not pregnant. Twenty-four of the pregnant women were *primigravid*.

The control subjects were selected medical students and staff. All control subjects had regular menstrual periods and none took contraceptive medication or had pituitary disorders. The menstrual periods of the control subjects were not taken into consideration at the time of the MR examination. In the pregnant subjects, no contraceptive medication had been taken for at least 6 months prior to pregnancy. The clinical histories of the subjects showed no evidence of endocrinopathy. Physical examination and routine laboratory tests revealed no abnormality in any subject.

MR examinations were performed after informed consent obtained from all subjects. Because of practical and ethical difficulties, women who were pregnant in the first trimester were not included in the study. The pregnant and control subjects were only examined once. Thirty-nine of the subjects had been referred for MR examination because of clinical suspicion of intracranial lesion(s) such as headache (n=24), seizure (n=10) and brain tumour (n=5). The rest of the subjects were volunteers without any suspicion of disease. Of the 39 subjects with clinical suspicion of intracranial abnormality: 4 were in group I; 5 were in group II; 11 were in group III; 3 were in group IV; 7 were in group V; and 9 were in group VI. MR examinations were performed with a 0.5 T unit (Vectra, General Electric). Sagittal T1-weighted (TR/TE 300–500/20) images with a 5-mm thickness, 192×256 matrix, 20-cm field of view, 2 NEX, and 1-mm intersection gap were obtained. Coronal spin-echo T1-weighted 3D images (TR/TE 200/16) with an 18-cm field of view, 1 NEX, 160×224 matrix, and 1.25-mm partition thickness were obtained, and the slab thickness ranged from 1.5 to 2.5 cm, covering the whole sella.

We evaluated the height, width, length and volume of the pituitary gland; the width of the infundibulum; and the convexity or concavity of the glands. We also investigated signal intensity in the posterior lobe of the pituitary gland on T1-weighted sagittal images. The morphological appearance of the gland was scored according to ELSTER et al. (7). A visual-based grading of pituitary concavity or convexity in a 5-point scoring system was used in sagittal MR images. With this scheme: grade 1 represented a markedly concave superior surface of the gland (partially empty sella appearance); grade 2 gland was minimally concave and had less than 2 mm of depression centrally; grade 3 had a flat appearance; grade 4 was minimally convex (less than 2 mm); and grade 5 was markedly convex in appearance.

Sagittal and coronal T1-weighted MR images were used to obtain all pituitary measurements except volume which was measured on coronal spin-

Table 1

Pituitary gland measurements and subject characteristics

Group	n	Age, years (range)	Gestational age, weeks (range)	Pituitary measurements						
				Volume 1, mm^3 (range)	Volume 2, mm^3 (range)	Width, mm (range)	Height, mm (range)	Length, mm (range)	Infundibular width, mm (range)	Infundibular morphology (range)
I	10	27.5±4.4 (22–36)	18.5±2 (12.5–24)	514±18 (360–775)	625±135 (439–909)	14±2.2 (9–16.5)	6.7±0.76 (5.6–7.8)	10.7±0.59 (10–12)	1.8±0.13 (1.7–2.1)	3.5±0.5 (3–4)
II	14	25.4±4.7 (28–35)	30.2±3 (25–39)	718±94 (614–923)	875±111 (749–1107)	15.09±1.1 (13.6–17.4)	8.26±0.56 (7.1–9.6)	11.7±0.9 (10.3–13.1)	2.4±0.73 (1.8–4.2)	4.2±0.46 (4–5)
III	32	27.3±2.8 (23–25)	–	847±110 (608–1043)	1103±126 (903–1356)	16.9±0.6 (15.6–17.8)	8.76±0.67 (7.5–10.2)	11.6±0.99 (10–14.6)	2.59±0.5 (1.6–3.7)	4.6±0.5 (4–5)
IV	10	25.2±2.4 (22–30)	–	569±69 (455–705)	692±81 (555–846)	15.3±1 (13.7–16.5)	6.65±0.7 (5.8–8.3)	11.1±0.7 (10–12.4)	1.9±0.2 (1.6–2.3)	3.4±0.5 (3–4)
V	12	26.3±5.1 (20–35)	–	385±79 (270–539)	497±117 (328–728)	13.2±1.3 (11.5–15.9)	6±0.99 (4.8–7.9)	9.7±0.73 (9–11.2)	2±0.36 (1.7–2.9)	3±0.85 (2–4)
VI	18	27.1±4.8 (23–38)	–	385±82 (317–670)	501±106 (412–871)	13.5±1.4 (10.9–15.5)	5.88±0.78 (4.8–8)	9.7±0.9 (8.2–11.2)	2.1±0.3 (1.6–3.1)	2.9±0.6 (2–4)

Group I = second trimester of pregnancy. Group II = third trimester of pregnancy. Group III = 0–3 days *post partum*. Group IV = 4 days to 2 months *post partum*. Group V = 2–6 months *post partum*. Group VI = non-pregnant control subjects.

Table 2

Intergroup differences according to the Newman-Keul test

Groups	Volume 1, % change	Volume 2, % change	Height, % change	Width, % change	Length, % change	Infundibular width, % change
I–II	40**	40**	22**	7 NS	9*	33*
I–III	65**	76**	30**	21**	8*	43**
I–IV	11 NS	11 NS	1 NS	9 NS	3 NS	5 NS
I–V	33**	26*	12 NS	7*	10*	11 NS
I–VI	25**	25**	14*	3 NS	10*	16 NS
II–III	18**	26**	6 NS	12**	1 NS	23 NS
II–IV	26**	26**	23**	1 NS	5 NS	26*
II–V	86**	76**	37**	15**	21**	20 NS
II–VI	86**	75**	39**	12**	21**	14 NS
III–IV	49**	59**	31**	10**	4 NS	36**
III–V	120**	122**	45**	29**	20**	30**
III–VI	120**	120**	48**	25**	20**	23**
IV–V	48**	39**	10 NS	17**	14**	5 NS
IV–VI	48**	38**	13*	13**	14**	10 NS
V–VI	0 NS	1 NS	2 NS	5 NS	0 NS	5 NS

* $p<0.05$, ** $p<0.01$.

Group I = second trimester of pregnancy (12–24 weeks). Group II = third trimester of pregnancy (25–39 weeks). Group III = *post partum*, 0–3 days. Group IV = *post partum*, 4 days to 8 weeks. Group V = *post partum*, 9–24 weeks. Group VI = control subjects.

Table 3

Results of the linear regression analysis of the pituitary measurements

Study parameters	*Pre-partum* period			*Post-partum* period		
	r	R^2, %	*p*	r	R^2, %	*p*
Volume 1 – height	0.77	60	<0.00001	0.89	81	<0.00001
Volume 2 – height	0.78	61	<0.00001	0.88	79	<0.00001
Volume 1 – length	0.68	47	<0.00023	0.73	54	<0.00001
Volume 2 – length	0.67	45	<0.00023	0.69	48	<0.00001
Volume 1 – width	0.63	40	<0.001	0.82	68	<0.00001
Volume 2 – width	0.67	40	<0.0009	0.81	67	<0.00001
Infundibular width – volume 1	0.60	37	<0.00017	0.44	20	<0.00082
Infundibular width – volume 2	0.61	39	<0.00013	0.48	24	<0.00002
Convexity – volume 1	0.65	43	<0.00048	0.81	67	<0.00001
Convexity – volume 2	0.65	43	<0.00047	0.79	63	<0.00001
Volume 1 – age*	0.80	65	<0.00001	–0.87	76	<0.00001
Height – age*	0.94	88	<0.00001	–0.82	69	<0.00001
Volume 2 – age*	0.82	75	<0.00001	–0.84	72	<0.00001
Convexity – age*	0.61	38	<0.001	–0.76	59	<0.00001
Infundibular width – age*	0.58	34	<0.01	–0.37	13	<0.0056

* = Gestational age as week in *pre partum*; and *post-partum* duration as week in *post-partum* period.

echo T1WI-3D images. In 3D coronal images, the cross-sectional area of the gland was outlined manually on every slice, using the trackball of the cursor on the screen. The calculated volume of the gland was found by multiplying the area by the slice thickness and adding the volume. In the volume measurements, two different formulas were used: volume 1=1/2×length×width×height; and volume 2=area measured by the trackball×slice-thickness. Average values were used in the analyses (5, 10, 12). Before the measurements, the images were magnified by 2 on the console screen. Each measurement was repeated three times and the average value was used for analysis. All measurements were performed by the same radiologist (F.E.).

Statistical analysis: Differences among the study parameters were checked by a one-way analysis of variance (ANOVA), and the mean values of the groups were compared by means of the Newman-Keul test. Correlation coefficients among independent parameters were calculated by linear regression analysis after segmentation of the data into *pre-par-*

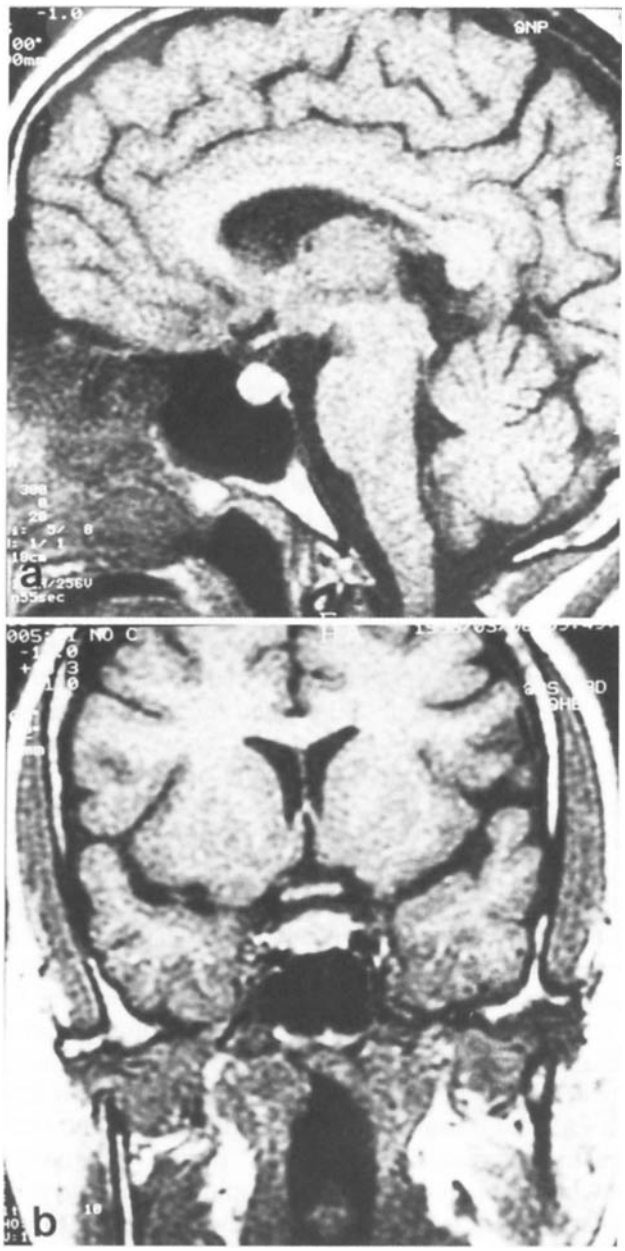

Figure. MR images of the pituitary gland in sagittal and coronal views during the first day *post partum* show a round appearance (a) and marked convexity (b) of the upper border of the pituitary gland.

tum and *post-partum* groups. The results are expressed as means±SD.

Results

Tables 1 and 2 summarize the pituitary measurements obtained with MR and the intergroup differences according to the Newman-Keul test. The results of the linear regression analysis of the pregnant subjects are summarized in Table 3. All the pituitary measurements (including volumes 1 and 2, area, length, height, width, gland convexity, and infundibulum width) showed a significant increase from the second trimester to the immediate *post-partum* period (within the first 3 days). The highest values were found within the first 3 days *post partum* (Table 1, Figure). The mean height of the glands was 8.26 mm during pregnancy and 8.76 mm immediately *post partum*. None of the gland heights exceeded 9.6 mm during pregnancy or 10.2 mm in the 3 days immediately *post partum*.

A progressive increase in gland convexity was also demonstrated throughout pregnancy and in the first 3 days *post partum*. Linear regression analysis revealed a correlation coefficient between height of the gland and gestational week ($r=0.94$, $p<0.00001$). The slope of the regression line was 0.12, which suggested that pituitary height should be expected to increase about 0.12 mm/week from the second trimester to delivery. The slope of the regression analysis line was 15.9 mm^3/week for the measurements of volume 1 and 19.4 mm^3/week for those of volume 2.

Volumes 1 and 2 showed the highest percentage of increase in the 3 days *post partum* compared with the non-pregnant control subjects. Increases of 120% were found in both volumes 1 and 2 (Table 2).

In 2 subjects, the diameter of the infundibulum exceeded 4 mm during pregnancy: the maximum diameter was 4.2 mm. The mean diameter of the infundibulum in the first 3 days *post partum* was larger than the diameters at the third trimester (Table 1). There was also a progressive increase in the width of the infundibulum during pregnancy and in the first 3 days *post partum*; this regressed to normal within 2 months. According to the Newman-Keul test, the highest significant differences were between group 1 and group 3, and between group 3 and group 4 ($p<0.01$). After 4 days *post partum*, all gland measurements diminished. The width of the infundibulum returned to normal earlier than the other parameters (Tables 1, 2). There were no statistically significant differences in gland volume, shape or size between the control subjects and the subjects in group 5 (Table 3).

High signal intensity in the posterior lobe of the pituitary gland was seen in 8 of the 10 first-trimester women, in 7 of the 14 second-trimester women, in 30 of the 54 *post-partum* women, and in 13 of the 18 control women, with an overall incidence of 60%. No statistically significant difference in signal intensity in the posterior pituitary gland was identified in the study group ($p>0.05$).

Discussion

To our knowledge, there are few imaging studies that have attempted to define the size, shape and volume of the normal pituitary gland *in vivo* during pregnancy or *post partum* (1, 6, 9, 10). In 1984, HINSHAW et al. (10) obtained coronal CT images in 8 volunteer *post-partum* subjects within one week of delivery. The median height of the gland in their study was 9.75 mm, with a range of 8.0–11.5 mm. In 1991, ELSTER et al. (7) obtained middle midsagittal MR images in 12 *post-partum* subjects within one week of delivey. They recorded a corresponding median height of 9.3 mm with a range of 6.5–11.8 mm. They also reported that a gland size of up to 12 mm might be acceptable immediately *post partum.* We found a corresponding median height of 8.8 mm and a range of 7.5–10.2 mm within 3 days of delivery and a mean gland height of 8.26 mm with a range of 7.1–8.6 mm during pregnancy. In contrast to ELSTER et al. (7), none of the subjects in the present study had a gland size of 10 mm or more during pregnancy. HINSHAW et al. (10) reported an upward convexity of the gland in 8 of 8 cases while ELSTER et al. (7) reported upward convexity in 10 out of 12 subjects studied during the first week *post partum.* In the present study we found an upward convexity of the gland in 32 out of 32 subjects during the first 3 days *post partum.* In 11 out of 32 (34%) subjects, the gland had a mild convex appearance (grade 4) while in 21 out of 32 (66%), it had a markedly convex appearance (grade 5).

GONZALES et al. (9) studied 32 women pregnant in the first, second and third trimesters by means of low-field strength (0.3 T) MR equipment. The mean heights of the gland reported for each trimester were respectively 6.6, 7.5 and 8.8 mm. The maximum and minimum values for the height of the gland were not stated.

In the present study, two different formulae were used to estimate the volume of the gland. The first (volume 1=1/2×length×width×height) is based on the formula for an ellipsoid, and was used to estimate pituitary volume based on plain radiographs of the sella. This equation tends to underestimate the pituitary volume. The second formula (volume 2=area×slice-thickness) probably overestimates the volume of the gland. Both volume measurements were consistent with the volume reported in MR and *post mortem* studies (9, 13). From the second trimester to 3 days *post partum,* the gland volume showed an increase of 65% according to volume 1 and an increase of 76% according to volume 2. Compared with the control volunteers, increases of 120% were found in the group at 3 days *post partum.* Both volume measurements correlated well with the increase of gland convexity.

To our knowledge, only one imaging study has attempted to define the volume of the normal pituitary gland *in vivo* during pregnancy (9), and no study has attempted to define the volume of the pituitary gland in the *post-partum* period. GONZALES et al. (9) reported an increase of 136% in pituitary gland size during pregnancy compared with non-pregnant volunteers. In their study, the gland volume of the women in the second and third trimesters were respectively 534 and 708 mm^3. In the third trimester, the mean gland measurements were: 14.8 mm in width, 10.8 mm in length, and 8.8 mm in height. These measurements agree well with our data.

In the present study, the slope of the regression line suggests that a linear increase in pituitary gland height of about 0.12 mm/week should be expected during pregnancy. ELSTER et al. (7) reported a linear gain in pituitary gland height of 0.08 mm/week during pregnancy. Our data also show that physiological hypertrophy of the gland occurred in different proportions. The height of the gland showed a larger increase than its width and length (Table 2). GONZALES et al. (9) reported that at the end of pregnancy, the enlargement of the pituitary gland was approximately the same (2.6 mm) in all three dimensions. During the 3 days *post partum,* the gland appeared taller, wider and more round than during the latter half of pregnancy. They also demonstrated that a marked hormonal stimulation occurred during parturition in the gland and in the puerperium, resulting in a physiological hypertrophy of the pituitary gland that was even greater than that seen during pregnancy (3). On the basis of autopsy studies, it has been demonstrated that the pituitary weight normally increases 30%–100% during pregnancy owing to physiological lactotrophic cellular hyperplasia (7, 9). It has also been shown that these pituitary changes are associated with an increase in the number and size of the chromophobic cells (1, 6).

After the first 3 days *post partum,* the pituitary measurements and the morphological appearance of the gland began to return to normal which was reached within 6 months. ELSTER et al. (7) reported that the mean infundibular width in pregnant women was 2.2 mm (range 0.8–4.0 mm). The largest infundibulum measured 4.00 mm in a woman in mid-pregnancy. There was no statistically significant difference in the mean diameters of the infundibuli in control, pregnant and *post-partum* subjects. In the present study, the mean diameter of the infundibulum was 2.4 mm with a range of 1.8–4.2 mm. The highest values were found within the first 3 days *post partum.*

The ideal scenario would have been to undertake repeat examinations of the same subjects from the second trimester up to 6 months *post partum* in order to characterize the changes in the pituitary volume and sizes, but this was not possible for ethical reasons.

Conclusion: The volume and dimensions of the pituitary gland in pregnancy increase linearly toward the end of pregnancy and reach their highest values in the early *post-partum* period. The largest value for the height of the gland was 10.2 mm.

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