tion were obtained. Wavering along the complete length of the midline appears to be a constant finding in hydrocephalus and occurs prior to an increase in biparietal diameter and in some cases prior to an abnormal lateral ventricular width: hemispheric width ratio. This sign may assist in the early diagnosis of hydrocephalus or at least identify a patient population who should be evaluated serially to eliminate the diagnosis of hydrocephalus.

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The ultrasound estimation of sex-related variations of intrauterine growth

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The fetal ultrasound parameters of biparietal diameter, head circumference, abdominal circumference, and the product of crown-rump length and trunk area were estimated from serial measurements at 16 weeks' gestation to term in a sample of 96 pregnant European women. The slower rate of growth in the female fetus compared to that in the male fetus was statistically significant by 28 weeks' gestation, and this discrepancy increased toward term. This sex-related difference was reflected in the birth weight, head circumference, and crown-heel length of the newborn infant. The variation of intrauterine growth affected both head and abdomen equally as the head/abdominal circumference ratio did not differ significantly between the sexes throughout pregnancy and the neonatal ponderal indices were similar. (AM. J. OBSTET. GYNECOL. 149:665, 1984.)

At birth, the male infant is larger than the female infant. Thomson et al.[1] showed that a consistent sex-related difference was present at 34 to 35 weeks' gestation and that after 38 weeks male infants were about 150 gm heavier than female babies. Fraccaro[2] noted a sex-related difference appearing about 31 weeks' gestation, whereas Lubchenco et al.[3] noted that the fiftieth percentiles of birth weight were lower in the female infant from 24 weeks' gestation onward. However, statistically significant differences in mean weights were not apparent until 38 weeks.

During a longitudinal ultrasound study of ethnic differences in intrauterine growth, the data from European women were used to examine the sex-related differences in intrauterine growth.

Subjects and methods

Ninety-six pregnant European women were studied. They were nonsmokers and had normal uncomplicated pregnancies. Heights and weights of all women were recorded at their first hospital visit (booking visit) and weight was also recorded at 32 weeks' gestation. The weight gain was calculated as the difference from booking to 32 weeks' gestation expressed as kilograms per 2-week interval. The maternal ponderal index was calculated as the weight (kilograms) at booking divided by the height (meters) squared. Social class was assigned from the husband's occupation.

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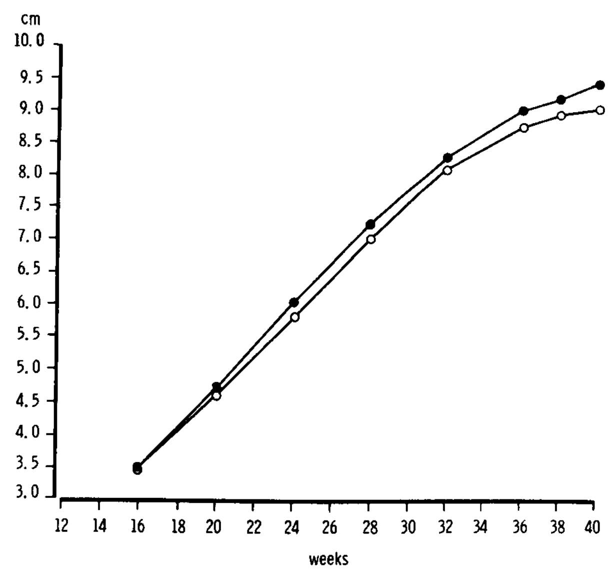

Fig. 1. Biparietal diameter (centimeters) as a function of gestational length (weeks) in both male (•) and female (o) fetuses.

At birth the sex of the infant was noted. The neonates were weighed, and the maximal occipitofrontal head circumference and crown-heel length were measured. The length of gestation to delivery was calculated only in those patients who went into spontaneous labor. The fetal ponderal index was calculated as the weight (grams) multiplied by 100 and divided by crown-heel length (centimeters) cubed.[4]

Menstrual dates of all pregnancies were accurate and were confirmed by ultrasound examination before 20 weeks' gestation[5, 6] with the use of the Toshiba SAL 20A real-time machine with a 2.4 MHz transducer.

The ultrasound examinations were arranged for each patient within 2 days of 16, 20, 24, 28, 32, 36, 38, and 40 completed weeks. Not all patients were able to attend each 4-week visit, a few were delivered early or elsewhere, and in some cases measurements were technically impossible to obtain. At each of these visits the following fetal ultrasound parameters were obtained: head circumference, biparietal diameter, abdominal circumference, trunk area, and crown-rump length.

The biparietal diameter was measured with the combined A and B mode after the method of Campbell.[7, 8] The head circumference was obtained by the method of Campbell and Thoms.[8] The abdominal circumference and the area enclosed within this circumference (trunk area) were measured from the fetal trunk cross section as described by Campbell and Wilkin.[9] The measurement of crown-rump length in the second and third trimesters of pregnancy and its use to obtain the product of crown-rump length and trunk area were initially described by Wittmann et al.[10] In a study in our laboratory abdominal circumference and the product of crown-rump length and trunk area were highly correlated with the weight of fetuses delivered within 3 days of ultrasound measurement [r (birth weight, abdominal circumference) = 0.96; r (birth weight, crown-rump length × trunk area) = 0.95] (Parker, A. J., and Davies, P.: Unpublished data). Campbell and Wilkin[9] also showed a strong correlation between abdominal circumference and birth weight.

Table I. Maternal characteristics (mean ± SD)

Characteristic	*Male fetuses*	*Female fetuses*
Maternal age (yr)	28.4 ± 5.1 (47)	28.8 ± 4.4 (49)
Maternal height (m)	1.63 ± 0.07 (47)	1.62 ± 0.06 (49)
Maternal weight at booking (kg)	62.3 ± 8.6 (47)	61.0 ± 8.2 (49)
Maternal weight at 32 wk (kg)	71.1 ± 8.2 (46)	69.4 ± 8.4 (47)
Weight gain (kg/2 wk)	0.84 ± 0.31 (46)	0.82 ± 0.29 (47)
Maternal ponderal index*	23.5 ± 3.6 (47)	23.1 ± 3.2 (49)

Numbers in parentheses are numbers of gestations evaluated.

*Weight (kilograms) at booking/height (meters) squared.

The ratio of head/abdominal circumference was calculated for each fetus at each gestation point.[8]

All of these ultrasound measurements were obtained with the use of the Emisonic 4200, a static B scanner with a 2.5 MHz probe. The crown-rump length was measured directly off the gray scale with on-screen multidirectional calipers. The circumference and area measurements were obtained with the Kretz Combison on-screen measuring system that incorporated a light pen.[11] All systems were calibrated to an assumed speed of sound in fetal soft tissue of 1540 $msec^{-1}$.

Comparison of the results for male and female infants mainly involved the use of Student's *t* test.

Results

The means and standard deviations of the maternal characteristics are listed in Table I. Although those mothers giving birth to male infants were marginally taller and heavier and had a greater weight gain in pregnancy than those delivered of female infants, none of these differences were statistically significant. The previous obstetric history was very similar in each group. The means and standard deviations of characteristics of the newborn infant are shown in Table II. As expected, the male infant was heavier and longer and had a greater head circumference. The length of gestation was shorter for the male infant although the difference was not statistically significant. There was little difference in fetal ponderal index.

Table II. Infant characteristics (mean ± SD)

Characteristic	*Male fetuses*	*Female fetuses*	*Student's* t *test*
Birth weight (kg)	364 ± 0.46 (47)	3.33 ± 0.51 (49)	$p < 0.001$
Head circumference (cm)	35.2 ± 1.3 (44)	34.0 ± 1.8 (49)	$p < 0.02$
Crown-heel length (cm)	51.7 ± 2.9 (45)	51.0 ± 3.4 (48)	NS
Length of gestation (days)	280.0 ± 9.3 (36)	283.9 ± 12.2 (43)	NS
Fetal ponderal index*	2.64 ± 0.34 (45)	2.53 ± 0.39 (48)	NS

Numbers in parentheses are numbers of gestations evaluated.
*Weight (grams) × 100/crown-heel length (centimeters) cubed.

Table III. Ultrasound parameters at 36 weeks' gestation (mean ± SD)

Parameter	*Male fetuses*	*Female fetuses*
Biparietal diameter (cm)	9.06 ± 0.31 (37)	8.82 ± 0.40 (35)
Head circumference (cm)	33.3 ± 1.1 (36)	32.0 ± 1.7 (33)
Abdominal circumference (cm)	33.0 ± 1.3 (42)	32.0 ± 1.7 (37)
Product of crown-rump length and trunk area (cm) cubed	2237 ± 293 (36)	2057 ± 306 (33)
Head/abdominal circumference ratio	1.01 ± 0.03 (36)	1.01 ± 0.05 (33)

Numbers in parentheses are numbers of gestations evaluated.

Table IV. Analysis of covariance of birth weight (mean ± SEM)

Male fetuses			*Female fetuses*		
Raw	*Adjusted*	*N*	*Raw*	*Adjusted*	*N*
3.58 ± 0.07	3.59	41	3.32 ± 0.08	3.31	38

For reasons of space, the full ultrasound tables are not presented, but Table III illustrates the male and female ultrasound parameters with their standard deviations at 36 weeks' gestation.

The ultrasound data are presented in Figs. 1 to 5. Fig. 1 shows the biparietal diameter means at the gestational points for male and female fetuses. The male fetuses had larger biparietal diameters than the female fetuses, and this difference became statistically significant at 24 weeks ($p < 0.02$). Head circumference is shown in Fig. 2 and the male mean value became significantly greater than that of the female fetus at 24 weeks' gestation ($p < 0.025$). Fig. 3 shows the growth of abdominal circumference in the two groups, with the mean of the male fetus being significantly larger than that of the female fetus at 28 weeks ($p < 0.005$). The product of crown-rump length and trunk area is shown in Fig. 4 and was significantly different between the sexes at 28 weeks ($p < 0.02$). Fig. 5 shows the head/abdominal circumference ratio which did not differ significantly at any time during pregnancy.

To see how the sex-related difference in birth weight was explicable or altered by taking into account the maternal characteristics of the male and female fetal groups, an analysis of covariance[12] was obtained in which birth weight was standardized for maternal weight at 32 weeks' gestation, parity, and length of gestation. The regression of birth weight on these three covariates was statistically significant ($p < 0.001$), but the other variables considered—maternal age, height, and social class—did not contribute statistically significant extra information. Table IV shows the raw means and means standardized for the covariates of the two sexes. It is evident that the standardization has the effect of slightly increasing the birth weight difference between the sexes. The smaller number of cases in Table IV, compared to Table II, is due to exclusion of cases with missing information on one or more of the covariates. Representative sample sizes for the ultrasound parameters at each gestational point are shown in Table V.

Comment

The larger size of mothers having male fetuses may be due to chance, although some of that difference would have a contribution from the larger fetus and its secundines.

Factors expected to influence birth weight, apart from fetal sex, were also tested with the use of analysis of covariance. With this method, standardization of birth weight allowing for the influence of maternal weight and parity and length of gestation produced an adjusted sex-related difference of about 280 gm. This is comparable to the difference between means of Persson et al.[13] of 180 gm.

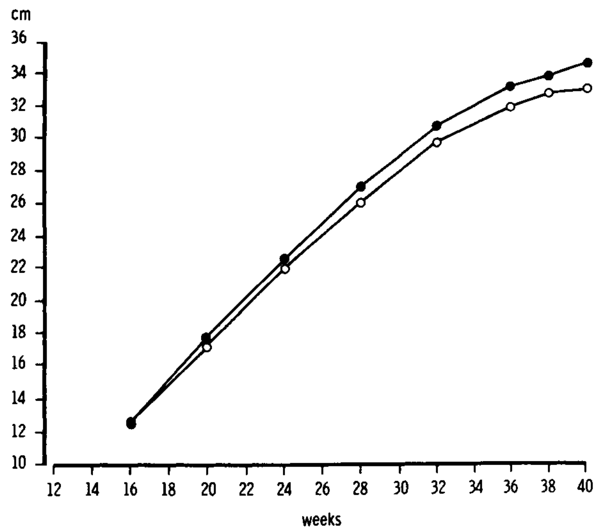

Fig. 2. Head circumference (centimeters) as a function of gestational length (weeks) in both male (•) and female (o) fetuses.

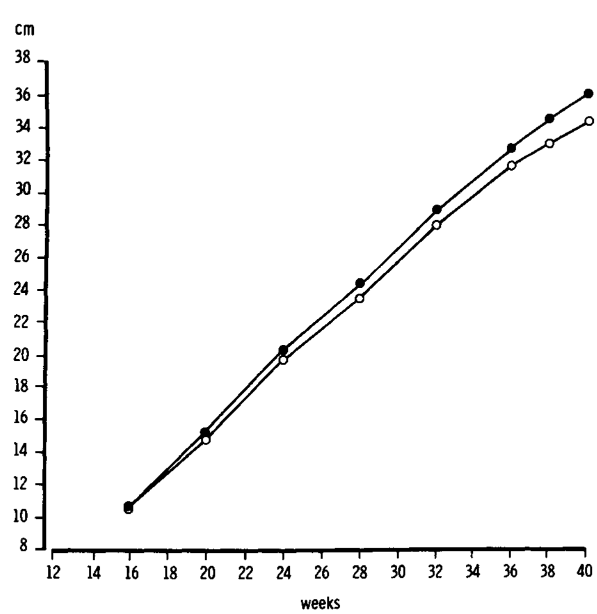

Fig. 3. Abdominal circumference (centimeters) as a function of gestational length (weeks) in both male (•) and female (o) fetuses.

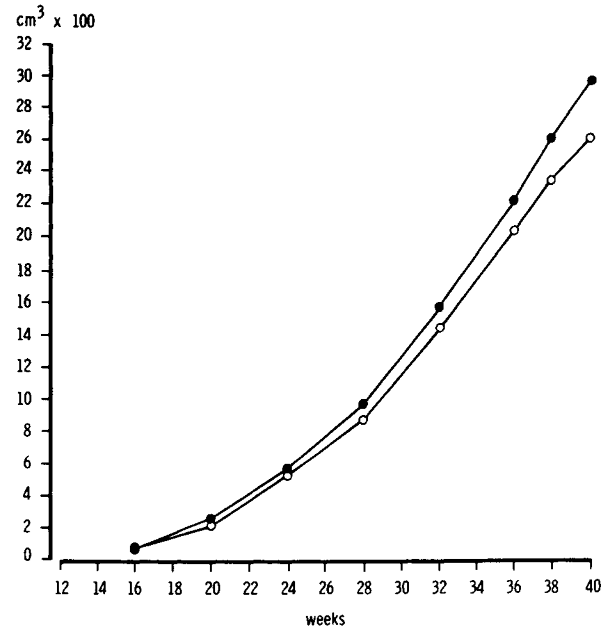

Fig. 4. Crown-rump length × trunk area (centimeters) cubed as a function of gestational length (weeks) in both male (•) and female (o) fetuses.

Our data suggest that a sex-related difference in ultrasound parameters is apparent in midgestation. Both abdominal circumference and crown-rump length × trunk area are highly correlated with fetal weight, and both of these show that the disparity in fetal size increases with advancing gestation. This pattern is also seen in the measurements of head circumference and biparietal diameter. Persson et al.[13] found that from 20 weeks' gestation there was a sex-related difference of 1.7% between mean biparietal diameter values. The difference in birth weight was 180 gm and the male infants had a crown-heel length that was on average 0.9 cm longer. The relative difference in biparietal diameter values was equal to that of the difference of crown-heel length.

This difference in biparietal diameter values was substantiated by Pedersen[14] who found that male biparietal diameter values were on average 1.4 mm longer than female values. Fetal crown-rump length values between 8 and 13 weeks' gestation were on average 2.0 mm longer in male fetuses than in female fetuses. Examination of the time necessary for the female fetus to reach male size showed that this increased from 1 day at 8 to 12 weeks to 6 or 7 days at term.

We have shown that the head circumference/abdominal circumference ratio does not differ significantly between the sexes throughout pregnancy so there is no evidence to suggest that the head and trunk are influenced unequally by this difference in growth rate. This is also reflected in the fetal ponderal indices which on average are similar in male and female neonates.

Thomson et al.[1] stated "that the sex differential does not appear before about 30 weeks" and suggests that the eventual further growth of the male fetus may be due to a sex hormone difference rather than to an innate characteristic of growth potential. However, Ounsted and Ounsted[15] have postulated that the sex differences in fetal growth rate are due to the maternal-fetal antigenic disparity created by the presence of a Y chromosome. From the difference in crown-rump

Table V. Representative sample sizes of ultrasound evaluations at different gestational lengths

	Weeks' gestation							
Fetuses	*16*	*20*	*24*	*28*	*32*	*36*	*38*	*40*
Male	22	19	30	38	39	37	33	22
Female	24	30	32	37	40	35	37	25

length in the first trimester Pederson[14] also felt that the disparity of fetal growth rate between the sexes was encoded at conception.

The ultrasound data of this study demonstrate that the sex-related differences in fetal size are present much earlier in pregnancy than has previously been demonstrated by the examination of the newborn infant.

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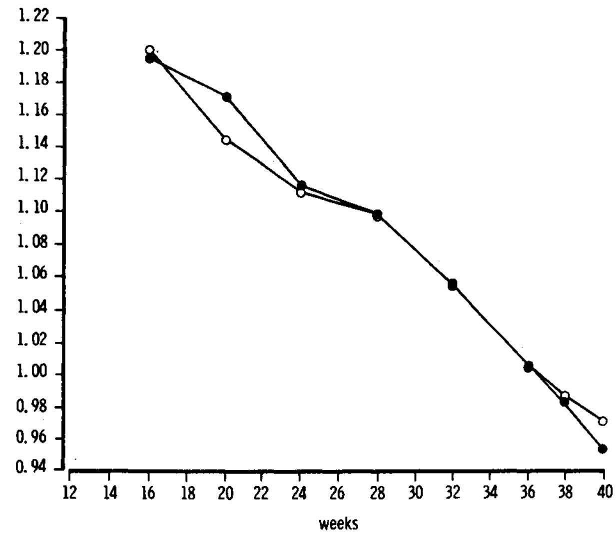

Fig. 5. Head circumference/abdominal circumference as a function of gestational length (weeks) in both male (•) and female (o) fetuses.

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