Fetal Abdominal Circumference as a Predictor of Menstrual Age

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The relation between fetal abdominal circumference and menstrual age was determined by cross-sectional analysis of 400 fetuses (15–41 weeks) examined with a linear-array real-time ultrasound scanner using specifically defined methodology. Mathematical modeling of the data demonstrated that the linear quadratic function was an optimal model (r^2 = 97.9%). Predicted abdominal circumference values at specific points in gestation based on this model were comparable to the data reported by other investigators using static-image equipment. Predicted menstrual age values associated with a given abdominal circumference measurement were calculated and are presented in tabular form. The variability (± 2 SD) in predicting menstrual age from abdominal circumference measurements is broader than that observed with the fetal biparietal diameter; nonetheless, this measurement can be useful as an adjunct in predicting menstrual age in cases in which the biparietal diameter is technically inadequate or impossible to obtain due to unusual positioning.

The sonographic measurement of the fetal abdominal circumference at the level of the umbilical vein was first described by Campbell and Wilkin [1] and Higginbottom et al. [2] for use in predicting fetal weight. More recent reports have emphasized the usefulness of this measurement in monitoring normal fetal growth and in detecting intrauterine growth retardation, macrosomia, and isoimmunization [3–9]. In this investigation, we focused on the usefulness of this measurement in predicting menstrual age, in the hope that it would provide an alternative method of determining menstrual age in cases in which head position precludes an accurate measurement of the biparietal diameter.

Subjects and Methods

The study consisted of 400 consecutive patients (over 95% middle-class white) chosen for analysis on the following criteria: (1) a history of regular menses; (2) known date of the beginning of the last menstrual period; (3) close agreement (± 1 week) between the menstrual age and the clinical evaluation; (4) absence of maternal disease known to affect normal fetal growth (e.g., diabetes mellitus, chronic hypertension); and (5) absence of multiple gestation (e.g., twins) in the current pregnancy.

All examinations were performed using a commercially available linear-array real-time system with a 3.5 MHz single-focus transducer (Advanced Diagnostic Resources, Tempe, AZ). The plane of section chosen for abdominal circumference measurement was the axial plane at the level of the umbilical vein–ductus venosus complex (fig. 1). All measurements were made from a Polaroid image or x-ray film by one of us (F. P. H.) using a hand-held map measurer (Dietzgen) or an electronic digitizer (Numonics Corp.); the measurements were made along the outer perimeter of the abdomen (fig. 1). Each fetus was measured only once in gestation.

The mean abdominal circumference values and their standard deviations were calculated at weekly intervals using standard methods [10]; each interval was centered on the week (e.g., 16 week interval, 15.50–16.49 weeks). Mathematical modeling of the relation of abdominal circumference to menstrual age was carried out using the linear, linear-quad-

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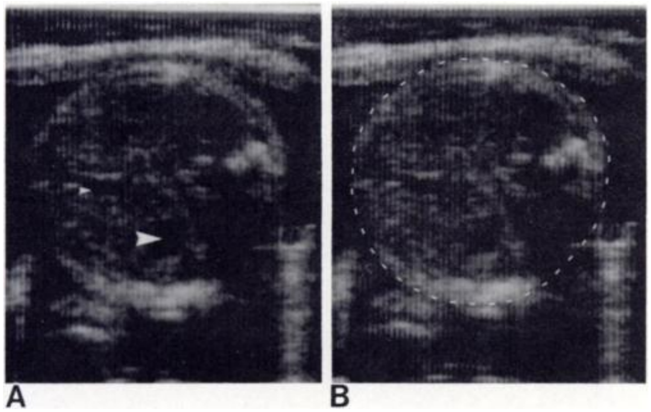

Fig. 1.—**A,** Representative real-time image of fetal abdomen at level of umbilical vein (*small arrowhead*) and stomach (*large arrowhead*). Spine is to right. **B,** Identical to **A.** Dotted lines represent boundary of abdominal circumference.

ratic, and linear-cubic models [10–11]. Optimal coefficient estimates were obtained by the least-squares method, and the adequacy of each function was evaluated by measurement of the coefficient of determination (r^2) [12]. An optimal model was chosen by comparing the coefficient of determination (r^2), the variances of the estimates of the regression coefficients, and the distributions of the residuals for each model. Predicted abdominal circumference values for different menstrual ages and predicted menstrual age values for different abdominal circumference measurements were calculated using the optimal models.

The overall variability about the regression model is measured by the standard delviation about the regression curve. The use of this measurement assumes that the variability is constant throughout gestation, an assumption that has proven incorrect with measurements of other fetal growth parameters such as the biparietal diameter. To investigate the possibility of a change in variability as pregnancy progresses, the predicted value of the abdominal circumference at 12, 18, 24, 30, 36, and 42 menstrual weeks was determined using the optimal model. The experimental data were then divided into five groups on the basis of these abdominal circumference bounding limits; for example, group 1 was composed of abdominal circumference values between 5.6 cm (12 weeks) and 12.8 cm (18 weeks). The standard deviation of menstrual age about the regression line was calculated within each 6 week subinterval. In this manner, the variability inherent in predicting menstrual age from abdominal circumference within each subgroup was estimated.

In order to assess intraobserver sources of variation in the process of measuring abdominal circumference, two Polaroid photographs of the abdominal cross-section were obtained within an interval of 5 min by the same investigator (F. P. H.) for each of 20 fetuses. For each pair of photographs on the same fetus, one was measured once and the other twice using the same instrument (Digitizer, Numonics Corp.). The measurements obtained from the two separate photographs were compared to assess the photographic process as a source of variation; the two measurements of the same photograph were used to assess the measurement process as a source of variation. The paired *t*-test was used to determine if the average differences were significantly different from zero.

Results

Preliminary data based on the initial 218 fetuses using the linear quadratic function are published elsewhere [13]. The *mean* abdominal circumference and the standard deviation for each week in gestation are indicated in table 1. The distribution of the observed abdominal circumference measurements were plotted against menstrual age (fig. 2).

Both the linear-quadratic function ($r^2 = 97.9\%$) and the linear-cubic function ($r^2 = 97.9\%$) could be considered the optimal model; the r^2 for the linear function was 97.7%. The *predicted* abdominal circumference value for a given menstrual week based on the quadratic function was compared with sonographic studies of Campbell [3], Hoffbauer et al. [4], and Tamura and Sabbagha [5] (table 2). The *predicted* menstrual age for any given abdominal circumference value is indicated in table 3; the calculated variability for predicting menstrual age from the abdominal circumference is presented in table 4.

In the assessment of intraobserver sources of error, the average absolute percentage difference between measurements of the same photograph by the same person was 0.7% (range, 0–1.7%). The hypothesis that the mean difference is zero was not rejected ($p = 0.34$), which indicates that there is no significant difference in the two measurements. The average absolute percentage difference between two photographs of the same fetus by the same examiner was 1.9% (range, 0.4%–5.9%). The hypothesis that the mean difference is zero was not rejected ($p = 0.74$).

Discussion

In our experience, establishing or verifying menstrual dates is still the most common indication for an obstetric sonogram. The fetal biparietal diameter is a reliable indicator of menstrual age up to 26 weeks, with a variability (± 2 SD) of only 7–10 days [14]. A need exists, however, for other sonographic methods of dating a pregnancy because (1) the biparietal diameter may not be obtainable because of an unfavorable head position (e.g., occiput anterior) and (2) the variability in predicting menstrual age from the biparietal diameter after 28 menstrual weeks is too great to be reliable (90% confidence interval = ± 3 weeks) [14].

The fetal abdominal circumference measurement is technically easier to obtain than the fetal biparietal diameter in the third trimester of pregnancy and may be measured equally well with static-image and real-time scanners [15, 16]. In our experience, very reproducable measurements can be made with real-time instruments in a matter of 1–2 min, using the umbilical vein–ductus venosus complex and/or the fetal stomach as anatomic landmarks. The major source of error is imaging obliquely through the fetal abdomen; this produces an image that is more oblong than round, and the resultant measurement will be larger than the actual circumference.

Because the fetal abdomen was measured routinely in our laboratory to determine fetal weight [17] and as part of head circumference/abdominal circumference ratio to rule out intrauterine growth retardation [6, 18], we decided to (1) determine normal values for our population at various points in gestation and (2) to evaluate the usefulness of this measurement in predicting menstrual age.

The normal values we obtained at various points in ges-

TABLE 1: **Mean Abdominal Circumference Values at Specific Weeks in Gestation**

Menstrual Age (weeks)	No. Fetuses	Mean Abdominal Circumference (cm)	1 SD (cm)
15	5	9.87	0.53
16	15	10.47	1.14
17	18	11.36	0.86
18	10	12.77	0.83
19	17	13.58	1.43
20	17	15.49	1.29
21	15	15.82	1.00
22	16	16.91	1.38
23	13	18.72	1.81
24	21	19.72	1.01
25	10	21.36	0.97
26	13	22.08	1.25
27	14	23.09	0.97
28	9	24.66	1.55
29	12	25.00	1.08
30	10	25.21	1.32
31	12	26.59	1.38
32	12	27.15	0.87
33	12	28.90	1.37
34	17	29.78	1.36
35	8	30.46	1.23
36	11	31.22	1.15
37	8	32.95	1.46
38	32	33.93	1.39
39	44	34.51	1.49
40	25	34.91	1.29
41	4	35.43	0.42

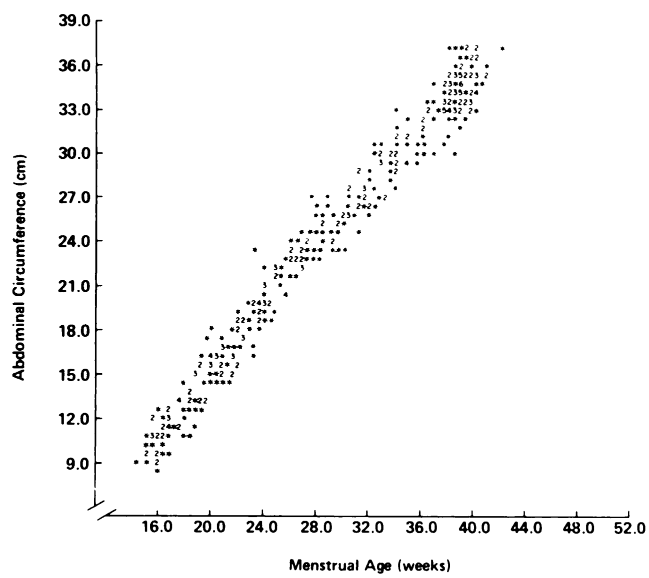

Fig. 2.—Distribution of observed abdominal circumference values at various points in gestation.

TABLE 2: **Comparison of Abdominal Circumference Measurements From Several Studies**

Menstrual Age (weeks)	Reference, Measurements (cm)			
	This Study*	[3]	[4]	[5]
15	9.3	···	6.8	···
16	10.5	10.3	7.8	···
17	11.7	···	9.0	···
18	12.9	12.8	10.5	13.1
19	14.1	···	13.4	14.4
20	15.2	14.8	14.8	15.4
21	16.4	···	16.0	17.0
22	17.5	17.0	17.0	18.0
23	18.6	···	18.0	19.3
24	19.7	19.5	19.0	20.5
25	20.8	···	20.0	21.3
26	21.9	21.3	21.0	22.1
27	22.9	···	22.0	23.7
28	24.0	23.3	23.0	25.3
29	25.0	···	24.0	26.9
30	26.0	25.3	25.0	27.4
31	27.0	···	26.0	28.0
32	28.0	27.7	27.0	28.7
33	29.0	···	28.0	29.0
34	30.0	29.7	29.0	30.1
35	30.9	···	30.0	32.2
36	31.8	32.0	31.0	33.3
37	32.7	···	32.0	34.4
38	33.6	33.5	33.0	35.7
39	34.5	···	34.0	35.9
40	35.4	35.3	35.0	36.1

* Predicted value from linear quadratic function: $AC = -10.4997 + 1.4256\,(MA) - 0.00697\,(MA)^2$; $r^2 = 97.9\%$; 1 SD = 1.23 cm.

tation are comparable to the results of other investigators. The smallest differences were observed in comparison with the data of Campbell [3], whose values were systematically smaller (mean difference, −1.6%; range, +0.3% to −2.9%). The data of Hoffbauer et al. [4] were also systematically smaller than our data (mean difference, −7.1%), while the data of Tamura and Sabbagha [5] were systematically larger than our data (mean difference, +3.4%). These differences are probably technical. For example, Deter et al. [19] demonstrated in a multifactorial analysis of variance that interobserver errors of up to 8% may be observed; sources of error include imaging and measurement equipment as well as imaging and measurement personnel. In any event, the sonographer using the equipment and technique we described should find these data useful in evaluating the normalcy of growth of a fetus with well established menstrual dates, especially those at risk for growth retardation and macrosomia.

Unfortunately, the evaluation of the variability in predicting menstrual age from abdominal circumference measurements indicates that it is actually a worse predictor of menstrual age than the biparietal diameter (table 4), except during the interval of 36–42 weeks, at which time it is slightly more accurate than the biparietal diameter. Nonetheless, these data can prove helpful in cases in which the biparietal diameter is technically impossible, or in cases (e.g., breech fetuses) in which molding of the fetal head can significantly alter the accuracy of the biparietal diameter in predicting menstrual age [20–23]. As with the biparietal diameter, the variability should be clearly stated when using the abdominal circumference alone in predicting menstrual age.

We are currently investigating the use of the abdominal circumference in a weighted formula for predicting menstrual age on the basis of measurements of several fetal

TABLE 3: **Predicted Menstrual Age for Abdominal Circumference Values**

Abdominal Circumference (cm)	Menstrual Age (weeks)	Abdominal Circumference (cm)	Menstrual Age (weeks)
10.0	15.6	23.5	27.7
10.5	16.1	24.0	28.2
11.0	16.5	24.5	28.7
11.5	16.9	25.0	29.2
12.0	17.3	25.5	29.7
12.5	17.8	26.0	30.1
13.0	18.2	26.5	30.6
13.5	18.6	27.0	31.1
14.0	19.1	27.5	31.6
14.5	19.5	28.0	32.1
15.0	20.0	28.5	32.6
15.5	20.4	29.0	33.1
16.0	20.8	29.5	33.6
16.5	21.3	30.0	34.1
17.0	21.7	30.5	34.6
17.5	22.2	31.0	35.1
18.0	22.6	31.5	35.6
18.5	23.1	32.0	36.1
19.0	23.6	32.5	36.6
19.5	24.0	33.0	37.1
20.0	24.5	33.5	37.6
20.5	24.9	34.0	38.1
21.0	25.4	34.5	38.7
21.5	25.9	35.0	39.2
22.0	26.3	35.5	39.7
22.5	26.8	36.0	40.2
23.0	27.3	36.5	40.8

Note.—$MA = 7.6070 + 0.7645\ (AC) + 0.00393\ (AC)^2$; $r^2 = 97.8\%$; 1 SD = 1.2 weeks.

TABLE 4: **Estimation of Variability in Predicting Menstrual Age from Abdominal Circumference Measurements**

Group (Menstrual Age, weeks)	Variability* (weeks)
1 (12–18)	± 1.9
2 (18–24)	± 2.0
3 (24–30)	± 2.2
4 (30–36)	± 3.0
5 (36–42)	± 2.5

* 95% confidence interval.

growth parameters, including the biparietal diameter, head circumference, abdominal circumference, and femur length. Preliminary experience (unpublished data) suggests that this combination of parameters is more accurate in predicting menstrual age than any single parameter, particularly in the third trimester of pregnancy.

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