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Original research article:

Ultrasonographic study of relationship between fetal biparietal diameter and gestational age

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Abstract

Background: Measurements of foetal developmental parameters like bi-parietal diameter, abdominal circumference, head circumference, femur length are important in light of variations in ovulation, menstrual irregularities and practical clinical difficulties like decision making for premature induction of labour. The present study is done to evaluate fetal biparietal diameter as a parameter to predict the fetal gestational age & to develop a regression equation from its measurement.

Material and Method: It is a prospective cross sectional study. A sample size of 404 women from age group 18 to 34 years with singleton uncomplicated pregnancies with sound knowledge about their menstrual dates attending ANC clinic for routine ultrasound fetal biometry was selected for the study. The data collected for fetal biparietal diameter (in cm) was tabulated according to the gestational age from 13 to 42 weeks. Statistical mean and standard deviation of biparietal diameter for each week were calculated. Simple linear regression analysis of the observations was done for estimating gestational age (G.A.) from the measurements of biparietal diameter (BPD) and regression equations were developed separately for 2nd and 3rd trimester. The study establishes the relationship of the biparietal diameter in centimeters, with the advancing gestational age in weeks.

Observations & Results: Interpretation of the data shows that the biparietal diameter gradually increased from 13 weeks to 36 weeks of gestation. Normograms for biparietal diameter can be constructed by the regression equation derived by this study for central india population. These normograms can be used to determine whether a given biparietal diameter is normal or abnormal for a particular gestational age.

Conclusion: The study establishes a linear and direct relationship between the biparietal diameter and the gestational age .The regression equation developed from measurements of biparietal diameter can be an important additional parameter for estimating gestational age along with other parameters.

Key words: Biparietal Diameter, Ultrasonography. Fetal Gestational Age.

Introduction

Measurements of foetal developmental parameter like bi-parietal diameter, abdominal circumference, head circumference, femur length are important in light of variations in ovulation, menstrual irregularities and practical clinical difficulties like decision making for premature induction of labour. Fetal imaging has advanced because of technological advancements in ultrasonography and MRI, with excellent improvements in resolution and image display. Ultrasonographic examination performed with the recommended guidelines of American Institute of

Ultrasound in medicine (2007) offers vital information about fetal anatomy, physiology, growth, maturity and well being.[1] Ultrasound is the name given to high frequency sound waves over 20,000 cycles per second (20 KHz). These ultrasonographic waves are produced from a transducer & travel through human tissues at a velocity of 1500 meter per second. Reflection takes place when ultrasound waves are bounced back to the transducer for image generation.[2]
In the first trimester- the gestational sac & the embryo are the two major structures to be identified. According to Hadlock FP, various parameters used in 2nd & 3rd trimesters are Abdominal circumference (AC), Biparietal diameter (BPD), Head circumference (HC),& Femur Length (FL).[3]
Perfect assessment of gestational age is fundamental in obstetric management & decision making. In particular, uncertain gestational age has been associated with adverse pregnancy outcomes, which includes low birth weight, spontaneous preterm delivery and perinatal death, independent of maternal characteristic. Making appropriate management decisions and delivering optimal obstetric care necessitates the accurate appraisal of gestational age.

Objective

This study was planned to evaluate the relationship between fetal biparietal diameter & gestational age & to develop regression equations from these parameters in second and third trimester ultrasound examinations.

Material and Method

Place of research, duration of study & Source of data: The cross sectional study included 404 pregnant women, who were selected from the antenatal care (ANC) patients attending obstetric & radiology departments for routine fetal obstetric ultrasound at Government Medical College And Hospital in central india region, a tertiary care center. Data collection of this study was carried over the period of January 2010 to November 2011. The draining area of this hospital is urban and rural areas in central India. The study subjects were informed about the nature of study, which was approved by Institutional Ethical Committee. We studied the biparietal diameter by Ultrasonography and assessed the same. The final study was done by defining the inclusion and exclusion criteria, so that the results (regression formula) will represent the ideal formula for healthy subjects representing central India region.

Inclusion & exclusion criteria: The subjects selected were from the age group of 18 to 34 years. All the subjects had sound knowledge about their menstrual dates. Gestational age (synonymous with Menstrual age) was established by reference to the last menstrual period in patients with a history of regular menses and known date of the beginning of the last menstrual period. Subjects who had singleton pregnancy and uncomplicated obstetric history were included. Subjects with maternal disease known to affect normal fetal growth (e.g., chronic hypertension, anemia, diabetes mellitus, hypothyroidism, etc. and history of recurrent miscarriages and of chronic medications etc...) were excluded, as well as subjects with preeclampsia, pregnancy induced hypertension, placenta previa, multiple gestations (e.g., twins), or major fetal abnormalities in the current pregnancy were excluded from the study. None of the patients were at risk for dwarfism by family history.

The Ultrasound system used: The grey scale real time Ultrasonographic examinations were performed using a TOSHIBA JUST VISION 200 Ultrasound System [Figure 1]. All scans were performed using a 3.7 MHz curvilinear transducer.

The Sonographic Technique used for measurement of biparietal diameter:

The subjects were given prior appointment in the morning hours and screened under the guidance of only one experienced radiologist throughout the study. The patients were informed regarding the nature and purpose of the study, and written consent was obtained from the patient in the presence of a impartial witness.

1. Particulars of the subjects selected for the study with special reference to their menstrual and obstetric history, age was recorded in the case record form.
2. Ultrasound screening examination was performed in supine position with a moderately distended urinary bladder. The equipment used was Toshiba just vision 200, 3.7 MHz macro convex probe ultrasonographic machine [Figure 1] routinely used in the obstetric practice. The transducer was placed on the skin surface after applying the sonogel cupling agent for airless contact.
3. The measurements of biparietal diameter (BPD) were made as per the recommendations of the American Institute of Ultrasound in Medicine.[4]

   The biparietal plane : [Figure 2] This is a cross section of the fetal head obtained at the level of the thalami. The cerebellum, orbits and ears should not be visualised in this scanning plane. The falx should be positioned horizontal and equidistant from both parietal bones to avoid acynclitism (head tilted to one side). The operator should look for a symmetrical appearance to both hemispheres. The continuous midline echo representing the falx is broken in the anterior third by the cavum septum pellucidum (CSP). Behind this in the middle of the falx a thin slit representing the third ventricle is often visible. The BPD measurement is obtained from outer skull bone to inner skull bone (leading edge to leading edge), perpendicular to the falx at the maximum diameter.[5] Slight gaps in the echogenic skull bone outline are evident and represent the skull sutures. There should be a normal oval skull shape with no depression of the petrous temporal bones and no angulation near the sutures. The normal bone density of the skull should be more echogenic than the falx. It is measured with a freeze framed electronic calliper technique.
4. The measurements of fetal biparietal diameter collected by above procedure was recorded in a case record form. Gestational age (synonymous with Menstrual age) of the fetus in terms of weeks was calculated from last menstrual period and date of ultrasonography of subject and then recorded in the case record form. The data so collected from 404 patients was then subjected to statistical analysis.
5. **Statistical methods:** The mean values of biparietal diameter(BPD) in cm, along with respective Standard Deviation (SD) were computed for each gestational age from 13 to 42 wks. The correlation and regression analysis has been carried out to quantify the relationship between the gestational age in weeks and biparietal diameter(BPD) in cm. Biomedical research often seeks to establish if there is a relationship between two variables; eg. BPD and GA. The methods used to do this are techniques, which can be of two basic kinds:

Fig. 1: Ultrasound System -Toshiba Just Vision 200

Fig. 2: Ultrasonographic image showing biparietal plane and measurement of biparietal diameter.

Correlation: used to establish and quantify the strength and direction of the relationship between two variables. It can be presented graphically in the form of scatter gram.

Regression: used to express the functional relationship between variables, so that the value of one variable can be predicted from the knowledge of the other. The regression line is actually the same "line of best fit" to the scattergram and regression lines can be represented by respective equations and determination (expresses proportion of variance in Y for variance in X). We can select linear, square, cubic or quadratic regression equations simply with the help of R^2 in the scattergram.

Statistical software: SPSS statistics software was used for the analysis of the data and Microsoft Word, Excel have been used to generate graphs, tables etc.

Result

The data so collected was tabulated (Table 1) according to the Gestational weeks from 13 to 42 weeks. The statistical mean and standard deviation of biparietal diameter for each week was calculated. The weeks of gestation were defined as completed week. For e.g.: 13^{th} week refers to 13.00 to 13.86 weeks of Gestational age. All the observations of the fetal biparietal diameter are in centimeters (cm.)

Table 1:Week wise mean and standard deviations of fetal biparietal diameter in centimeters in present study.

Gestational age in weeks	Number of cases	Mean(cm)	Standard deviation
13	8	2.45	0.43
14	13	2.77	0.42
15	12	3.38	0.24
16	7	3.37	0.40
17	12	3.70	0.14
18	9	4.15	0.23
19	7	4.64	0.26
20	11	4.84	0.23
21	12	5.05	0.39
22	16	5.19	0.60
23	12	5.45	0.62
24	17	5.73	0.35
25	12	6.49	0.36
26	12	6.12	0.53
27	4	7.22	0.34
28	18	6.92	0.32
29	10	7.42	0.32
30	11	7.34	0.49
31	13	7.98	0.23
32	28	7.90	0.44
33	22	8.12	0.60
34	15	8.37	0.55
35	30	8.66	0.37
36	39	8.76	0.49
37	16	8.85	0.28
38	20	9.17	0.43
39	8	9.02	0.28
40	7	8.81	0.77
41	1	8.5	-
42	2	8.75	0.35
Total	404		

Table 2: Correlation co-efficient by karl pearson's correlation method between the gestational age (in wks) and biparietal diameter [in cm] (n=404).

Correlation coefficient (r)	t-value	p- value
0.968	76.044	0.000*

*p<0.05

Relationship between the gestational age and the biparietal diameter: The results of measurements of the biparietal diameter at each week of gestational age from 13- 42 weeks are shown in Table 1. It is observed that the biparietal diameter increased from 2.45 cm at 13 weeks to 9.17 cm at 38 weeks of gestation except in the terminal part of intrauterine life when the curve is almost horizontal due to minimal growth. The biparietal diameter in fetuses of subjects from 13 to 38 weeks of gestation is plotted with gestational age and it is observed that there is a linear relationship between the biparietal diameter and the gestational age in weeks (Figure 3). The mean values of biparietal diameter (in cm) plotted against advancing gestational age from 13 to 38 wks showed a perfect increasing linear trend with increasing gestational age (Figure 4).

It is observed from 95% confidence interval that gestational age can be accurately predicted from the biparietal diameter.

From the results of Table 2 it can be seen that,

1) A significant and positive relationship was observed between gestational age and the biparietal diameter ($r=0.968$, $p<0.05$) at 5% level of significance as shown in Table 2.
2) It means that the gestational age and the biparietal diameter are dependent on each other. The biparietal diameter increases with increasing gestational age (in weeks). The correlation coefficient between the gestational age and the biparietal diameter is 0.968 and t-value is 76.044. Therefore there is a positive correlation observed between the gestational age and the biparietal diameter. This shows that the biparietal diameter is a good predictor of gestational age.

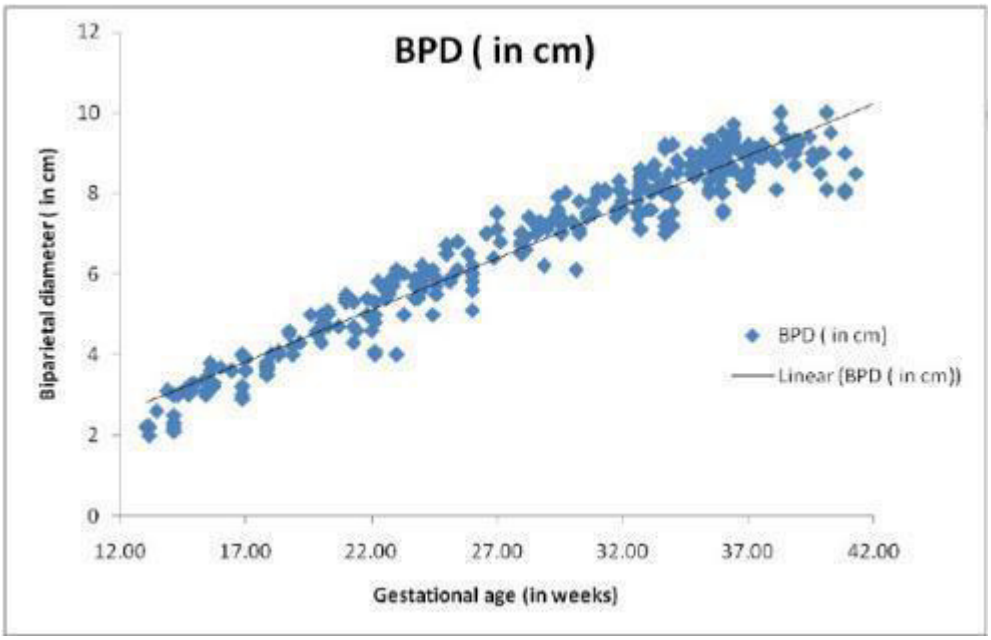

Figure 3: Scatter diagram of biparietal diameter (in cm) with gestational age (in weeks) of all cases.

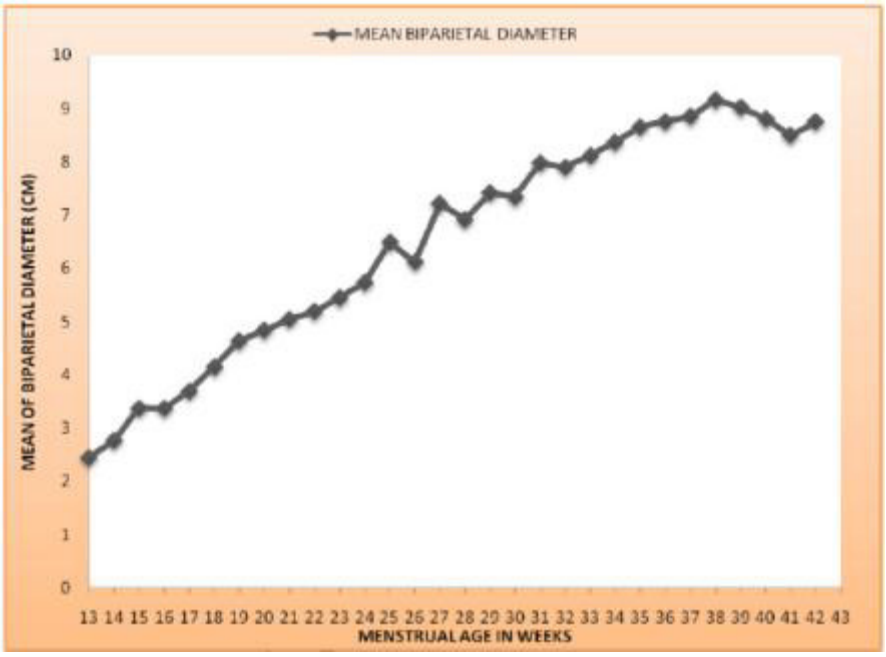

Figure 4: Mean values of biparietal diameter (in cm) plotted against advancing gestational age from 13 to 42 wks.

Regression analysis of relationship between the gestational age and the biparietal diameter: Simple linear regression analysis of the observations was done for predicting the gestational age (fetal maturity) from the measurements of bi parietal diameter, separately for 2nd and 3rd trimester. Here the dependent variable is Gestational Age & independent variable is biparietal diameter. The data show that the biparietal diameter is directly related to gestational age, with simple linear regression model yielding the equation in the form of

$Y = a + b \times X$

where 'Y' is the dependent variable, 'a' is the regression coefficient Constant, b is regression coefficient for independent variable and X is the independent variable itself i.e.

GA= a + b [BPD]

where GA is the gestational age in weeks and BPD is the biparietal diameter in cm.

Regression output for 2nd trimester (13 to 28 weeks)

Constant	6.25
Standard error of Y_{est}	1.33
Correlation square (R^2)	0.91
Number of observations (n)	182
Degree of freedom	180
Regression coefficient of Y on X	3.04

Regression equation for 2nd trimester is:

G.A = 6.25 + 3.04 × BPD

Hence the gestational age can be predicted by the above derived formula.

From the above equation it is clear that during the second trimester, for every 1cm increase in BPD, the gestational age (G.A)\fetal maturity (F.M) increases by 3.04 weeks.

As the value of R^2 is 0.91 the variation in fetal maturity on the basis of biparietal diameter during second trimester can be explained to the extent of 91%. The value of R^2 is highly significant showing that there is statistically positive or strong association between gestational age (fetal maturity) and biparietal diameter in 2nd trimester.

Regression output for 3rd trimester (29 to 42 weeks)

Constant	9.80
Standard error of Y_{est}	2.08
Correlation square (R^2)	0.49
Number of observations (n)	222
Degree of freedom	220
Regression coefficient of Y on X	2.98

Regression equation for 3rd trimester is:

G.A = 9.80 + 2.98 × BPD

From the above equation it is clear that during the third trimester, for every 1cm increase in BPD, the gestational age (G.A)\fetal maturity (F.M) increases by 2.98 weeks. As the value of R^2 is 0.49 the variation in fetal maturity on the basis of biparietal diameter during third trimester can be explained to the extent of 49%.The value of R^2 is moderately significant showing that there is statistically positive or moderate association between gestational age (fetal maturity) and biparietal diameter in third trimester.

Discussion

Utilization of ultrasound has modernized obstetric management. Because of ultrasound we are able to do early confirmation of pregnancy and check viability of developing embryo. Similarly determination of gestational age, early diagnosis of congenital anomalies & growth abnormalities, evaluation of placenta and its abnormalities are some of the uses of ultrasonography in obstetrics. Ultrasound guided procedures like fetal therapy, amniocentesis are now possible in 2nd & 3rd trimester.[6] Latest high resolution imaging equipment has increased diagnostic capability of fetal anatomy allowing measurement of many growth parameters for the estimation of gestational age.[7] The present study has assessed the relationship of ultrasonographically measured biparietal diameter with gestational age and the growth pattern of biparietal diameter with advancing gestational age. The study showed that the biparietal diameter increases steadily with increasing gestational age in a linear fashion. The observations & results of this study are consistent with studies of previous authors.

Moawia Gameraddin et al did a study to estimate the GA from BPD on 100 uncomplicated pregnancies. They applied linear regression analysis to determine the fetal GA. The regression equation for this study data analysed for biparietal diameter was GA= 3.385 + 0.359 BPD.[8]

Hwa Young Choi, Jeong Ha Kim et al estimated a mathematical equation to estimate median values of fetal BPD for each gestational week. To validate these formulae, three different linear equations were derived from previously reported reference values of median BPD, AC and FL using regression analysis at each gestational week. Finally, calculated data through the inferred formula were compared to retrospectively collected data (observed data). The equation revealing the relationship between BPD and GA was: median BPD (cm) =GA (wk)/4.[9]

Mador ES et al did a cross sectional study in which the foetal biparietal diameter (BPD) of 13,740 foetuses were measured with grey ultrasound machine in 13,740 Nigerian women during normal pregnancy and the mean BPD values for each week of pregnancy between 12 and 42 weeks were determined. Results he found shows mean biparietal diameter value 29.4mm at 14 weeks, 49.4mm at 20 weeks, 78.4mm at 30 weeks, 91.5 at 37 weeks and 95.6mm at 40 weeks. There was a positive relationship between gestational age and biparietal diameter with correlation coefficient of $R^2 = 0.999$ ($P < 0.001$). The increase in BPD with increasing age in the study population showed a curve similar to that of Europeans.[10]

Syed SS et al. did study on 300 pregnant women with an aim to find correlation between BPD with GA. Pregnant women with single live uncomplicated pregnancy were selected for the study. Fetal BPD was measured & results were analyzed for accuracy in estimation of GA by BPD and were compared with findings of other workers.

It was observed that BPD was 24.5 mm at 14 weeks GA and 90 mm in the 37 weeks. The fetal BPD increases with increase in gestational age. Graph produced observed that average BPD shows linear growth with increase in gestational age. The correlation coefficient was found to be 0.9940. The regression equation was derived Y= 3.8632 + 0.35 * X where Y is Gestational age, X is BPD. The correlation between GA and BPD was highly significant and also comparable with other studies.[11]Salomon LJ et al prepared new reference equations for fetal BPD, using a large sample (19647) of fetuses examined from 15 to 40 wks gestation. Data was analysed and a cubic polynomial model for biparietal diameter was prepared as follows: BPD = 31.2452 − 2.8466 × GA + 0.2577 × GA2− 0.0037 × GA3(R^2= 95.77); where BPD is in mm and GA is in weeks.[12]

Leung TN in Hong Kong ethnic Chinese population constructed regression equations for fetal biometry involving 709 subjects with singleton uncomplicated pregnancies between 12 to 40 completed weeks of gestation. Biometric parameters measured included BPD, FL, HC, AC. Regression model were fitted to estimate the mean and SD at each Gestational Age. The raw data were fitted to the GA in weeks satisfactorily with a cubic polynomial model. Regression model equation developed for BPD was: GA = 7.996225 + 2.277074 × BPDoi + 0.025200× BPDoi2 + 0.008007 × BPDoi3.[13]

In the present study the simple linear regression equations derived for the calculation of gestational age using the biparietal diameter are

2nd Trimester G.A = 6.25 + 3.04 × BPD

3rd Trimester G.A = 9.80 + 2.98 × BPD

where GA is the gestational age in weeks and BPD is the biparietal diameter in cm.

Regression equations derived separately for second and third trimesters from biparietal diameter can be used for estimating gestational age and fetal growth in women who present late in pregnancy with uncertain or unknown menstrual dates. These equations can also be used for confirmation of gestational age in women with known menstrual dates.

For example: A women presents with signs & symptoms of pre-eclampsia late in third trimester of pregnancy with uncertain menstrual dates, whose BPD after USG comes out to be 8.60 cm. When we put up this BPD (in cm) in equation derived of third trimester in present study the approximate gestational age / fetal growth in weeks comes out to be 35.42 weeks. This will help in the best possible decision making for management of patient.

Graph of biparietal diameter plotted against gestational age shows linear growth curves(Table 3.). Previous studies and authors also had similar observations.[8,9,10,11,12,13]

Limitations of the study: The present study is a cross-sectional study. It is been predicted from observations on different subjects. It is not a actual growth curve of biparietal diamater of a single patient throughout gestation. So, it may not reflect in individual growth patterns. However, it is a good approximation of a actual growth curve of biparietal diameter. The parameter for biparietal diameter may vary among different population groups. Population specific normograms may be derived from large sample sizes.

Conclusion

There is linear and direct relationship between the biparietal diameter and the gestational age. Measurement of biparietal diameter is an important parameter for estimating gestational age along with other parameters. The

biparietal diameter increases with increasing gestational age. Gestational age can be predicted from the regression equation derived by this study for this particular geographical area. This equation can be used to determine whether a given biparietal diameter is normal or abnormal for a particular gestational age. Growth curve of biparietal diameter correlated with gestational age can also help in early diagnosis of IUGR, downs syndrome, macrosomia, skeletal dysplasia etc. in early stages.

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