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Medico-Legal Aspect of Fetal Age Determination from Ultrasound Parameters

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Abstract:
Background: *Fetal Biometry can be used to estimate gestational age. An exact method to find out gestational age is measurement of Crown rump length (CRL) in the first trimester of pregnancy and Bi-parietal diameter (BPD) in second trimester , so gestational age in present study was calculated with respect to Bi-parietal diameter, Femur length and Crown rump length using Hadlock's formulae.*
Material and Methods: *The study was undertaken on 200 human foetuses amongst the women attending antenatal clinic, who came for routine obstetric ultrasonography in MMIMSR, Mullana Distt. Ambala , Haryana and the collected data was analysed at GMC, Amritsar, afterwards.*
Results: *The mean of total age of the sample studied was 26.21 years with standard deviation of ±4.27.. The total mean of parity of the sample studied was 0.64 with standard deviation of ±0.76. Mean gestational age of cases studied was 20.68 weeks with standard deviation±10.84 weeks and range of 5.86 with standard deviation of ± 40.71 weeks. Mean of BPD was 6.03 cm with standard deviation is ±2.58, with range 1.72 cm to 9.79cm. Mean femur length of the cases studied was 4.3cm, with standard deviation ±2.44cm, were within range of 1.10cm to 7.77cm.*
Conclusion: *The advantage of measuring multiple parameters is that the same single ultrasound examination employed for measuring of BPD is sufficient to measure all the multiple parameters without any potential hazards to both mother and foetus, easier to measure, is reliable parameters for estimation of gestational age and can be used easily by anyone. The variability associated with this prediction was found to be comparable to Hadlock's formulae in the gestational period of >5 weeks.*
Keywords: *Ultrasound, Bi-parietal diameter, Crown rump length, Femur length, Gestational age.*

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I. Introduction

Estimation of the fetal age is mainly the first characteristic for the identification and is usually the only available parameter to identify the fetuses and neonates as they do not have other type of identification along with them.[1–3] According to MTP Act1971, pregnancy can be terminated by a single registered medical practitioner (RMP) when duration of pregnancy is within 12 weeks, whereas opinion from two RMPs is essential if the duration of pregnancy exceeds 12 weeks but is less than 20 weeks.Any abortion beyond 20 weeks,except in case of emergency has been deemed illegal or criminal even if performed by Registered Medical Practitioner. In a country like India, wherein most of the women are unaware of their date of Last Menstrual Period (LMP), it becomes imperative to calculate the gestational age of the foetus before proceeding to carry out medical abortion and treatment.Assesmentof Foetal age is very much significant in the courts both in criminal abortion and infanticide cases.[4]

Study of measurements of different body parts of the fetus is known as Fetal Biometry, and the age estimation of a foetus can be determined by applying different formulae, after collection of data from radiographs and ultrasonography (USG).[5-6]

An exact method to find out gestational age in the First trimester of pregnancy is the measurement of Crown-rump length (CRL), where Bi-parietal diameter (BPD) is a useful method after the first trimester. Biparietal diameter is mentioned as a dependable method of calculating the age of gestation.[7,8] Up to 20weeks of gestation, an increase in BPD is uniform, which becomes highly variable after 20 weeks, which makes it difficult to estimate gestational age. Sometimes the fetal position makes it difficult to measure the BPD. Hence

sole dependence on Bi-parietal diameter becomes relatively unreliable. Therefore averaging the estimates of age based on measurements of diaphyseal lengths of femur and humerus can be used as an alternative in pregnancy dating. These additional measurements provide a more 'universal view' of the fetal development than can be afforded by any single measurement. Furthermore, the advantage of this method of measuring multiple parameters is that the same single ultrasound examination employed for BPD measurement is sufficient to measure all the multiple parameters, without any potential hazard to both mother and the fetus.

Knowledge of the exact date of LMP is useful in correlating length of the femur, biparietal diameter, and crown rump length with gestational age. The expected date of delivery (EDD) can also be calculated by using these charts or graphs to obtain gestation age from the biparietal diameter calculated during the ultrasound in antenatal cases where the last menstrual period (LMP) is unknown. Further, the exact idea about the gestational age is a paramount inability of an obstetrician to successfully manage the antepartum care of a patient and is of critical importance in tests done in the antenatal period as well as the successful planning of appropriate therapy or intervention. Failure to do so can lead to iatrogenic prematurity, which is known to be associated with increased perinatal morbidity and mortality.

As in forensic settings, the commonly used formula for determination of gestational age of the fetus is calculated from the crown heel length, commonly described as the Hasse' Rule, which determines the gestational age in months, that too in lunar months. The formulae derived herein from a crown-rump length, femur length and biparietal diameter can provide a better estimate than single parameter of crown heel length, that too with a better range and error estimate in weeks. The only disadvantage of this method is that sometimes during age determination the body of fetus is decomposed or mutilated and then there are no routine features available which can help in determination of age as sometimes only the bones are available.[9,10] Biparietal diameter was the first fetal parameter utilized for determining the age of the fetal in the 2nd trimester, many present authors have studied the significance of biometric parameters including abdominal circumference (AC)[11], foot length[12], head circumference (HC)[13], ear size[14], femur length (FL)[15], orbital diameters[16,17,18] cerebellar diameter[19,20] and other various parameters used by doctors.

The demonstration by other investigators, that the use of a combination of parameters provides better results than a single parameter in estimating gestational age.[5,21,22,23,24,25.]According to Hadlock's formulae using the same parameters, fetal age was determined with respect to these parameters[21] .

II. Material & Method

The study was done under the routine obstetric ultrasound examination without using any additional investigations or interventions. Informed written consent of the mother was taken. Results were entered in a pre-designed proforma. Real time **Philips** sonographic equipment was used in this study. Routine transabdominal ultrasonography was done to measure Crown Rump Length (CRL), Biparietal Diameter (BPD) and Femur Length (FL). The inclusive criteria was foetuses of gestational age 5 weeks or more were considered. Exclusive criteria was foetuses with obvious congenital anomalies (spina bifida, anencephalus etc.), skeletal deformities and the cases of known maternal disease (DM, PTH deficiency etc.), multiple pregnancies, known cases of intra-uterine growth retardation and the cases where LMP was not known, were excluded. Pearson's correlation coefficient was used to calculate the significance of correlation between various fetal biometric parameters and gestational age. These parameters were also used to derive linear regression models for estimation of gestational age. Moreover, stepwise polynomial regression models were constructed including linear and quadratic terms of the biometric parameters measured along with the cross products of the linear terms. The linear and quadratic models were found to be appropriate because inclusion of cubic terms and cross products did not improve the predictability of regression. Comparisons were then made between the accuracy of the derived models in estimation of gestational age to establish the best model to date pregnancy between 5 to 45 weeks.The data obtained was used to generate regression equations for the local ethinic population of Haryana Region.

III. Aims and Objectives

The Aim of this study was not to evaluate specific formulae but instead to compare the accuracy of several sonographic measurements for gestational age prediction, by using the current objective standard Hadlock's formulae to establish gestational age, against estimated fetal age.

IV. Observations and Results

4.1 Distribution of cases according to maternal age groups and its relation to maternal age and parity

Table no. 1

Maternal age groups (years)	Cases		Maternal age (years)		Parity	
	N	%	Mean±SD	Range	Mean±SD	Range
18-27	134	67.0	23.87 ±2.30	18-27	0.49 ±0.65	3
28-37	65	32.5	30.75 ±2.77	28-37	0.89 ±.87	4
38-47	1	0.5	45	38-47	3	-
Total	200	100.0	26.21 ±4.27	18-45	0.64 ±.76	0-4

Table No. 1 – Showing distribution of cases according to maternal age groups and its relation to maternal age and parity

First trimester cases constituted (n=47) 23.5% out of the total 200 pregnancy cases, followed by (n=91) 45.5% in the second trimester and (n=62) 31% in the third trimester of pregnancy. The maximum 134 (67%) number of cases in the present study were between 18 to 27 years of age followed by 65 (32.5%) in age group between 28-37 years, further followed by only 1 case (0.5%) in age group between 38- 47 years. The mean of total age of the sample studied was 26.21 years with standard deviation of ±4.27. The patient with maximum age was 45 years old and minimum was of 18 years. In the above table, it is found that between ages of 18 to 27 years, range of parity varies upto 3, between ages 28-37 years, it was upto 4. The total mean of parity of the sample studied was 0.64 with standard deviation of ±0.76.

4.2 Distribution of cases according to gestational age (range in weeks)

Table 2

Gestational age groups (weeks)	Cases		Gestational age (weeks)	
	N	%	Mean ± SD	Range
1-12	47	23.5	9.2±1.67	5.86-12
12-27	91	45.5	16.46±3.76	12.14-27
>27	62	31	35.56±2.67	30-40.71
Total	200	100	20.68±10.84	5.86±40.71

Table No. 2 – Showing Distribution of cases according to gestational age (range in weeks).

The above table shows the cases studied according to gestational age in weeks. Most of the cases 91 (45.5%) undergoing ultrasound examination were in the gestational age group of 12-27 weeks, followed by 62 cases (31%) in >27 weeks. Minimum 47 cases (23.5%) were in the group of gestational age of 1-12 weeks. Mean gestational age of cases studied was 20.68 weeks with standard deviation ±10.84 weeks and range of 5.86 with standard deviation of ± 40.71 weeks.

It is also found in the above table that in the gestational age group of 1-12 weeks mean of gestational age was 9.2 with standard deviation of ±1.67. In the group of 12-27 weeks mean of gestational age was 16.46 with standard deviation of ±3.76. In the group of >27 weeks mean was 35.56 with standard deviation of ±2.67.

4.3 -Distribution of cases in relation to Crown Rump length (CRL) according to range of CRL (in centimeters)

Table 3

CRL (cm)	Cases		Gestational age (weeks)		CRL (cm)	
	N	%	Mean±SD	Range	Mean±SD	Range
0-3	36	40.0	8.75±1.66	5.86-12.43	1.63±0.68	0.33-3
3-6	29	32.2	12.17±1.30	9.86-14.14	4.76±0.83	3.20-5.90
6-9	25	27.8	13.57±0.91	12.14-14.86	6.52±0.44	1.10-8.10
Total	90	100.0	20.68±10.84	5.86-14.86	4±2.16	0.33-8.10

Table No. 3 - Showing Distribution of cases in relation to Crown Rump length (CRL) according to range of CRL in cms.

The above table shows that maximum number of 36 cases (40%) had Crown Rump length in the range of 0-3cm, followed by 29 (32.2%) cases in the range of 3- 6 cm which was followed by 25 (27.8%) cases in range of 6-9cm. The mean of CRL was 4cm with SD of ±2.16cm; with range 0.33 to 8.10.

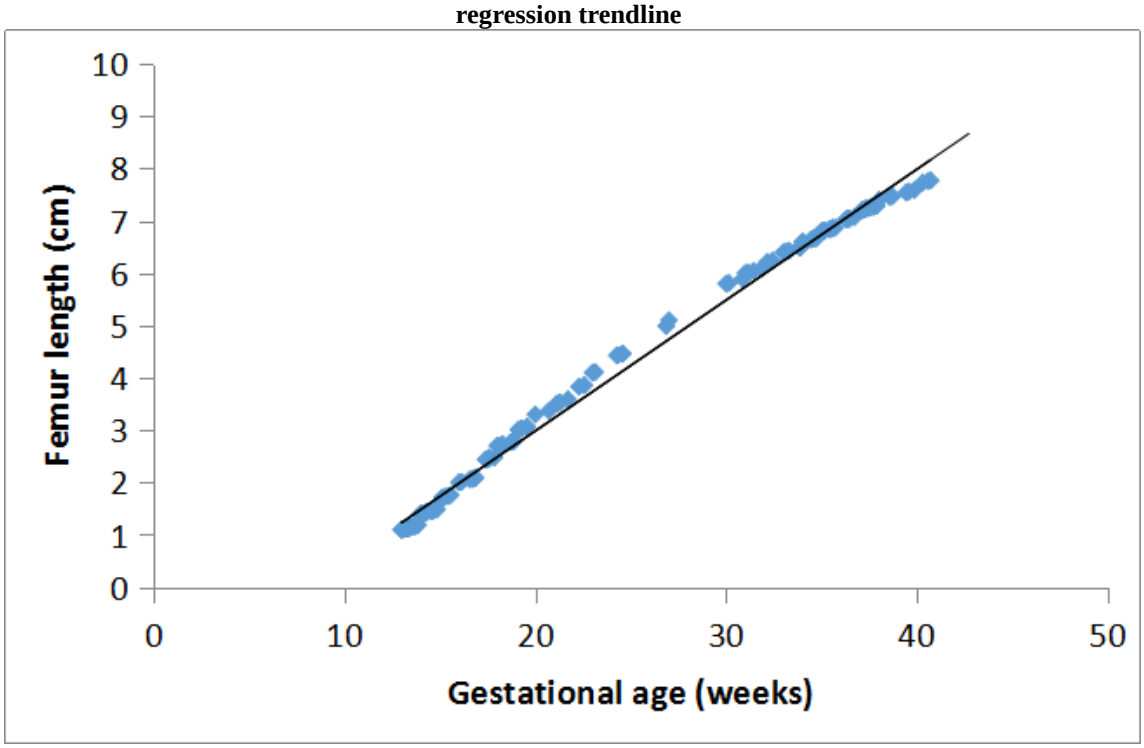
4.4 - Distribution of cases in relation to biparietal diameter (BPD) according to range of BPD in centimetres.

BPD (cm)	Cases		Gestational age (weeks)		BPD (cm)	
	N	%	Mean±SD	Range	Mean±SD	Range
1-5	54	42.52	16.52±2.62	8.29-22.57	3.25±8.75	1.72-4.95
5-10	73	57.48	33.80±4.92	21.14-40.71	8.09±1.02	5.10-9.79
Total	127	100	29.00±7.83	8.29-40.71	6.03±2.58	1.72-9.79

Table No. 4 - Showing Distribution of cases in relation to biparietal diameter (BPD) according to range of BPD in cms.

The above table shows the cases according to bi-parietal diameter in centimetres. The maximum number of 73 cases (57.48%) with mean gestational age of 33.80±4.92 were reported in range of 5.10 to 9.79 cm of biparietal diameter, followed by BPD of 1.72-4.95cm in 54 cases (42.52%). Mean of BPD was 6.03 cm with standard deviation is ±2.58, with range 1.72 cm to 9.79cm.

Chart 1: Scatter diagram showing plot of femur length (cm) in relation to gestational age (weeks) with the regression trendline



4.5 Distribution of cases in relation to Femur length (FL) according to range of Femur length in centimeters.

Table no 5

FL (cm) Groups	Cases		Gestational age (weeks)		FL (cm)	
	N	%	Mean±SD	Range	Mean±SD	Range
0-2.5	50	35.97	14.89±1.54	13-17.86	1.6±0.47	1.10-2.48
2.5-5.0	27	19.43	20.96±2.45	18-26.86	3.46±0.68	2.70-4.99
>5.0	62	44.60	35.46±2.88	27-40.71	6.84±0.56	5.10-7.77
Total	139	100	20.68±10.84	13-40.71	4.3±2.44	1.10-7.77

Table No. 5 – Showing Distribution of cases in relation to Femur length (FL) according to range of Femur length in cms.

The above table shows that total of 139 cases were studied for femur length in centimeters by ultrasound examination. Maximum 62 cases (44.60%) had femur length in the range of 5.10-7.77 cm , followed by 50 cases (35.97%) having femur length in the range of 1.10-2.48cm, followed by 27 cases (19.42%) having femur length of 2.70-4.99 cm. Mean femur length of the cases studied was 4.3cm, with standard deviation ±2.44 cm, were within range of 1.10cm to 7.77cm.

V. Discussion

For all the formulae, variability in the current study was about 2 weeks. In Hadlock's as well as in current study, establishment of true GA (against which the regression equations were analyzed for variability) was on the basis of history of regular menses and known date of LMP (in agreement with the first trimester clinical findings). From the study sample, women attending the antenatal clinic during the study period were between the age group of 18 - 47 years that represent the reproductive age, whereby a majority 67% were in the age group of 18 - 27 years. According to the results, majority of women 45.5% were in second trimester. Their mean gestation age by LMP was 16.46±3.76 weeks. Mean gestation age of crown-rump length, femur length and biparietal diameter were same as 20.68±10.84 weeks.

Beyond 13 weeks, measurement of fetal biparietal (BPD) was used in conjunction with the femur length (FL) to assess an interval fetal growth.

A simple linear correlation was performed to determine if there is a considerable relationship between femur lengths estimated, gestational age and mother's estimated age from LMP. Correlation coefficient for this variable was relatively high compared to individual tested variables, lying within 95% confidence interval. This may be due to linear growth of femur from second trimester throughout the pregnancy and proper measurement of the diaphysis (p value of less than 0.001). This was supported by a study on length of femur in fetus as a predictor of menstrual age sonographically, whereby variability associated with predicting menstrual age from femur length (FL) was ±14.89 days from 13 to 41 weeks of gestational age.

The crown rump length (CRL) showed stronger correlation. The results therefore show convincing evidence to reject the null hypothesis. Its measurement technique contributes in error reduction that reduces inaccuracy in case of head variation. Analysis of the data demonstrated that the crown rump length growth curve is non-linear, similar to biparietal diameter growth curve.

The biparietal diameter (BPD) was independent parameter to last normal menstrual period showed correlation coefficient r = 0.96. The correlation was relatively low compared to the correlation value obtained by other tested variables, femur length. This may be due to non-linear growth of fetal head, error occurred while taking the measurement as obliquely oriented fetal head changes to an occiput transverse position with only minimal pressure with the real time transducer is frequently sufficient to do so. Slightly excess pressure may lead to inaccuracy. The results suggested that the biparietal diameter and femur length are equal estimator of gestation age in late pregnancy. **Campbell S et al (1977)** and **Sabbagha RE et al (1978)** Studies have also shown that biparietal diameter can predict gestational age within ±5days, in the 1st trimester of pregnancy. In the second trimester of pregnancy, gestational age estimated by biparietal diameter measurement is accurate to within ±1 - 1.5 weeks (±2 SD), but in the third trimester the reported accuracy is less; biparietal diameter obtained after 28 weeks is accurate only within ±3 weeks (±2 SD).[26,27]

All fetal biometric parameters discussed above correlate closely with gestational age estimated from last normal menstrual period. A composite assessment of gestation age using all parameters (FL, CRL, BPD) gives a lower systemic random error than any single parameter. Calculated gestation age from the average of the three parameters done by ultrasound showed relatively strongest correlation compared to the correlation from individual parameter r = 0.99, 95%CI (1.381). Combining two or more variables maintained the closest correlation with gestation age estimated by LMP. **Beazley JM et al (1970)** observed that a significant proportion of pregnant women are uncertain of dates of their last menstrual period (LMP) and it is widely recognized that estimation of gestational age (GA) based on menstrual dating, and/or physical examination, is fraught with errors.[28] This is supported by the study done by Hadlock et al[21] on estimation of fetal age.

In India variations in fetal weight as studied by **Kinare AS et al (2010)**, found that the size of the fetus was small in Indian rural population as compared to Indian urban populations and European in the mid pregnancy. The variation was seen for various fetal dimensions; it was found higher for BPD and AC and lower for HC and FL.[29]

In a study conducted by **Lalitha B et al (2016)** on 1000 normal third trimester pregnant women belonging to South Indian population, used head circumference, abdominal circumference, biparietal diameter and femur length in fetuses ranging from 31 to 40 weeks of the age of gestation; reported a significant positive correlation between the gestational age and all the parameters.[30]

In an other study by **Mongelli M et al (2005)** Obstetricians from Singapore concluded that USG estimation of age of gestational in late pregnancy is better than stated by previous publications. The unexpected finding that FL was a good indicator of the age of gestational compared to HC was due to differences in measurements of head in the population that was ethnically mixed, or due to poor imaging of the head of fetus after it is engaged in late pregnancy.[31] In a study by **Campbell S et al (1985)** conducted on 4527 pregnant women at London, showed that dimensions of the biparietal taken between 12 and 18 weeks of gestation were more correct in predictions of gestational age than those depend on the history of menstrual ($p<0.001$).[32] In the present study significant positive correlation was found between fetal age and FL ($r=0.997$, $p<0.001$). Statistical analysis revealed FL to be a reliable parameter for assessment of GA (linear regression, $R^2=0.995$, Standard error of estimate = 0.72). Its accuracy in predicting GA was found to be better than the established standard sonographic parameters i.e. BPD ($r=0.96$, $R^2=0.939$, SEE=2.35) and CRL ($r=0.667$, $R^2=0.663$, SEE=0.271) was consistent with the study of **Benson CB et al (2008) according to which** Femur length is a better method to find out foetal age.[33] **Smazal SF et al (1983)** have observed that CRL was more specific and accurate than Growth- focused sonographic age, but less accurate than a single BPD received between 20 and 24 weeks or reliable maternal dates.[34] Biparietal diameter (BPD) found between 20 and 24 weeks of gestation, with growth adjusted sonographic age, and with close maternal dates.

According to another study by **Malhotra N et al (2014)** measurement of femur length (FL) is as accurate as the bi-parietal diameter (BPD) in prediction of gestational age. It is useful in confirming the gestational age estimated from BPD measurements and can be obtained when foetal position prevents the measurement of BPD.[35]

According to **Campbell S et al (1977)** and **Sabbagha RE et al (1978)** their studies have shown that biparietal diameter can predict gestational age within ±5days, in the 1st trimester of pregnancy. In the second trimester of pregnancy, gestational age estimated by biparietal diameter measurement is accurate to within ±1 - 1.5 weeks (±2 SD), but in the third trimester the reported accuracy is less; biparietal diameter obtained after 28 weeks is accurate only within ±3 weeks (±2 SD).[26.27]

Similarly according to **Hadlock FP et al (1983)** the combination of multiple parameters for gestational age assessment have found a significant increase in their accuracy of predicting fetal age. The best combination of parameters is the BPD, AC, and FL before 36 weeks gestation. However, the HC, AC, and FL are the best parameters with significant drop in the standard deviation, mean errors and size of maximum error after 36 weeks.[21] Further a study in 1984 has also shown that if the age of gestation measured from BPD, FL, HC and AC dimensions were averaged to obtain a gestational age mean, the reliability and accuracy of gestational age assessment improves as compared with use of any single measurement for fetal age estimation.[22]

According to **Warda AH et al and Shalev E et al (1985)** also established correlation between gestational age and femur length have found that it is a reliable growth and dating parameter,[36,37] which is consistent with the present study.

According to a study by **Kinare AS, et al** conducted in Pune, India to explain size of the fetus in Indian rural population and analysed it with Indian Urban populations and European with the help of USG; size of the fetus is small in Indian rural population as compared to Indian Urban populations and European in mid pregnancy. The variation was seen for various fetal dimensions; it was found higher for biparietal diameter and abdominal circumference and lower for head circumference and femur length.[29]

Out of the three standard sonographic parameters (BPD, FL and CRL) for GA estimation, FL was found to be the single best predictor of fetal age. This finding is in agreement with findings of Hadlock et al[23], Chervenak et al[5], and Benson and Doubilet[33], who compared the performance of these parameters using different dating models for establishing true GA and using different study designs. The present study also revealed that combination of BPD, FL and CRL gives a better prediction of gestational age than the use of any individual parameter, a finding that has been confirmed by Hadlock et al[23] earlier, though with a lesser reliability as compared to the present study. Variability in estimation using a combination of all parameters was ±2 weeks according to the present study as well as, per Hadlock et al.[24]

In the present study significant positive correlation was found between fetal age and FL ($r=0.997$, $p<0.001$). Statistical analysis revealed FL to be a reliable parameter for assessment of GA (linear regression, $R^2=0.995$, Standard error of estimate = 0.72). Its accuracy in predicting GA was found to be better than the established standard sonographic parameters i.e. BPD ($r=0.96$, $R^2=0.939$, SEE=2.35) and CRL ($r=0.667$, $R^2=0.663$, SEE=0.271). The establishment of true GA on the basis of an initial first trimester sonogram using CRL measurements has been **proven to be a highly reliable "gold standard" predictor of GA more importantly in the present context.** [37]

Present study also revealed that there was improvement in accuracy of determining GA when all

parameters were used together. Combination of CRL, BPD and FL gave the best linear regression equation for estimating GA (by stepwise regression analysis). Combination of CRL, BPD and FL gave the best polynomial regression equation. This was even better than the linear regression formula. This can be because all the three parameters involve different parts, sides and axis of the body.

All fetal biometric parameters discussed above correlate closely with gestational age estimated from last normal menstrual period. A composite assessment of gestation age using all parameters (FL, CRL, BPD) gives a lower systemic random error than any single parameter. Calculated gestation age from the average of the three parameters done by ultrasound showed relative strongest correlation compared to the correlation from individual parameter r = 0.99, 95%CI (1.381). Combining two or more variable maintain the closest correlation with gestation age estimated by LMP. This is supported by the study done by Hadlock et al[23] on estimation of fetal age. A number of combinations of parameters including combination of biparietal diameter and femur length provided age estimate that were significantly better than those using single parameter alone.

The analysis used (correlation) does not show how best the biometric methods can predict the gestation age. From the study, values of gestation age calculated from last menstrual period showed strong positive linear correlation with the gestation age values obtained by the use of ultrasound fetal biometry. Based on literatures, experience and the observed results these two methods seem to agree with one another in estimation of gestation age.

VI. Conclusion

The present study has revealed that combination of BPD, FL and CRL gives a better prediction of gestational age than the use of any individual parameter, a finding that had been confirmed by **Hadlock et al[22] earlier,** though with a lesser reliability as compared to the present study. Variability in estimation using a combination of all parameters was ±2 weeks according to the present study as well as, per **Hadlock et al.[23]** Present study has also revealed that there was improvement in accuracy of determining GA when all parameters were used together

In the present study significant positive correlation was found between fetal age and FL (r=0.997, $p<0.001$). Statistical analysis revealed FL to be a reliable parameter for assessment of GA (linear regression, R^2=0.995, Standard error of estimate = 0.72). Its accuracy in predicting GA was found to be better than the established standard sonographic parameters i.e. BPD (r=0.96, R^2=0.939, SEE=2.35) and CRL (r=0.667, R^2=0.663, SEE=0.271).

A number of combinations of parameters including combination of biparietal diameter and femur length provided age estimate that were significantly better than those using single parameter alone.

In forensic settings, the formulae derived herein from crown rump length, femur length and biparietal diameter can provide a better estimate than the crown heel length (Haase Rule), that too with a better range and error estimate in weeks.

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