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# ULTRASOUND MEASUREMENTS OF FETAL KIDNEY LENGHT IN NORMAL PREGNANCY AND ITS CORRELATION WITH GESTATIONAL

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**Abstract**

An accurate gestational age (GA) is essential for the diagnosis of fetal growth and for planning the exact labour date which provides a better maternity care. Compared with the traditional methods of dating pregnancy using LMP and other clinical measurements, ultrasonographic dating has been recognized as the most accurate method of assessing GA. Any inaccuracy in estimation of GA lead to perinatal morbidity and mortality due to iatrogenic pre or post maturity.

This study aimed to evaluate the accurate GA and precise scheduling of EDD by measuring FKL parameters using USG guided electronic calibration. This prospective study was carried out in 63 women with single uncomplicated pregnancy over a period of 1 year in Arogya Madha Hospital-Gengavalli, after getting an informed consent. Fetal Kidney Length (FKL) and BPD, FL, HC and AC were measured between 24th-28th week of gestation by using USG (Linear array Transducer). All the parameters were measured by using Electronic calipers, repeated twice and the mean values were calculated to reduce experimental variation. A t-test performed for comparing right and left kidney and it revealed that there is no difference in the length between rightt and left Kidneys. Paired Two Sample for Means P(T<=t) two-tail 0.21813301. In the present study, the FKL correlated with the GA with a correlation coefficient of 0.17157906 and a determination coefficient of 0.822 which was better than all the conventional parameters used. The study shows good correlation between gestational age derived from FKL and gestational age from established biometric indices like BPD, HC, AC, and FL.

***Keywords:*** gestational age, kidney length, ultrasonography

## Introduction

Truthful knowledge of gestational age (GA) is significant for well antenatal care, planning, and positive management of all pregnancies. In high-risk pregnancies like preeclampsia, intrauterine growth retardation, gestational diabetes mellitus, and termination of pregnancy is planned considering the GA. Failure in correct estimation of GA can result in iatrogenic prematurity or post maturity, both of which are related with increased perinatal mortality and morbidity.

Number of parameters have been in use to calculate GA. Depending on the trimester of pregnancy, first date of last menstrual period (LMP), gestational sac diameter and volume, crown–rump length (CRL) measurements, biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are the traditional indices measured by ultrasonography to calculate GA. [1-9]. But there exists limited value for first trimester parameters like LMP and CRL. And also there happens increasing unreliability in using the other third trimester fetal biometric indices like BPD, HC, AC, and FL in GA estimation [10-13].

The quest of finding an correct sonographic predictor of GA during late pregnancy beyond second trimester resulted in many studies which found fetal kidney length (FKL) as a potential index.[12-20] Studies have also noted a linear increase in FKL with increase in GA. .[21-31]. The growth of fetal kidney was shown to be 1.07 to 1.1 mm by a couple of studies. [32,33]. The fetal kidneys were claimed to have a constant increase in length of 1.7 mm fortnightly[34 ]. This constant growth pattern of fetal kidneys remains unaltered by fetal growth disorders and so this parameter stands as a more reliable index for calculating GA even for complicated pregnancy [11,17]. Limited Indian studies validating FKL and GA prompted this study. This study also compared the accuracy of FKL with other third trimester indices which are being used traditionally for GA estimation in late pregnancy.

Fetus Biometrics by the ultrasound

Ultrasound waves consist of a mechanical disturbance of a mediumr. The disturbance passes through the medium at a fixed speed causing vibration. The rate at which the particles vibrate is the frequency, measured in cycles per second or hertz (Hz). Sound becomes inaudible to the human ear above about 20 KHz and is then known as ultrasound. Most medical diagnostic application of ultrasound employs frequencies from 2-20 MHz. [35]. Diagnostic imaging uses much higher frequencies, in the order of megahertz. The higher the frequency used, the better the resolution.

**Fetal Biometry - Biparietal Diameter (BPD)**

It is the maximum distance between two parietal bones at the level of cavum septum pellucidum. This parameter is used in the second and third trimester, from 12th week onwards. It measures the maximum distance between the two parietal bones taken from the leading edge of the skull to the lagging edge i.e. outer to inner. It can also be measured from outer to outer table of the skull. Studies report that growth of the skull in the mid trimester is linear and rapid and biological variation at each week of gestation is small. The measurement of BPD from 14-26 weeks predicts the correct duration of gestation to the extent of ± 9 days in 95% of cases. However, the measurement of BPD in second trimester routine scan is performed in all good antenatal centers. At times when the fetal head may be short and wide (brachycephaly) or long and flattened (dolichocephaly), the assessment of age from BPD will be under or over estimated. Therefore, if the shape of head appears brachicephalic or dolichocephalic, the cephalic index is calculated, and if found to be outside the normal range the head circumference should not be used to estimate age.

**Head Circumference (HC)**

This parameter is used in the third trimester along with other parameters such as FL. It is measured at the same level at which BPD is taken by using the ellipsoid mode of the machine and adjusting the ellipsoid calipers to the outer margin of the skull table. The accuracy of this parameter is ±2-3 days with 95% confidence interval.

**Abdominal circumference (AC)**

This ultrasonic fetal biometric parameter is less used for assessment of GA. adjusting the ellipsoid calipers to the outer margin of the skull table. The accuracy of this parameter is ±2-3 days with 95% confidence interval.

**Kidney Length**

Measurement of Kidney length can be done reliably beyond 18 weeks of gestation, both by transabdominal and transvaginal ultrasound [36, 37, 38]. In a transverse section through the fetal abdomen the kidneys can be visualized as two circular structures on either side of the fetal spine. In the longitudinal section, they appear as two oval structures in a typical paraspinal location. The fetal kidney appears ultrasonically as a sonoluscent halo of tissue surrounding the somewhat more echo pyelocalyceal sinus [39].

**Fetal Kidney**

During the 1st trimester, the kidney appears as hyperechoic oval structures at both sides of the spine (their hyper-echogenicity can be compared to that of spleen) [40]. This echogenicity progressively decreases. During the second and third trimesters, kidneys are easily identified by imaging the dorso-lumbar spine and scanning on either side in parasagittal and transverse axial sections [41].

**Methods**

An observational prospective study was conducted on pregnant ladies in the third trimester in the General, Obstetrics and Gynaecology Hospital Gengavally, Salem, tamilnadu, India from September 2019 to january 2020. Research was started after obtaining clearance by the Institutional Ethical Committee. Sample size was 63 pregnant women with typical single pregnancies whose gestational age were confirmed by LMP and early ultrasound (<13weeks). All relevant clinical history was obtained. Ultrasound scan was performed using GE logic V5 using a 3- 5 MHz convex transducer. In all the patients following parameters were obtained including BPD, HC, AC, FL and FKL. Fetal kidneys were recognized by moving transducer descending from fetal AC estimation level and each fetal kidney length was acquired by pivoting test in the sagittal plane, until full length of each fetal kidney with renal pelvis was pictured. Maximum length of each fetal kidney was measured from upper pole of kidney to lower pole.

All healthy women with uncomplicated singleton pregnancies from 24 to 32 weeks having less than 1-week discrepancy between LMP and CRL were recruited. Pregnancies with less than 24 weeks of

GA, Oligohydramnios, Polyhydramnios, dilated renal pelvis>4mm, renal abnormalities, Diabetic mother, Pregnancy induced hypertension; Pre-eclampsia, Multiple gestations, and Fetal chromosomal abnormalities were excluded from study.
Data were tabulated and all the statistical analyses were done using SPSS software. Pearson's correlation coefficient, linear Regression was calculated for each parameter and 95% Confidence interval was obtained from that. All the averages were presented as mean±standard deviation.

**Results**

All the patients were aged between 18 and 39 years, nearly 52% of all patients were nulliparous, while 48% were the mothers of one child. If consider the weight of the patients, average weight of the patients was 61.23 kg. All the patients were more or less evenly distributed among different GA. All patients were between 27 and 30 weeks of gestation.
With these demographic data, we started measuring the parameters and correlated them one by one with the GA calculated using LMP.

**Regression – BIPARIETAL DIAMETER vs. GA**

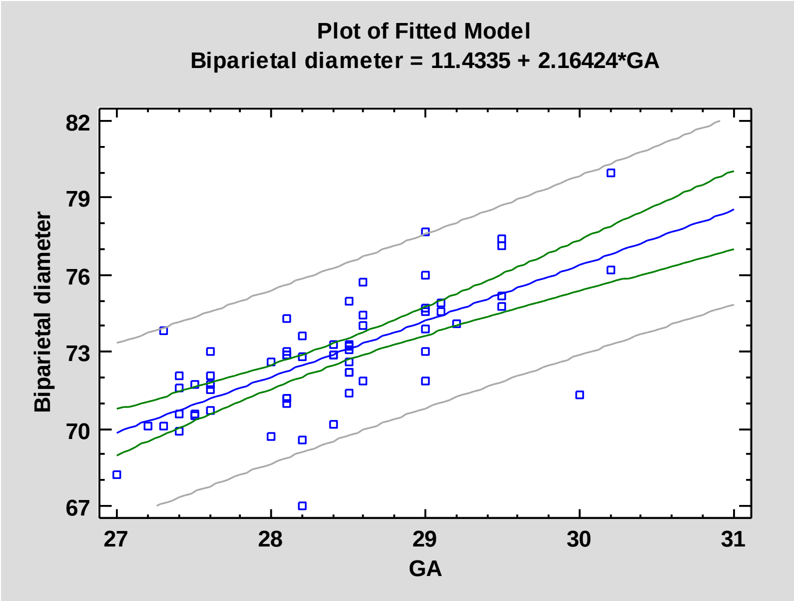
**Coefficients**

| | *Least Squares* | *Standard* | *T* | |
|---|---|---|---|---|
| *Parameter* | *Estimate* | *Error* | *Statistic* | *P-Value* |
| Intercept | 11.4335 | 8.00428 | 1.42843 | 0.1583 |
| Slope | 2.16424 | 0.281901 | 7.6773 | 0.0000 |

**Analysis of Variance**

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| Model | 164.706 | 1 | 164.706 | 58.94 | 0.0000 |
| Residual | 170.46 | 61 | 2.79443 | | |
| Total (Corr.) | 335.166 | 62 | | | |

Correlation Coefficient = 0.701011
R-squared = 49.1416 percent
R-squared (adjusted for d.f.) = 48.3079 percent
Standard Error of Est. = 1.67165
Mean absolute error = 1.18276
Durbin-Watson statistic = 1.60455 (P=0.0540)
Lag 1 residual autocorrelation = 0.191075
The output shows the results of fitting a linear model to describe the relationship between Biparietal diameter and GA. The equation of the fitted model is
Biparietal diameter = 11.4335 + 2.16424*GA
The P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between Biparietal diameter and GA at the 95.0% confidence level. The R-Squared statistic indicates that the model as fitted explains 49.1416% of the variability in Biparietal diameter. The correlation coefficient equals 0.701011, indicating a moderately strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 1.67165. The mean absolute error (MAE) of 1.18276 is the average value of the residuals.




**Regression - ABDOMINAL CIRCUMFERENCE vs. GA**

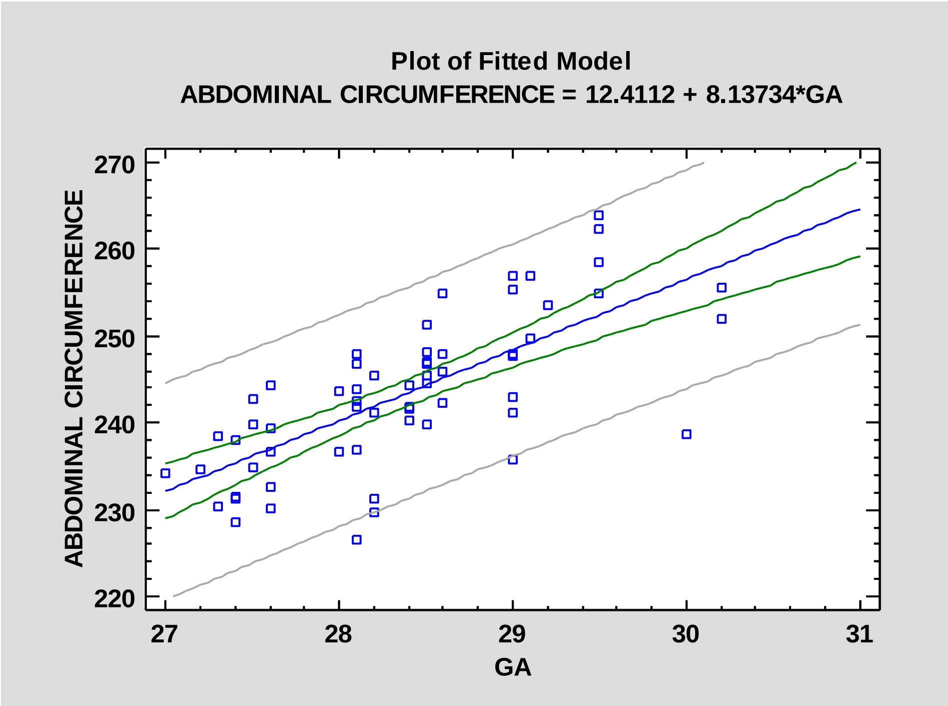
**Coefficients**

| | *Least Squares* | *Standard* | *T* | |
|---|---|---|---|---|
| *Parameter* | *Estimate* | *Error* | *Statistic* | *P-Value* |
| Intercept | 12.4112 | 28.9212 | 0.429138 | 0.6693 |
| Slope | 8.13734 | 1.01857 | 7.989 | 0.0000 |

**Analysis of Variance**

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| Model | 2328.44 | 1 | 2328.44 | 63.82 | 0.0000 |
| Residual | 2225.41 | 61 | 36.4821 | | |
| Total (Corr.) | 4553.85 | 62 | | | |

Correlation Coefficient = 0.715061
R-squared = 51.1312 percent
R-squared (adjusted for d.f.) = 50.3301 percent
Standard Error of Est. = 6.04005
Mean absolute error = 4.60766
Durbin-Watson statistic = 1.59047 (P=0.0479)
Lag 1 residual autocorrelation = 0.165186
The output shows the results of fitting a linear model to describe the relationship between ABDOMINAL CIRCUMFERENCE and GA. The equation of the fitted model is
Abdominal circumference = 12.4112 + 8.13734*GA
The P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between ABDOMINAL CIRCUMFERENCE and GA at the 95.0% confidence level. The R-Squared statistic indicates that the model as fitted explains 51.1312% of the variability in ABDOMINAL CIRCUMFERENCE. The correlation coefficient equals 0.715061, indicating a moderately strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 6.04005.
The mean absolute error (MAE) of 4.60766 is the average value of the residuals.




**Regression - HEAD CIRCUMFERENCE vs. GA**

**Coefficients**

| | Least Squares | Standard | T | |
|---|---|---|---|---|
| Parameter | Estimate | Error | Statistic | P-Value |
| Intercept | 11.5789 | 28.7397 | 0.402888 | 0.6884 |
| Slope | 8.90249 | 1.01218 | 8.79539 | 0.0000 |

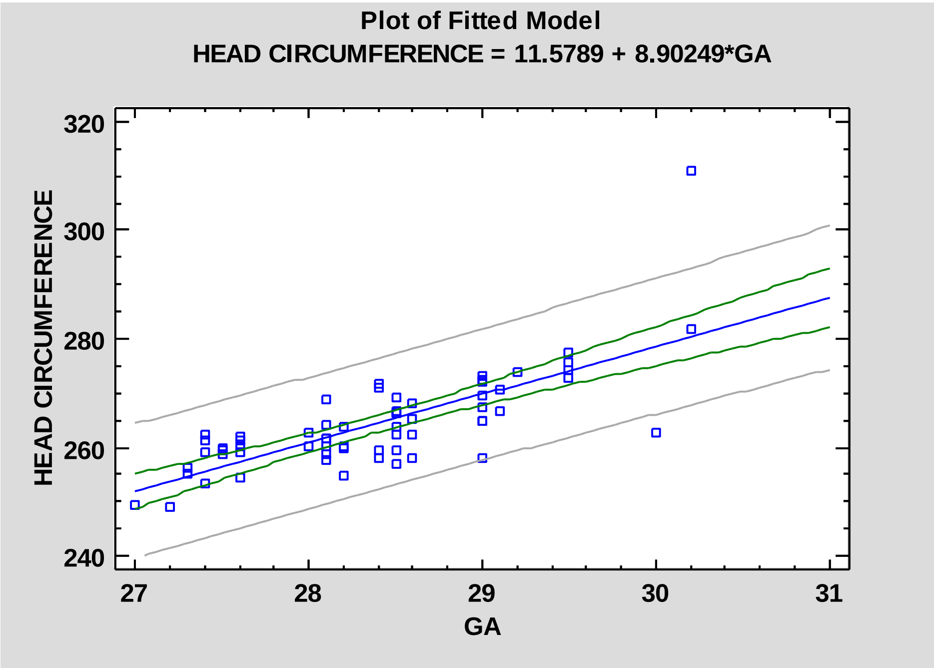
**Analysis of Variance**

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value |
|---|---|---|---|---|---|
| Model | 2786.91 | 1 | 2786.91 | 77.36 | 0.0000 |
| Residual | 2197.57 | 61 | 36.0257 | | |
| Total (Corr.) | 4984.48 | 62 | | | |

Correlation Coefficient = 0.747742
R-squared = 55.9118 percent
R-squared (adjusted for d.f.) = 55.189 percent
Standard Error of Est. = 6.00214
Mean absolute error = 3.9028

Durbin-Watson statistic = 1.89354 (P=0.3306)
Lag 1 residual autocorrelation = 0.0471393

The output shows the results of fitting a linear model to describe the relationship between HEAD CIRCUMFERENCE and GA. The equation of the fitted model is
HEAD CIRCUMFERENCE = 11.5789 + 8.90249*GA
The P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between HEAD CIRCUMFERENCE and GA at the 95.0% confidence level. The R-Squared statistic indicates that the model as fitted explains 55.9118% of the variability in HEAD CIRCUMFERENCE. The correlation coefficient equals 0.747742, indicating a moderately strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 6.00214.




**Regression - FEMOR LENGTH vs. GA**

**Coefficients**

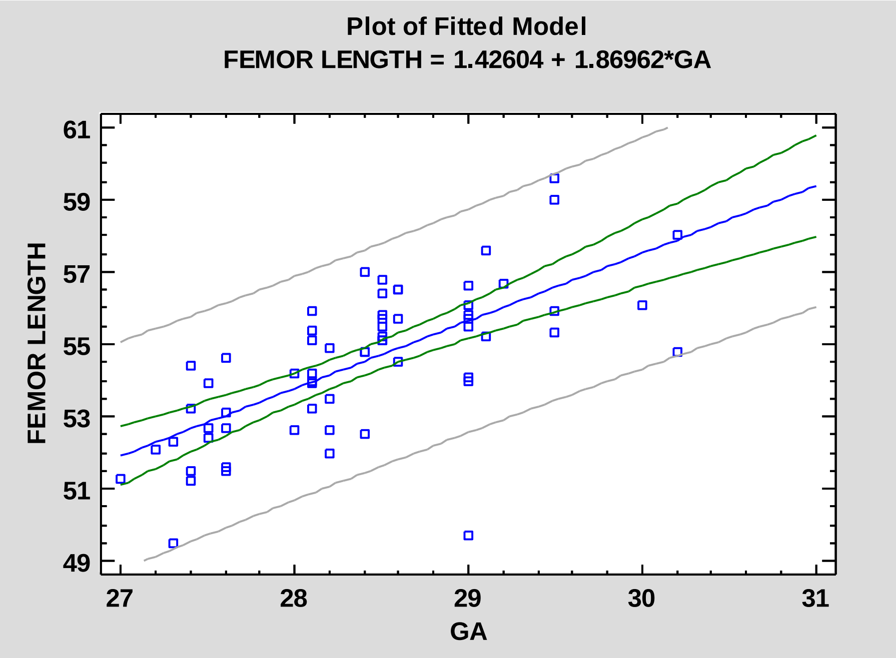
| | *Least Squares* | *Standard* | *T* | |
|---|---|---|---|---|
| *Parameter* | *Estimate* | *Error* | *Statistic* | *P-Value* |
| Intercept | 1.42604 | 7.32464 | 0.194691 | 0.8463 |
| Slope | 1.86962 | 0.257965 | 7.24759 | 0.0000 |

**Analysis of Variance**

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| Model | 122.916 | 1 | 122.916 | 52.53 | 0.0000 |
| Residual | 142.742 | 61 | 2.34003 | | |
| Total (Corr.) | 265.657 | 62 | | | |

Correlation Coefficient = 0.68021
R-squared = 46.2685 percent
R-squared (adjusted for d.f.) = 45.3877 percent
Standard Error of Est. = 1.52971
Mean absolute error = 1.12811
Durbin-Watson statistic = 1.85599 (P=0.2780)
Lag 1 residual autocorrelation = 0.0483478

The output shows the results of fitting a linear model to describe the relationship between FEMOR LENGTH and GA. The equation of the fitted model is
FEMOR LENGTH = 1.42604 + 1.86962*GA
The P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between FEMOR LENGTH and GA at the 95.0% confidence level. The R-Squared statistic indicates that the model as fitted explains 46.2685% of the variability in FEMOR LENGTH. The correlation coefficient equals 0.68021, indicating a moderately strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 1.52971. The mean absolute error (MAE) of 1.12811 is the average value of the residuals.



**Regression – FETAL WEIGHT vs. GA**

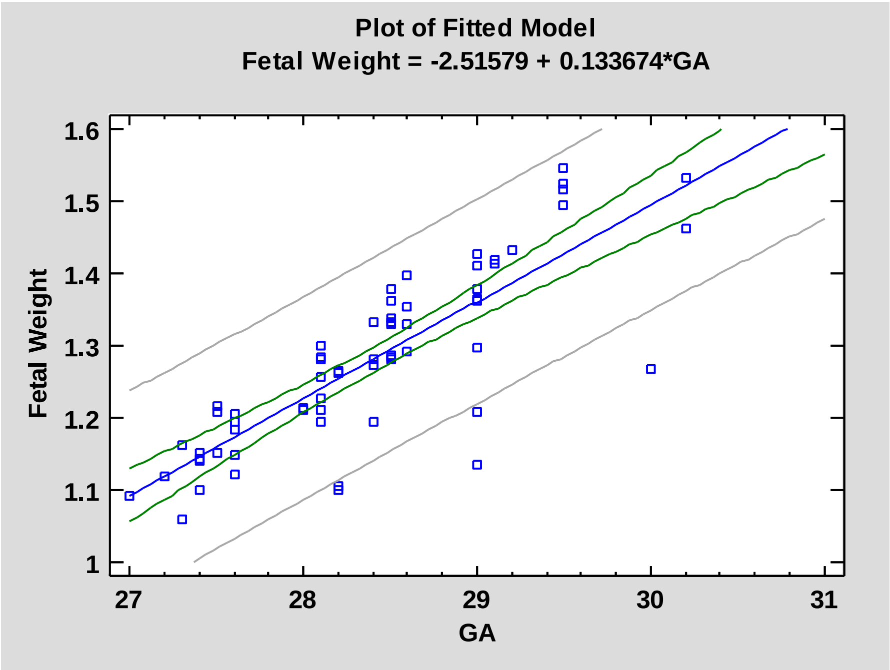
**Coefficients**

| | *Least Squares* | *Standard* | *T* | |
|---|---|---|---|---|
| *Parameter* | *Estimate* | *Error* | *Statistic* | *P-Value* |
| Intercept | -2.51579 | 0.333025 | -7.55436 | 0.0000 |
| Slope | 0.133674 | 0.0117287 | 11.3971 | 0.0000 |

**Analysis of Variance**

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| Model | 0.628334 | 1 | 0.628334 | 129.89 | 0.0000 |
| Residual | 0.295075 | 61 | 0.0048373 | | |
| Total (Corr.) | 0.923409 | 62 | | | |

Correlation Coefficient = 0.824894
R-squared = 68.045 percent
R-squared (adjusted for d.f.) = 67.5212 percent
Standard Error of Est. = 0.0695507
Mean absolute error = 0.0478051
Durbin-Watson statistic = 1.4051 (P=0.0073)
Lag 1 residual autocorrelation = 0.250577
The output shows the results of fitting a linear model to describe the relationship between Fetal Weight and GA. The equation of the fitted model is
Fetal Weight = -2.51579 + 0.133674*GA
The P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between Fetal Weight and GA at the 95.0% confidence level. The R-Squared statistic indicates that the model as fitted explains 68.045% of the variability in Fetal Weight. The correlation coefficient equals 0.824894, indicating a moderately strong relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 0.0695507. The mean absolute error (MAE) of 0.0478051 is the average value of the residuals.



**Regression – FETAL HEART RATE vs. GA**

**Coefficients**

| | *Least Squares* | *Standard* | *T* | |
|---|---|---|---|---|
| *Parameter* | *Estimate* | *Error* | *Statistic* | *P-Value* |
| Intercept | 69.3874 | 40.7 | 1.70485 | 0.0933 |
| Slope | 2.82999 | 1.4334 | 1.97432 | 0.0529 |

**Analysis of Variance**

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| Model | 281.625 | 1 | 281.625 | 3.90 | 0.0529 |
| Residual | 4407.23 | 61 | 72.2497 | | |
| Total (Corr.) | 4688.86 | 62 | | | |

Correlation Coefficient = 0.245077
R-squared = 6.00626 percent
R-squared (adjusted for d.f.) = 4.46538 percent
Standard Error of Est. = 8.49998
Mean absolute error = 6.23767
Durbin-Watson statistic = 2.01136 (P=0.5129)
Lag 1 residual autocorrelation = -0.00757508
The output shows the results of fitting a linear model to describe the relationship between Fetal Heart Rateand GA. The equation of the fitted model is
Fetal Heart Rate = 69.3874 + 2.82999*GA

The P-value in the ANOVA table is greater or equal to 0.05, there is not a statistically significant relationship between Fetal Heart Rate and GA at the 95.0% or higher confidence level. The R-Squared statistic indicates that the model as fitted explains 6.00626% of the variability in Fetal Heart Rate. The correlation coefficient equals 0.245077, indicating a relatively weak relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 8.49998. The mean absolute error (MAE) of 6.23767 is the average value of the residuals.

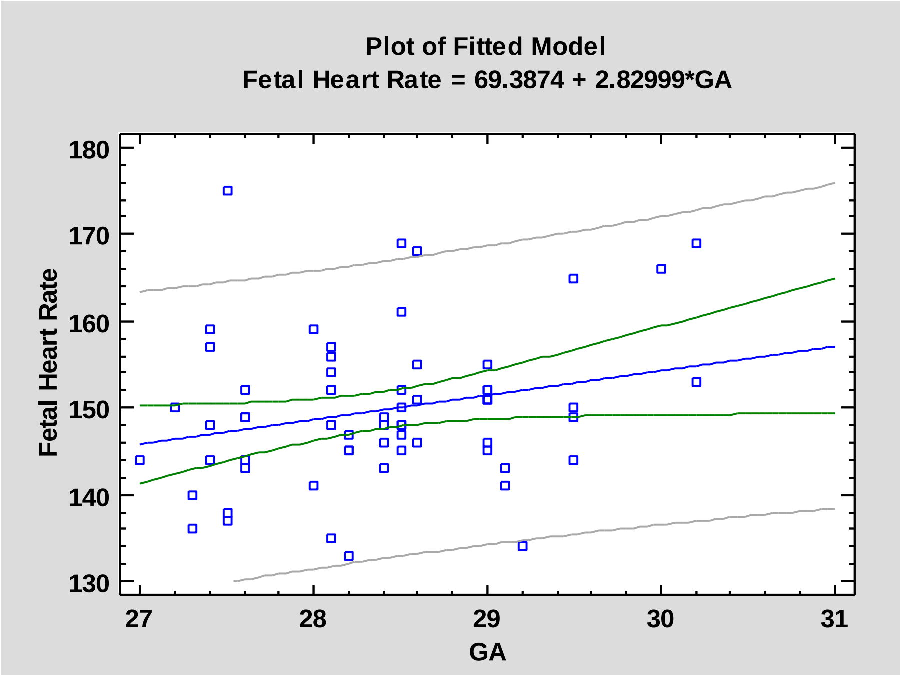



**Table.1.** A t-test performed for comparing right and left kidney as shown in table.1 and it revealed that there is no difference in the length between right and left Kidneys.

| | | |
|---|---|---|
| t-Test: Paired Two Sample for Means | | |
| | | |
| | *Variable 1* | *Variable 2* |
| Mean | 21.6253968 | 21.7206349 |
| Variance | 2.78547363 | 2.64037378 |
| | | |
| Observations | 63 | 63 |
| Pearson Correlation | 0.93229419 | |
| Hypothesized Mean Difference | 0 | |
| df | 62 | |
| t Stat | -1.24413491 | |
| P(T<=t) one-tail | 0.1090665 | |
| t Critical one-tail | 1.66980416 | |
| P(T<=t) two-tail | 0.21813301 | |
| t Critical two-tail | 1.99897152 | |

**Table.2**

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 24.6654913 | 1.20321866 | 20.4995917 | 4.7495E-29 | 22.2595069 | 27.0714757 | 22.2595069 | 27.0714757 |
| Average FKL | 0.17157906 | 0.05536511 | 3.0990464 | 0.00293547 | 0.06086967 | 0.28228845 | 0.06086967 | 0.28228845 |

The linear regression model calculated as shown in Table.2 and its revealed that predicts that for One mm increase in FKL there ia 0.17mm increase in GA weeks ie 1 day.

In the present study, the FKL correlated with the GA with a correlation coefficient of 0.17157906 (Table 2) and a determination coefficient of 0.822 which was better than all the conventional parameters used. We found a very strong correlation between FKL and GA as compared to previous studies. The correlation coefficient (pr = 0.93229419) observed in the present study was higher as compared to Cohen et al. (r = 0.82), Schlesinger et al. (r = 0.859), Gloor et al. (r = 0.90), Chiara et al. (for RK, r = 0.84, for LK, r = 0.87) and less than the studies performed by Konje et al. (r = 91) and Kaul et al. (r = 0.958).[1-6]

**Discussion**

Sonographic measurement of fetal body parts is known as fetal biometry. To determine the appropriateness of the dimension of fetal structures against each other (ratio) and/or against GA.

The first trimester USG is a very useful and reproducible modality for the assessment of GA. Crown-rump length and mean gestational sac diameter are the two parameters for assessment of GA in the 1st trimester. If GA has not already been established at a dating or first-trimester scan, it should be determined at the mid-trimester scan. Sonographic parameters that are used in the third-trimester pregnancy are as follows: BPD, HC, AC, and FL. Combining measurements significantly improve accuracy compared with a prediction based on standard parameters. However, the clinical significance of this improvement is marginal because the improved accuracy represents <1 day.

Rumack et al., in their textbook, mentioned that the kidneys grow throughout pregnancy and can provide a nomogram of renal lengths at 14–42 weeks of gestation and the renal/AC ratio remains constant at 0.27–0.30 throughout pregnancy.

USG is an accurate and useful modality for the assessment of GA in pregnancy and, as a routine part of prenatal care, can greatly impact obstetric management and improve antepartum care. From this study, we could find that the most accurate method for evaluation of GA was the KL followed by standard parameters. Kidneys are easy to identify and measure. Measuring KL can help in the determination of GA, especially in cases where the date of the mother's last menstruation is unknown. In addition to that, it could be a more valuable tool in cases where other established biometric indices are difficult to obtain and show gross discrepancies with each other or with GA.

**Conclusion**

From present study, we can see FKL increases linearly with gestational age. There is a good correlation between gestational age derived from FKL and gestational age from established biometric indices like BPD, HC, AC, and FL. The FKL in mm collaborates nicely with GA in weeks. This parameter alone can predict the gestational age. FKL can be combined with the other four biometric indices to give a fair estimation of gestational age. Hopefully, the results will demonstrate its applicability in routine practice.

**Abbreviations:**

Age:Patient's Age

Weight: Mother's Weight in Kg

LMP:Last Menstrual Period

GA-in weeks:Gestational Age in weeks-3rd trimester
F.Weight:Fetal ewight in Kg-3rd Trimester
FHR: Fetal Heart Rate/minute-3rd Trimester
BPD:Biparietal diameter in mm -3rd Trimester
HC:Head circumference in mm -3rd Trimester
AC:Abdominal circumference in mm- 3rd Trimester
FL:Femoral length in mm - 3rd Trimester
FKL-Right Fetal Right kidney length in mm - 3rd Trimester
FKL-Left Fetal Left kidney length in mm- 3rd Trimester

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