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## **Estimation of fetal gestational age by fetal kidney length measurement from 20-40<sup>th</sup> weeks of gestation in healthy women with uncomplicated pregnancy**

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**Abstract**--In the precise estimation of gestational age, fetal kidney length measurement by ultrasound proves to be an effective parameter from 20-40<sup>th</sup> weeks of gestation. To conduct an ultrasound examination for healthy women with uncomplicated pregnancy from 20 weeks to 40 weeks to determine the association between fetal kidney length and gestational age determined by the last menstrual period and other ultrasound parameters (such as biparietal diameter, head circumference, abdominal circumference and length of the femur). Obtain a nomogram and estimate the gestational age of the fetus by the length of the fetal kidney measured by ultrasound. This study aims to validate the measurement of fetal kidney length as an additional morphological parameter with less variability for estimating fetal growth. This measurement can be included into the pregnancy dating model after 20 weeks of gestation as it is easy to perform, especially when the measurement of biparietal diameter and head circumference is difficult.

**Keywords**---gestational age, kidney length, fetal growth.

## **Introduction**

In the last two decades, the application of ultrasound as a diagnostic method has advanced enormously, which has allowed management to develop in the direction of better care.[1] This is especially due to its non- invasive and non-ionizing properties, as well as its cost effectiveness which leads to greater acceptance. The impeccable safety record of ultrasound diagnostics may be the main reason for its widespread use. [2] Ultrasound is safe for patients, fetuses as well as the radiologists. Ionizing radiation risks like in X-ray or any other known biological or embryonic effects have not been reported with ultrasound. There is no requirement of radiopaque dye injections [3, 4]. There is no additional risk of repeated exposure to intrauterine ultrasound in early or late pregnancy as is of developing myeloid or lymphoid childhood leukaemia, which can be seen with X-ray imaging. It will not cause any harm to the fetus's early life, growth, vision or hearing during infancy [5,6]. Also, no adverse effects on neurodevelopment and later academic performance have been observed in children [7].

Since the advent of diagnostic ultrasound, more definitive pregnancy dating methods have been developed. In the first trimester these include the diameter and volume of the gestational sac, as well as the measurement of the crown to rump length. According to studies, measuring crown-to- rump length can accurately predict gestational age within  $\pm 4.7$  days. This variability can be decreased by 25% to 30 % by using all the above parameters. There are some conditions, such as multiple pregnancy, breech presentation, oligohydramnios and intrauterine growth restriction (IUGR), which can affect the fetal skull shape, which in turn affects BPD and increases variability. Abdominal circumference and femur length can also be affected by multiple pregnancy and IUGR[8].

## **Methodology**

The prospective study was conducted in 100 healthy pregnant women in their 20-40<sup>th</sup> weeks of gestation without any complications which were referred from the Department of Obstetrics and Gynaecology at Sree Balaji medical college and Hospital in Chennai. The study period was for 20 months, from March 2020 to October 2021. The fetal kidney length measurements were obtained in mid sagittal plane when the entire length of the kidney along with renal pelvis was seen. Measurement was taken from the upper to the lower pole such that the maximum length of any single fetal kidney was obtained at least three times and average of the measured values was considered.

## **Examination method**

All pregnant women were required to fill the PCPNDT form or the F form and were asked the relevant medical history along with the correct LMP. Obstetric ultrasonography was conducted on the patient in the supine position. GE logiq P7 ultrasound scanner (Fig. 13) with 3.5 MHz convex probe was used for obstetric ultrasound examination and the images were recorded. Parameters like BPD, FL,

HC, AC, TCD, fetal heart rate, AFI, estimated fetal weight, and position of placenta were obtained in all patients. The plane passing through the third ventricle and thalamus with cavum septum pellucidum visible in the anterior portion and tentorial hiatus in the posterior was used to measure BPD and HC. For BPD, the cursor was located from the outer edge of the near skull wall to the inner edge of the far skull wall. For HC, the cursor was on the outer edge of the near skull wall and on the outer edge of the far skull wall. Plane showing that the umbilical vein is perpendicular to the fetal spine and gastric bubble was taken for AC measurement. FL was acquired by keeping the transducer along the long axis of femoral diaphysis. The measurement cursor was positioned at the cartilaginous epiphysis and bone junction, with exclusion of the thin cartilaginous epiphysis reflection.

The fetal kidney length measurements were obtained in mid sagittal plane when the entire length of the kidney along with renal pelvis was seen (Table/Figs 1,2). Measurement was taken from the upper to the lower pole such that the maximum length of any single fetal kidney was obtained at least three times and average of the measured values was considered.



Table/Fig 1: Fetal kidney length measurement in second trimester



Table/Fig 2: Fetal kidney length measurement in third trimester

### Statistical analysis method

Development of predictive model using multiple linear regression. The parameters such as clinical gestational age, femur length gestational age, abdominal circumference gestational age and head circumference gestational age will be taken as dependent variable and foetal kidney length will be taken as independent variable and a predictive model using multiple linear regression will be created. The significant predictive variable of foetal kidney gestational age with given foetal kidney length, will be taken for predicting foetal kidney gestational age. With the significant predictive variables, a new model will be created and a constant and variable(s) coefficient(s) will be obtained.

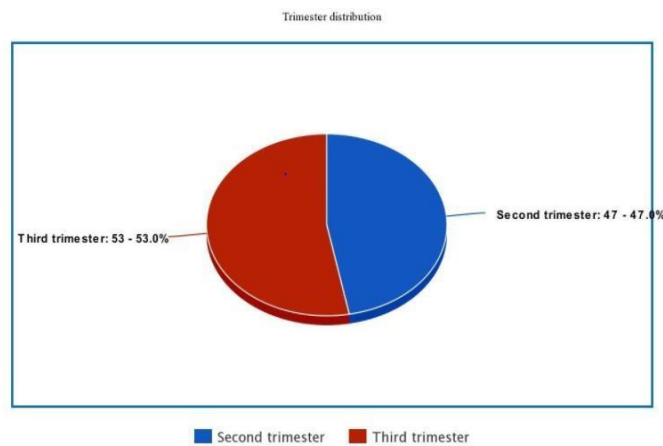
Prediction of foetal gestational age with regression formula :

$Y = \alpha + \beta * x_i$  Where

Y=predicted value for value of one independent variable( $x_i$ )  $\alpha$  =constant obtained from the model

$\beta$ =variable coefficient(s)  $x_i$ =independent variable

### Results



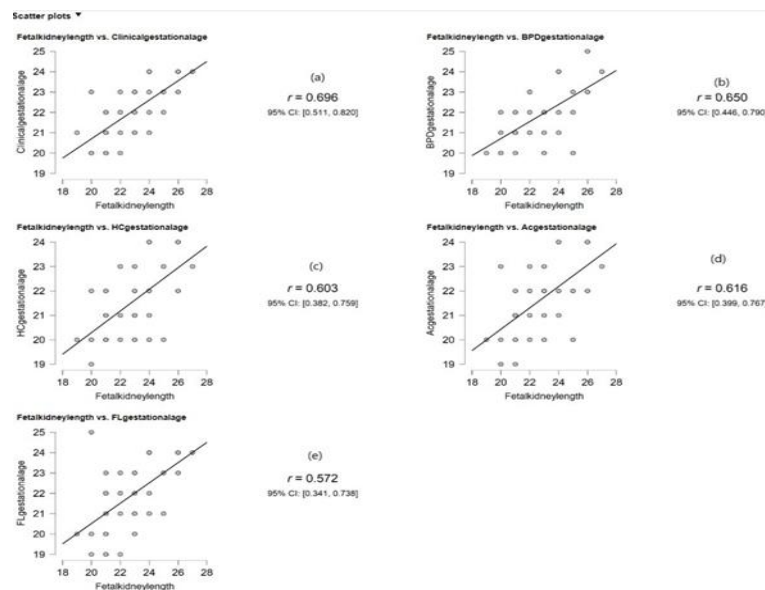
Table/Fig 3: Trimester distribution

Out of the 100 pregnant women, 47(47%) were in the second trimester of their pregnancy, remaining 53(53%) pregnant women were in their third trimester. The average gestational age of the study population was 27.65 weeks. The average gestational age of the pregnant women in third trimester was 32.77 weeks and that of second trimester was 21.87 weeks (Table/Fig 3).

Table/Fig 4: Correlation of fetal kidney length with gestational age (clinical, ac, fl, ac, hc, bpd) in second trimester pregnancy.

| Variable    | Variable    | n  | Pearson's r | p      | Lower 95% CI | Upper 95% CI |
|-------------|-------------|----|-------------|--------|--------------|--------------|
| FKL         | Clinical GA | 47 | 0.696       | < .001 | 0.511        | 0.820        |
| FKL         | BPD GA      | 47 | 0.650       | < .001 | 0.446        | 0.790        |
| FKL         | HC GA       | 47 | 0.603       | < .001 | 0.382        | 0.759        |
| FKL         | Ac GA       | 47 | 0.616       | < .001 | 0.399        | 0.767        |
| FKL         | FL GA       | 47 | 0.572       | < .001 | 0.341        | 0.738        |
| Clinical GA | BPD GA      | 47 | 0.697       | < .001 | 0.513        | 0.820        |
| Clinical GA | HC GA       | 47 | 0.708       | < .001 | 0.528        | 0.827        |
| Clinical GA | AC GA       | 47 | 0.753       | < .001 | 0.595        | 0.855        |
| Clinical GA | FL GA       | 47 | 0.722       | < .001 | 0.549        | 0.836        |
| BPD GA      | HC GA       | 47 | 0.872       | < .001 | 0.780        | 0.927        |
| BPD GA      | AC GA       | 47 | 0.853       | < .001 | 0.750        | 0.916        |
| BPD GA      | FL GA       | 47 | 0.782       | < .001 | 0.638        | 0.873        |
| HC GA       | AC GA       | 47 | 0.887       | < .001 | 0.804        | 0.936        |
| HC GA       | FL GA       | 47 | 0.779       | < .001 | 0.633        | 0.871        |
| AC GA       | FL GA       | 47 | 0.849       | < .001 | 0.743        | 0.914        |

Table/Fig 5: Second trimester correlation



### Observations based on correlation coefficient and scatter plot

- The correlation and regression analysis of the FKL with CGA in second trimester are depicted in a scatter plot. Here FKL has correlated with CGA by 69.6%.
- The correlation and regression analysis of the FKL with BPD in second trimester are depicted in a scatter plot. Here FKL has correlated with BPD by 65 %.
- The correlation and regression analysis of the FKL with HC in second trimester are depicted in a scatter plot. Here FKL has correlated with HC by 60.3%.
- The correlation and regression analysis of the FKL with AC in second trimester are depicted in a scatter plot. Here FKL has correlated with AC by 61.6%.
- The correlation and regression analysis of the FKL with FL in second trimester are depicted in a scatter plot. Here FKL has correlated with FL by 57.2 %.

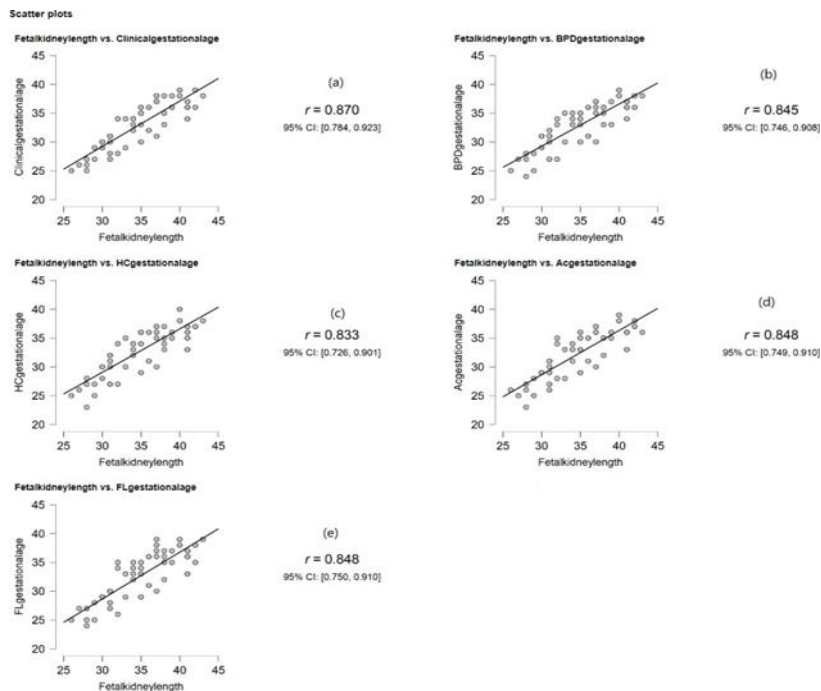
Based on Pearson's correlation, the highest correlation for clinical gestational age was with abdominal circumference gestational age with 75.3% correlation among both the variables. Foetal kidney length had moderately positive correlation with all the parameters including clinical gestational age. Foetal kidney length had the least correlation with clinical gestational age among all the parameters.

Table/Fig 6: correlation of fetal kidney length with gestational age (CLINICAL, AC, FL, AC, HC, BPD) in third trimester pregnancy

| variable    | variable    | n  | Pearson's r | p      | Lower 95% CI | Upper 95% CI |
|-------------|-------------|----|-------------|--------|--------------|--------------|
| FKL         | Clinical GA | 53 | 0.870       | < .001 | 0.784        | 0.923        |
| FKL         | BPD GA      | 53 | 0.845       | < .001 | 0.746        | 0.908        |
| FKL         | HC GA       | 53 | 0.833       | < .001 | 0.726        | 0.901        |
| FKL         | Ac GA       | 53 | 0.848       | < .001 | 0.749        | 0.910        |
| FKL         | FL GA       | 53 | 0.848       | < .001 | 0.750        | 0.910        |
| Clinical GA | BPD GA      | 53 | 0.970       | < .001 | 0.949        | 0.983        |
| Clinical GA | HC GA       | 53 | 0.969       | < .001 | 0.947        | 0.982        |
| Clinical GA | AC GA       | 53 | 0.969       | < .001 | 0.946        | 0.982        |
| Clinical GA | FL GA       | 53 | 0.980       | < .001 | 0.966        | 0.989        |
| BPD GA      | HC GA       | 53 | 0.981       | < .001 | 0.968        | 0.989        |
| BPD GA      | AC GA       | 53 | 0.964       | < .001 | 0.938        | 0.979        |
| BPD GA      | FL GA       | 53 | 0.968       | < .001 | 0.944        | 0.981        |
| HC GA       | AC GA       | 53 | 0.976       | < .001 | 0.958        | 0.986        |

|       |       |    |       |        |       |       |
|-------|-------|----|-------|--------|-------|-------|
| HC GA | FL GA | 53 | 0.960 | < .001 | 0.931 | 0.977 |
| AC GA | FL GA | 53 | 0.959 | < .001 | 0.929 | 0.976 |

Table/Fig 7: Third trimester correlation



### Observations based on correlation coefficient and scatter plot

- The correlation and regression analysis of the FKL with CGA in third trimester are depicted in a scatter plot. Here FKL has correlated with CGA by 87%.
- The correlation and regression analysis of the FKL with BPD in third trimester are depicted in a scatter plot. Here FKL has correlated with BPD by 84.5%.
- The correlation and regression analysis of the FKL with HC in third trimester are depicted in a scatter plot. Here FKL has correlated with HC by 83.3%.
- The correlation and regression analysis of the FKL with AC in third trimester are depicted in a scatter plot. Here FKL has correlated with AC by 84.8%.
- The correlation and regression analysis of the FKL with FL in third trimester are depicted in a scatter plot. Here FKL has correlated with FL by 84.8%.

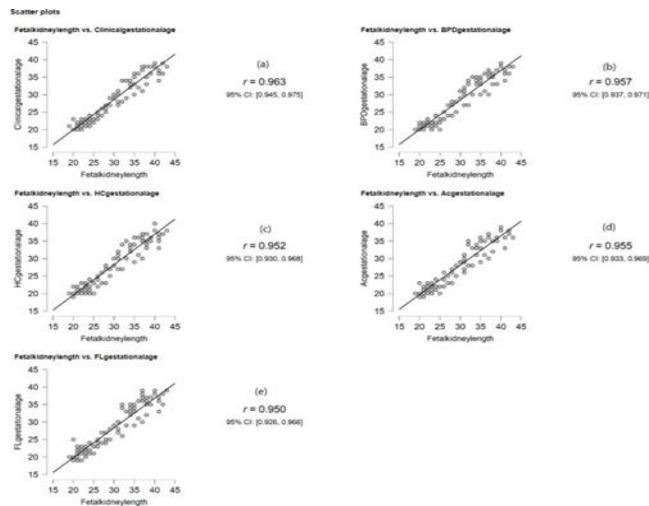
Based on Pearson's correlation, the highest correlation for clinical gestational age was with femur length gestational age with 98% correlation among both the variables. Foetal kidney length had high positive correlation with all the parameters including clinical gestational age in third trimester of pregnancy.

Foetal kidney length had the least correlation with clinical gestational age among all the parameters during third trimester of pregnancy.

Table/Fig 8: Combination of second and third trimester correlation

| Variable    | Variable    | n   | Pearson's r | p      | Lower 95% CI | Upper 95% CI |
|-------------|-------------|-----|-------------|--------|--------------|--------------|
| FKL         | Clinical GA | 100 | 0.963       | < .001 | 0.945        | 0.975        |
| FKL         | BPD GA      | 100 | 0.957       | < .001 | 0.937        | 0.971        |
| FKL         | HC GA       | 100 | 0.952       | < .001 | 0.930        | 0.968        |
| FKL         | Ac GA       | 100 | 0.955       | < .001 | 0.933        | 0.969        |
| FKL         | FL GA       | 100 | 0.950       | < .001 | 0.926        | 0.966        |
| Clinical GA | BPD GA      | 100 | 0.988       | < .001 | 0.982        | 0.992        |
| Clinical GA | HC GA       | 100 | 0.987       | < .001 | 0.981        | 0.991        |
| Clinical GA | AC GA       | 100 | 0.988       | < .001 | 0.982        | 0.992        |
| Clinical GA | FL GA       | 100 | 0.987       | < .001 | 0.981        | 0.991        |
| BPD GA      | HC GA       | 100 | 0.993       | < .001 | 0.990        | 0.996        |
| BPD GA      | AC GA       | 100 | 0.989       | < .001 | 0.983        | 0.992        |
| BPD GA      | FL GA       | 100 | 0.985       | < .001 | 0.978        | 0.990        |
| HC GA       | AC GA       | 100 | 0.992       | < .001 | 0.988        | 0.995        |
| HC GA       | FL GA       | 100 | 0.983       | < .001 | 0.975        | 0.989        |
| AC GA       | FL GA       | 100 | 0.985       | < .001 | 0.978        | 0.990        |

Table/Fig 9: Combination of second and third trimester correlation



### Observations based on correlation coefficient and scatter plot

- a) The correlation and regression analysis of the FKL with CGA in second and third trimesters are depicted in a scatter plot. Here FKL has correlated with CGA by 96.3%%.
- b) The correlation and regression analysis of the FKL with BPD in second and third trimesters are depicted in a scatter plot. Here FKL has correlated with BPD by 95.7%%.
- c) The correlation and regression analysis of the FKL with HC in second and third trimesters are depicted in a scatter plot. Here FKL has correlated with HC by 95.2%%.
- d) The correlation and regression analysis of the FKL with AC in second and third trimesters are depicted in a scatter plot. Here FKL has correlated with AC by 95.5%.
- e) The correlation and regression analysis of the FKL with FL in second and third trimesters are depicted in a scatter plot. Here FKL has correlated with FL by 95%.

Based on Pearson's correlation, more than a 98% correlation was seen between clinical gestational age and femur length GA, BPD GA, HC GA, AC GA. Foetal kidney length had very high positive correlation with all the parameters including clinical gestational age. Foetal kidney length had the least correlation with clinical gestational age among all the parameters.

Table/Fig 10: mean fetal kidney length according to fetal kidney gestational age

| GA (weeks) | Samples | Mean of FKL (mm) | SD of FKL (+/- mm) | CI       |          |
|------------|---------|------------------|--------------------|----------|----------|
| 20         | 8       | 20.75            | 0.25               | 20.95901 | 20.54099 |
| 21         | 11      | 21.727           | 0.42               | 22.00916 | 21.44484 |
| 22         | 13      | 22.231           | 0.36               | 22.44855 | 22.01345 |
| 23         | 9       | 23.444           | 0.6                | 23.9052  | 22.9828  |
| 24         | 6       | 25.167           | 0.54               | 25.7337  | 24.6003  |
| 25         | 2       | 27               | 1                  | 35.98464 | 18.01536 |
| 26         | 2       | 27.5             | 0.5                | 31.99232 | 23.00768 |
| 27         | 4       | 29               | 0.7                | 30.11386 | 27.88614 |
| 28         | 2       | 31.5             | 0.5                | 35.99232 | 27.00768 |
| 29         | 3       | 30.667           | 1.2                | 33.64797 | 27.68603 |
| 30         | 4       | 31.5             | 1.19               | 33.39356 | 29.60644 |
| 31         | 4       | 32.5             | 1.5                | 34.88683 | 30.11317 |
| 32         | 2       | 35               | 1                  | 43.98464 | 26.01536 |
| 33         | 3       | 35.66            | 1.2                | 38.64097 | 32.67903 |

|    |   |       |       |          |          |
|----|---|-------|-------|----------|----------|
| 34 | 6 | 34.33 | 1.38  | 35.77822 | 32.88178 |
| 35 | 4 | 36.5  | 0.866 | 37.878   | 35.122   |
| 36 | 6 | 39    | 1.18  | 40.23833 | 37.76167 |
| 37 | 3 | 38.33 | 1.33  | 41.6339  | 35.0261  |
| 38 | 6 | 39    | 0.93  | 39.97598 | 38.02402 |
| 39 | 2 | 41    | 1     | 49.98464 | 32.01536 |

Table/Fig 11: Predictive linear regression model for predicting gestational age using fetal kidney length using gestational age obtained from other parameters that are in significant predictive relationship with foetal kidney length.

| Variable | Coefficient | P value  |
|----------|-------------|----------|
| CGA      | 0.881784    | 0.000482 |
| BPD GA   | 0.495648    | 0.10283  |
| HC GA    | -0.3442     | 0.282648 |
| AC GA    | 0.227967    | 0.416749 |
| FL GA    | -0.16963    | 0.432276 |

Only clinical gestational age had significant predictive relationship with foetal kidney length.

Table/Fig 12: Projected gestational age for respective fetal kidney length

| Foetal Kidney Length (Mm) | Foetal Kidney Gestational Age (Week) |
|---------------------------|--------------------------------------|
| 19                        | 19                                   |
| 20                        | 20                                   |
| 21                        | 21                                   |
| 22                        | 22                                   |
| 23                        | 23                                   |
| 24                        | 23                                   |
| 25                        | 24                                   |
| 26                        | 25                                   |
| 27                        | 26                                   |
| 28                        | 27                                   |
| 29                        | 28                                   |
| 30                        | 29                                   |
| 31                        | 29                                   |
| 32                        | 30                                   |
| 33                        | 31                                   |
| 34                        | 32                                   |
| 35                        | 33                                   |
| 36                        | 34                                   |
| 37                        | 35                                   |
| 38                        | 36                                   |
| 39                        | 36                                   |
| 40                        | 37                                   |
| 41                        | 38                                   |

|    |    |
|----|----|
| 42 | 39 |
| 43 | 40 |

## Discussion

The most crucial aspect of pregnancy management is the precise gestational date estimation. The procedure for calculating the date of pregnancy, regardless of GA, should be simple and uncomplicated. For optimal pregnancy and obstetric care, accurate and easily repeatable ultrasonography foetal biometric data for pregnancy dating is critical. This is particularly relevant when selecting the best obstetric results by scheduling different pregnancy tests, measuring growth adequacy, and timing delivery. [5-7]

This prospective study of 100 healthy women with uncomplicated pregnancies showed a correlation between gestational age (in weeks) and FKL (in millimetres) as a linear correlation during the second trimester (12 weeks to 28 weeks) and the third trimester (29 weeks to 40 weeks). There is a statistically significant link between foetal kidney development and gestational age. Many researches have been done to calculate the variability of gestational age estimation by assessing the FKL throughout the second and third trimesters of pregnancy. This linear correlation was seen in the second and third trimesters of pregnancy in this study, and was strongly corresponding to clinical gestational age.

Studies have revealed that gestational age estimated by measurements, such as BPD ( $r = 0.81$ ), femoral length ( $r = 0.82$ ), abdominal circumference ( $r = 0.83$ ), and the average of the three, had a high association with embryonic renal length. Each may be used to correlate kidney length as these values do not differ statistically (49-54). [8]

There is noteworthy association between gestation age and foetal renal length ( $r=0.94$ ) as compared to other parameter biparietal diameter ( $r=0.932$ ), femur length ( $r=0.936$ ), head circumference ( $r=0.932$ ) and abdominal circumference ( $r=0.89$ ). When comparing lengths between 18 and 41 weeks of pregnancy, Kohen et al. found a substantial variation in the average length of the foetal kidney. From week 18 to week 41, the average kidney length increased from  $2.2 \pm 0.2$  cm to 4.5 cm. Even stillbirths and preterm infants showed a good correlation of these values as estimated by menstrual age. In measuring kidney length, the inter-observer and intra-observer variability was 2.4 percent and 1.5 to 3.5 percent, respectively (49).

Fetal kidney length is most accurate with 10.29 days standard deviation in predicting gestation age as compared to the biparietal diameter (11.62 days), femur length (10.96 days), head circumference (14.54 days) and abdominal circumference (14.54 days). A combination of biparietal diameter (BPD), femoral length (FL), head circumference (HC), abdominal circumference (AC), and foetal kidney length (FKL) is the greatest predictor of gestational age with accuracy of predicting gestational age approximately  $\pm 8.48$  days and  $\pm 9.48$  days with and without foetal kidney length (FKL) respectively (49). [9,10]

## Conclusion

The effectiveness of FKL as a measure of anticipated gestational age was tested using obstetric ultrasonography on 100 pregnant females without any complications in their pregnancy and with gestational ages ranging from 20 to 40 weeks. Patients with known LMP, a normal menstrual history, and no exclusion criteria were included in the research. BPD, HC, AC, FL, and FKL were among the foetal biometrics which were studied. The correlation of FKL and other fetal parameters was discovered to be substantial. The FKL nomogram reveals a linear correlation between kidney size and gestational age. As a result, FKL may be utilised to accurately determine gestational age.

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