

Ultrasound Fetal Kidney Length for Assessment of Gestational Age

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ABSTRACT

Fetal kidney length (FKL) has recently been found to have a strong correlation with gestational age. According to the findings of these investigations, the fetal kidney length may be utilized to estimate gestational age when dates are ambiguous or when women seek ultrasound fetal biometry dating during the third trimester itself.

GA estimation is also a prerequisite to interpret certain tests (amniotic fluid assay, serum assay, chorionic villus sampling) and to plan timing of various forms of fetal therapy. Failure in estimating GA accurately can result in unnecessary induction, dysfunctional labor, operative delivery, iatrogenic prematurity or post maturity, false interpretation of tests and delay or failure of fetal therapy, thereby increasing perinatal morbidity and mortality.

This review looks in to various studies assessing correlation of Fetal kidney length with gestational age in third trimester of pregnancy and provide a comprehensive view on use of Fetal kidney length for estimation of gestational age in third trimester of pregnancy.

INTRODUCTION

The foundation of the obstetrician's ability to properly manage prenatal care, prenatal testing, and successful treatment or intervention planning. Precise knowledge of gestational age. Prematurity, which is linked to higher perinatal morbidity and mortality, can result from failure.[1] Even if the menstrual cycles start date is accurate, the exact moments of ovulation, fertilization, and implantation are unknown. During the typical menstrual cycle, women may experience many "waves" of vesicle growth, which could lead to irregular ovulation during any one cycle. The "known" pregnancy date is not entirely trustworthy because sperm can stay in a woman's reproductive system for 5 to 7 days. According to recent studies, the interval between ovulation and implantation might vary by 11 days, which may have an impact on the size and growth

of the fetus. [2]

Delay in ovulation is a significant factor in the perception of a prolonged pregnancy, and it is more likely to happen than early ovulation even in women who are confident in the timing of their monthly cycles. Some writers have advised that 282 days should be used in place of 280 days to increase date accuracy. It seems to be difficult to accurately estimate gestational age from menstruation history given all of these factors. [2]

Menstrual irregularities, lactational amenorrhea, oral contraceptive failure, bleeding in the first trimester, and persistent anovulation may further affect the ability to accurately calculate GA from the date of LMP. [3] When an early termination is required as soon as the fetal reaches maturity, such as in the case of pre-eclampsia, chronic renal disease, severe intrauterine growth retardation

(IUGR), diabetes, placenta praevia centralis, and Rh-negative women, an accurate GA is crucial. Accurate GA estimation is also required when specific tests, including as chorionic villus sampling, amniotic fluid and serum testing, and Fetal therapy planning, must be carried out. A more recent tendency is for women to request an elective caesarean delivery on a specific date, such as 11.11.11, 12.12.12, the first day of the New Year, or a date recommended by an astrologer. On these dates, an abrupt increase in operation rates was observed. [4]

When done in the first and early second trimester (less than 24 weeks), ultrasound measurements of the fetal biometry, including the Crown rump length (CRL), Bi-parietal diameter (BPD), Femur length (FL), Abdominal circumference (AC), and Head circumference (HC), are thought to be reliable. In the third trimester, there is presently no single Fetal measurement that can be used to precisely predict gestational age, particularly in cases when the mother booked late and was dubious of her LMPs. [5] For women who seek maternity care late and are unclear about the date of their LMP, accurate timing of pregnancies in the late second or third trimester continues to be a challenge. [6] However, because to the inherent variability of size in proportion to age, they become more and more unreliable as gestational age increases.

Fetal kidney length (FKL) has recently been found to have a strong correlation with gestational age. According to the findings of these investigations, the fetal kidney length may be utilized to estimate gestational age when dates are ambiguous or when women seek ultrasound fetal biometry dating during the third trimester itself. [7] The length of the fetal kidney has been measured using sonography in a number of long-term investigations conducted in western nations. These were initially carried out to diagnose prenatal renal malformations, and later tests were used to determine whether there was a relationship between fetal kidney length and gestational age. [5] For the purpose of reducing variability, all pregnancies longer than 20 weeks are suggested to employ all four biometric indices. BPD, HC, AC, and FL can reasonably predict GA in the second trimester (\pm 10–14 days). These criteria grow more and more inaccurate in estimating GA as pregnancy progresses. [6] Throughout pregnancy, the fetal kidney has been observed to expand at a constant rate of 1.7 mm every two weeks and is unaffected by growth anomalies. Fetal kidney length (FKL), according to a number of studies, closely corresponds with gestational age in the

third trimester. Although ultrasound textbooks frequently include tables of various sizes, the fetal kidney has not received much research as a biometric criterion for estimating gestational age. [8]

Although fetal biometry measurements aid in an accurate estimation of GA in the early second trimester, the biological variations of size lead to these parameters' accuracy to vary as the age of the fetus advanced, making it challenging to date a fetus accurately in the late second or third trimester. Therefore, some investigations concentrated on the relationship between a normal fetus' kidney size and gestational age. [9]

This review looks in to various studies assessing correlation of Fetal kidney length with gestational age in third trimester of pregnancy and provide a comprehensive view on use of Fetal kidney length for estimation of gestational age in third trimester of pregnancy.

IMPORTANCE OF ESTIMATION OF GESTATIONAL AGE

Accurate gestational Age estimation is very important to an obstetrician for diagnosis of growth disorders, in assessment of wrong dates or forgotten dates and timing of delivery either by induction or caesarean section.

It is particularly important in high-risk pregnancies (severe preeclampsia, chronic hypertension, severe IUGR, central placenta Previa, sensitized Rh-negative mother etc.) where in some cases early termination may become necessary as soon as fetus becomes mature.

GA estimation is also a prerequisite to interpret certain tests (amniotic fluid assay, serum assay, chorionic villus sampling) and to plan timing of various forms of fetal therapy. Failure in estimating GA accurately can result in unnecessary induction, dysfunctional labor, operative delivery, iatrogenic prematurity or post maturity, false interpretation of tests and delay or failure of fetal therapy, thereby increasing perinatal morbidity and mortality. [10]

FETAL KIDNEY

The fetal kidneys can be seen trans-abdominally from 14 weeks' gestation and are easily visible at 20–22 weeks. The first clue that you have found the kidney is the hypoechoic area – delineated by a hyperechoic bright border that represents the renal pelvis. [11]

The sonographic cortico-medullary differentiation starts at 15 weeks and will become more clear with advancing gestational age. The outer, more hyperechogenic renal cortex can be clearly distinguished from the inner, more hypoechogenic medulla at the 20th week of gestation. Renal echogenicity will also decrease; lower than that of the liver and spleen from 17 weeks. The antero-posterior diameter of the renal pelvis (APPD) should be less than 4mm in the second trimester and less than 7mm in the third trimester. [12]

PUBLISHED LITERATURE

Gonzales J. et al (1980) [13] studied the growth rate of the kidney in both length and width during the last three months of pregnancy. This is the first study to correlate fetal kidney parameters with gestational age. Examining 390 anatomical specimens did the study in the gestational age between 26-41 weeks. The study concluded that even in IUGR fetuses the measurement of kidney length correlates with the GA of the fetus. The result showed that size and weight of kidney increase with increase in duration of pregnancy.

Lawson et al in 1981[14], Studied the ultrasound appearance fetal kidneys and its size and growth in different stages of pregnancy. In this study, fetal renal diameter was measured with calipers in an antero-posterior direction on the axial images whenever the kidney could be identified. Renal length was measured on the coronal or sagittal views. When both kidneys were identified on the same image, the measurements were averaged. To document the accuracy of the observation and measurements, the authors sectioned 14 stillborn premature infants in axial, coronal or sagittal plane and fetal anatomical relationships were studied and renal length and width were measured directly from the cut sections using a centimeter ruler.

Age was estimated from the hospital record and measurements of BPD, head circumference and crown heel length. The fetal kidneys appeared ultrasonographically as hypoechogenic circular structures, surrounding the strongly echogenic pyelocalyceal system. From 15-17 weeks, the kidneys were seen in less than half of the fetuses evaluated. One or both the kidneys were identified in 90% of cases from 17- 22weeks and in 95% of cases after 22 weeks. Continued non-visualization after 22 weeks occurred in five cases.

Jeanty PJ et al in 1984[15], Studied the fetal kidney growth measurements using ultrasound before the

publication by SpiegelG. The kidneys appear as hypoechogenic oval structures in the middle of the posterior abdomen at 20 weeks. At 27th week, the capsule and renal pyramids appear as a distinct structure. The length of the kidney was measured from upper pole to lower pole. The width of the kidneys measured in the transverse section of the fetus. It was obtained at the height of the renal pelvis, or at the position where the renal section was large visually. Caliper positioning could be very difficult due to the low contrast between renal parenchyma and the surrounding tissues. When difficulty was present, respiratory motions were extremely helpful in defining the cleavage plane between kidney and adjacent tissues. The width was not measured exactly perpendicular to the length. The equation for volume of kidney = length x width x thickness x 0.5233

The kidney, which is proximal to the transducer, was measured. Because the contour of the contralateral kidney will be hidden by spine shadow. Measurements were made without prior knowledge of the gestational age. They concluded that volume was the parameter that correlated well with gestational age and BPD. The results were well comparable with those of Lawson et al. and with those of Gonzales obtained from stillborn.

Bertagnoli L. et al in 1983[16], studied the changes in the antero-posterior diameter and length of the fetal kidneys according to gestational age. 280 pregnant women in the gestational age between 22-40 were examined. Statistical analysis was done. cross-sectional and longitudinal studies of kidney growth were performed to assess the correlation of the antero-posterior diameter and length of the fetal kidney to the gestational age. From the results, they concluded that fetal kidney measurements could be used as an additional parameter in the routine antenatal assessment of fetal wellbeing and to rule out anomalies of kidney characterized by changes in kidney size.

Mahony BS et al in 1985[17] studied the ultrasound measurement of average kidney diameter and BPD, and the ratio between the two in normal and fetuses with anomalous kidney. The study result shows that the ratio was constant in normal fetus and different in fetus with urinary tract pathology.

Sampaio FJ. et al in 1990[18] did the study of the fetal kidney lengths growth during the second and third trimesters of gestation. Study was done in 120 human fetuses between 10 to 36 weeks of gestation. The longitudinal length of each kidney was measured and compared with gestational age.

The growth rate of each kidney, in male and female fetuses were studied. The study result showed that fetal kidney length measurement could be used for estimation of gestational age and detection of renal anomalies.

In 1991, Cohen et al. [19] studied the ultrasound measurement of fetal kidney length in 397 fetuses from 18 to 41 weeks of pregnancy. The study included only normal fetuses, and the gestational age was estimated using LMP and fetal biometry. The mean fetal kidney lengths were found to be greater when compared to previous study. According to this study, strong correlation existed between fetal kidney length measurement and gestational age estimated by fetal biometry (bi-parietal diameter, femoral length, and abdominal circumference, and an average of the three). The study concluded that there is no correlation between height and weight of the parents and fetal kidney length. The study also concluded that there no significant difference between the Right and Left kidney lengths.

Gloor JM et al in 1997[20] studied the ultrasound evaluation of fetal renal growth, fetal body weight according to gestational age. Prenatal ultrasound were performed in 100 pregnant women between 18 and 39 weeks of gestation. Fetal renal length and volume were determined and compared with gestational age and estimated fetal body weight. The study result showed that the fetal body weight, the renal length and renal volume increased throughout gestation and the ratio between renal volume and body weight remained constant.

Ansari SM et al in 1997[21], in Bangladesh, studied the ultrasound measurement of normal fetal kidney lengths of fetus's between 16 and 40 weeks of gestation. In this study, 793 fetuses were included. They found that the average length of the kidney at term (3.95 cm) was same as previous studies. The kidney length measurement correlated well with other parameters in gestational age estimation.

Konje JC et al in 1997[22], Studied the differences in the fetal kidney measurements between normal and small for gestational age fetuses at different gestational age. 219 singleton fetuses from 22 to 38 weeks of gestation were studied. The fetal kidney length, circumference and antero-posterior and transverse diameters were measured at each gestational age. The fetuses were classified as small or appropriate for gestational age, depending on the birth weight. The various kidney measurements for the two groups were compared. The circumference, transverse and anteroposterior diameters were greater for normal fetuses when compared

with small for gestational age fetusus. The differences in fetal kidney size with gestation start manifesting from 26 to 28 weeks. The kidney length measurement in both groups at various gestational ages were similar. They concluded that fetal kidney length measurement correlated well with the gestational age both in small and appropriate for gestational age fetuses.

Konje JC et al in 2002[6], studied gestational age determination by measuring fetal kidney length after 24th week of gestation. 73 pregnant women with uncomplicated pregnancies were selected for the study. Serial measurement of fetal biometry and kidney length were done from 24 to 38 weeks of gestation with an interval of 2 weeks. Using this gestational age was calculated and compared with crown-rump length (taken between 8-10 weeks of gestation) dating. Linear regression analysis was done. The results showed that FL and fetal kidney length are the best parameters for determination of gestational age (+10.29 and 10.96 days respectively). They concluded that fetal kidney length measurement was a more accurate method of estimating gestational age than other fetal biometric indices like BPD, HC, AC, FL.

Yusuf N et al in 2007[5] studied the correlation of fetal kidney length with gestational age. The study included 102 pregnant women after 30 weeks of gestation. All the patients had dating scan done at early weeks of pregnancy. The fetal kidney length measurement showed a linear correlation with gestational age. The mean fetal kidney length in mm corresponds to gestational age in weeks. The result concluded that measurement of fetal kidney length could be used as an additional parameter for the estimation of gestational age.

JJ Kansaria et al in 2009[23], done a study in 70 antenatal women with excellent dates. Fetal biometry (BPD, HC, AC, FL) along with fetal kidney length were measured serially between 22 -38 weeks of gestation with an interval of 2 weeks. They concluded that fetal kidney length predicted gestational age with better precision than other biometric indices.

Indu Kaul et al., in 2012[10]: A total of 98 pregnant women with singleton pregnancy underwent serial biometric & FKL measurements ultrasonographically at 24, 28, 32, 36 and 38 weeks of gestation. These measurements were used to date the pregnancies relative to dating by last menstrual period. Linear regression models for estimation of GA were derived from the biometric indices and FKL. Fetal Kidney Length (FKL) is most accurate single pa-

parameter for estimating GA than other biometric indices in late 2nd and 3rd trimester and could be easily incorporated into the models for estimating gestational age.

Shanmughavadivu in 2014[24], studied two hundred pregnant women with singleton uncomplicated pregnancies with the gestational age between 24 to 40 weeks of gestation were selected for the study. They underwent ultrasound fetal biometry and fetal kidney length measurement. These measurements were used to date the pregnancies and compared with clinical gestational age derived from last menstrual period and dating scan. Linear regression analysis was done to find out the best parameter for estimating gestational age. Pearson correlation was done to determine the accuracy of these parameters in the estimation of gestational age. The mean fetal kidney length showed a linear correlation with gestational age. Fetal kidney length determines gestational age with the accuracy of ± 9.8 days. BPD dates pregnancy with the accuracy of ± 11.5 days, Femur length by ± 11.3 days. From this study, it was concluded that fetal kidney length measurement is the most accurate method of determining gestational age than other fetal biometric indices like biparietal diameter, head circumference, abdominal circumference, and femur length between 24 to 40 weeks of gestation.

Divyasree et al., in 2017[25]. Studied the correlation between fetal kidney length and fetal biometry for 150 pregnant women after 28 weeks of gestation who were sure of their last menstrual period. The fetal kidney length measurements showed that there is a linear relationship between fetal kidney length and gestational age. The mean kidney length in mm approximates the gestational age in third trimester as predicted by BPD, HC, AC and FL. The fetal kidney length dates the pregnancy more accurately (correlation coefficient 0.98) when compare with BPD, HC AC and FL. The result obtained concluded that fetal kidney length could be use as reliable parameter for determination of gestational age.

Ramchandran K et al (2020) [26] conducted prospective study among the antenatal women with singleton uncomplicated pregnancy during 18 to 40 weeks of gestation attending the outpatient department for routine ultrasound Fetal biometry in a tertiary care referral institution in South India, during January 2019 to June 2019. A total of hundred and thirty-five antenatal mothers were included in this study. Data entry was done in Microsoft Excel and data analysis was done using Statistical Package for Social Sciences (SPSS). There was a strong

positive correlation between GA and MKL. Regression model (Model 1) for Mean kidney length showed significant correlation and regression models (Model 2) for MKL and routine Fetal biometric parameters like biparietal diameter, femur length and abdominal circumference were found to be significantly correlated. Mean Fetal kidney length can alone predict gestational age and by combining it with the other biometric indices to give a better estimation of gestational age.

Al-Mlah S et al (2019) [27] performed the observational study. The study was conducted at the antenatal outpatient clinics of Obstetrics and Gynecology at Alzahraa University hospitals and Ahmed Maher Teaching hospital in the period between December 2017 and December 2018. Approval from Ethical Committee at Al Zahraa University was taken. This study included 120 asymptomatic, pregnant women, with singleton pregnancy (30 cases at each gestational age 32-, 34-, 36- & 38-weeks gestation). The study shows that fetal kidney length is a good indicator of gestational age and can be used alone due to its accuracy in comparison to other measurements (BPD, FL & AC) that may be changed in the third trimester. There was a significant difference between right and left kidney length through different age of gestation (The Lt KL measurement was larger than the measurement Rt KL). Gestational age in weeks is nearly equal to MKL. Fetal kidney length correlates well with gestational age, so it can be concluded that kidney dimensions can be helpful in determining the gestational age when menstrual dates are uncertain.

Ugur MG et al (2016) [28] conducted prospective study included 180 pregnant women followed up in the outpatient clinic at the Department of Obstetrics and Gynecology, Gaziantep University, Turkey, between January 2014 and January 2015. The gestational age (GA) was estimated by early fetal ultrasound measures and last menstrual period. Routine fetal biometric parameters, fetal kidney length, and amniotic fluid index were measured. We studied the correlation between fetal kidney length, amniotic fluid index, and gestational age. The mean gestational age depending on last menstrual period and early ultrasound was 31.98 ± 4.29 (24-39 weeks). The mean kidney length was 35.66 ± 6.61 (19-49 mm). There was a significant correlation between gestational age and fetal kidney length ($r=0.947$, $p=0.001$). However, there was a moderate negative correlation between GA and AFI. Adding fetal kidney length to the routine biometrics improved the effectiveness of the model used to estimate GA ($R^2=0.965$ to $R^2=0.987$). Gestational age can be bet-

ter predicted by adding fetal kidney length to other routine parameters.

Joshi BR et al (2021) [29] performed study in 108 pregnant women with uncomplicated pregnancy to evaluate the efficacy of FKL as a measure to calculate the predicted gestational age. Gestational age ranged from 20 weeks to term. Only patient with known LMP, previous history of normal menstrual cycle and without any exclusion criteria were included in the study. The study showed mean fetal kidney length at 20-24, 25-29, 30- 34- and 35-37-weeks' gestation as 22.5 ± 0.5 , 26.9 ± 0.7 , 32.32 ± 0.7 and 36.3 ± 0.6 respectively. Overall, in combined second and third trimester, fetal kidney length showed strong linear correlation with gestation age with highest significant Pearson correlation coefficient of 0.989 as compared to other parameters (BPD=0.986, HC=0.976, AC=0.971, FL=0.984). Fetal kidney showed strongest linear correlation with clinical gestational age and it also demonstrated positive correlation with biparietal diameter, head circumference, abdominal circumference and femur length. Therefore, fetal kidney length can be used as a reliable parameter for determination of gestational age.

Akram M et al (2019) [30] conducted a cross sectional study on 399 pregnant women with singleton pregnancies having no complications at Baloch Hospital Lalian. Pregnant women with single fetuses underwent standard ultrasound fetal biometry. The fetal kidney length measurements were performed from 20th weeks to 38th weeks of gestation. These measurements were used to date the pregnancies. Results: A positive linear relationship was found between gestational age (measured by femur length) and length of left kidney. GA in weeks (measured by femur length) = $25.430 + 1.912$ (Left Kidney in cm) with $R^2 = 0.939$ and p value = $0.000 < 0.05$. Another statistically significant positive linear relationship was found between gestational age (measured by femur length) and length of right kidney. GA in weeks (measured by femur length) = $13.496 + 5.727$ (Right Kidney in cm) with $R^2 = 0.939$ and p value = $0.000 < 0.05$. Conclusion: FKL is easy to identify and measure. It is most accurate single parameter for estimating GA than other biometric indices especially in cases when the other parameters like BPD, FL, AC and HC are not reliable for assessing GA in the 2nd and 3rd trimester of pregnancy.

Shruthi BN (2017) [31] conducted a study on sixty singleton uncomplicated pregnant women of different parity underwent standard ultrasound examina-

tion for Fetal biometry like Bi-Parietal Diameter [BPD], Head Circumference [HC], Abdominal Circumference [AC], Femur Length [FL] and kidney length [bipolar] measurement in sagittal plane. The maximum kidney length was taken from upper pole to lower pole of any one Fetal kidney in sagittal plane, which was compared with GA obtained by LMP. The measurements obtained were statistically analyzed by interclass correlation coefficient by using IBM- SPSS trial version 21.0 software. There was a statistically significant positive correlation between the GA estimated by clinical method [LMP] and FKL. The interclass correlation coefficient was 0.79 with a 95% confidence interval of 0.67 to 0.87 [$p < 0.001$]. FKL could predict GA with an accuracy of ± 2.19 wks [95% CI 2.03 to 2.35 wks]. This proves that kidney length can be used as an additional parameter to confirm the GA and essential in detection of intrauterine kidney development and in the evaluation of fetal growth.

CONCLUSION

From this review we can conclude that there are good number of evidence to state that kidney length can be used as an additional parameter to confirm the GA and essential in detection of intrauterine kidney development and in the evaluation of fetal growth.

REFERENCES

1. Konje JC, Abrams KR, Bell SC et al. (2002): Determination of gestational age after the 24th week of gestation from fetal kidney length measurements. *Ultrasound Obstet Gynecol.*, 19(6):592-7.
2. Butt K (2014): Determination of gestational age by ultrasound. *J Obstet Gynaecol Canada*, 36(2):171-83.
3. Kaul I, Menia V, Anand AK et al. (2012): Role of Fetal Kidney Length in Estimation of Gestational Age. *JK Science*, 14(2): 65-69.
4. Gupta DP, Gupta HP, Saxena DK et al. (2013): Accuracy in estimation of gestational age in third trimester by fetal kidney length in Indian women. *Indian Journal of Clinical Practice*, 24(5): 459-463.
5. Yusuf N, Moslem F and Haque J (2009): Fetal Kidney Length: Can be a New Parameter for Determination of Gestational Age in 3rd Trimester. *TAJ: J of Teachers Assoc.*, 20(2):147-150.
6. Konje J.C., K.R. Abrams, S.C. Bell, D.J. (2002) Taylor. Determination of gestational age after the 24th week of gestation from fetal kidney length measurements. *Ultrasound Obstet Gynecol*;19: 592-597
7. Kansaria JJ and Parulekar SV (2009): Nomogram for Fetal Kidney Length. *Bombay Hospital Journal*, 51(2):155- 62.

8. Goyal L, Agarwal S, Chandra S et al. (2016): Fetal Kidney Length: A Useful Parameter For Ultrasonographic Gestational Age Calculation. *Natl J Integr Res Med.*, 7(1):55-58
9. Lobo ML, Favorito LA, Abidu-Figueiredo M et al. (2011): Renal pelvic diameters in human fetuses: Anatomical reference for diagnosis of fetal hydronephrosis. *Urology*, 77(2):452-7.
10. Indu, K .and Vinay, M. Amandeep, K, Anand, Renu Gupta (2012). Role of ultrasound in estimation of gestational age. Dept. of Obstetrics and Gynecology, Medical College and Associated Hospital, JK science 14(2), p 65-69.
11. Trish, C. and Thilaganathan, B. (2004), *Obstetric ultrasound. How, Why and When.* 3th e d. London: Elsevier, p109.
12. Nguyen, HT. Herndon CDA, Cooper C (2010) The society for fetal urology consensus statement on the evaluation and management of antenatal hydronephrosis. *Journal of Pediatric Urology*, (6) p212–231.
13. Gonzales J, Gonzales M, Mary JY. Size and weight study of human kidney growth velocity during the last three months of pregnancy. *Eur Urol.* 1980;6(1):37-44. doi: 10.1159/000473285. PMID: 7353577.
14. Lawson T.L., W. Dennis Foley, L.L. Berland, K.E. Clark. (1981) Ultrasonic evaluation of fetal kidneys. *Radiology*; 138: 153-156.
15. Jeanty, P. J et. al., (1984). Estimation of gestational age from measurements of fetal long bones, *J Ultrasound Med*, 3, 75-79.
16. Bertagnoli.L, Lalatta.F, Gallicchio.R et al. (1983) quantitative characterization of growth of fetal kidney. *J. Clinical ultrasound*; 11: 349-356.
17. Mahony, B. S., Callen, P. and Filly, A. R., (1985). The distal femoral epiphysal ossification center in the assessment of third trimester menstrual age: sonographic identification and measurement, *Radiology*, 155, 201-204.
18. Sampaio FJ, Mandarim-de-Lacerda CA, Prates JC. Allometric study of renal growth in human fetuses. *SurgRadiolAnat*1989; 11(1): 29- 31.
19. Cohen HL, Cooper J, Eisenberg P, et al. Normal length of fetal kidneys: sonographic study in 397 obstetric patients. *AJR Am J Roentgenol*1991;
20. Gloor JM, Breckle RJ, Gehrking WC, et al. Fetal renal growth evaluated by prenatal ultrasound examination. *MayoClinProc*1997; 72: 124-29.
21. Selim M Ansari, Madhusudan Saha et al . (1997) Ultrasonographic study of 793 fetuses: Measurement of normal Fetal kidney lengths in Bangladesh. *Australasian Radiology* ,41, 3-5.
22. Konje JC, Okaro CI, Bell SC, de Chazal R, Taylor et al. (1997). A cross sectional study of changes in fetal renal size with gestation in appropriate and small for gestational age fetuses. *Ultrasound bstet Gynecol*; 9: 35-7.
23. JJ Kansaria , SV Parulekar et al.(2009) Nomogram for Fetal Kidney Length Bombay Hospital Journal, Vol. 51, No. 2, 156-163.
24. Shanmughavadivu C.M (2014) evaluation of fetal kidney length measurement in estimation of gestational age in late trimester. department of obstetrics and gynecology, Medical university, Chengalpattu Medical college, India, April.
25. Divyasree B Reddy and Kanakapura B Suma (2017) correlation between fetal kidney length and fetal biometry for gestational age determination in third trimester in low-risk pregnancy. *Journal of South Asian federation of Obstetrics and Gynecology*,9(4) p 404-406.
26. Ramachandran K, Gnaneshwar A, Kumar RD, CR P, V SSK. Estimation of gestational age using Fetal kidney length during second and third trimester in south Indian population. *Biomedicine [Internet]*. 2021 Jan. 1 [cited 2022 Oct. 5];40(4):436-41. Available from: <https://bio-medicinonline.org/home/article/view/310>
27. Al-Mlah S, Nasef A, El-Masry H. Assessment of Fetal Kidney Length as a Parameter for Detection of Gestational Age at the Third Trimester of Pregnancy. *The Egyptian Journal of Hospital Medicine (April 2019) Vol. 75 (5), Page 2839-2844*
28. Ugur MG, Mustafa A, Ozcan HC, Tepe NB, Kurt H, Akcil E, Gunduz R. Fetal kidney length as a useful adjunct parameter for better determination of gestational age. *Saudi Med J.* 2016 May;37(5):533-7. doi: 10.15537/smj.2016.5.14225. PMID: 27146616; PMCID: PMC4880653.
29. Joshi BR, Chaurasia AK and Khanal UP. Determination of Gestational Age by Fetal Kidney Length Measurement after the 20th Week in Healthy Women with Uncomplicated Pregnancy in Tertiary Care Centre. *Austin J Radiol.* 2021; 8(1): 1121.
30. Akram, Muhammad & Farooqi, Umair & Arif, Naima & Riaz, Adeel & Yousaf, Muhammad & Fatima, Mehreen & Gilani, Syed Amir & Gilani, Syed. (2019). Estimation of Gestational Age from Fetal Kidney Length in the Second and Third Trimester of Pregnancy by Ultrasonography. *Saudi Pharmaceutical Journal.* 5. 222-229. DOI: 10.21276/sjmps.2019.5.3.10.
31. Shruthi B N, Vinay B S, Roopkala, Praveen. Determination of gestational age by fetal kidney length during 28-36 weeks of pregnancy by ultrasonography. *Natl J Clin Anat* 2017;6:162-7