Original Article

Evaluation of Fetal Kidney Length in Relation to Femur Length as an Accurate Method of Estimation of Gestational Age Between 24 and 34 Gestational Weeks

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ABSTRACT

Objectives: To assess how the Fetal Kidney Length (FKL) in single pregnancies between 24–34 weeks correlates with gestational age (GA) determined from the last menstrual period (LMP) and to compare this with GA estimates based on femur length.

Study Design: A prospective observational study.

Patients and Methods: In this forward-looking observational study, 330 expectant mothers between 24 and 34 weeks of gestation were examined using two-dimensional ultrasound technology.

Results: The average GA was 29 ± 3 weeks, with a range of 24 to 34 weeks. Femur length averaged 67.5 ± 6 mm, ranging from 54 to 79 mm. The lengths of the right and left kidneys, along with their average, were 33.5 ± 3 mm (range 27 to 40 mm), 34 ± 3 mm (range 27.4 to 40.6 mm), and 33.5 ± 3 mm (range 27 to 40.5 mm), respectively. The accuracy of predicting GA in the third trimester was higher with the mean kidney length (R2= 0.92) compared to femur length (R2 = 0.87). Although statistically significant, the difference in length between the right and left kidneys was minimal (0.5 mm) and deemed clinically negligible, with the left kidney being slightly larger.

Conclusion: FKL emerges as a reliable marker for use in ultrasound evaluations and prenatal visits, notably from the 24th to the 34th week of gestation. FKL is an effective predictor of the expected date of delivery (EDD).

Key Words: Early third trimester; femur length; fetal kidney length; gestational age; second trimester.

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INTRODUCTION

Determining fetal gestational age (FGA) accurately is crucial for predicting the expected date of delivery (EDD) and identifying birth defects early on[1]. Traditional measures of fetal growth, including average sac diameter, crown-rump length, biparietal diameter (BPD), femur length (FL), head circumference (HC), and abdominal circumference (AC), are utilized at various stages of pregnancy but tend to become less accurate as the pregnancy advances[2]. In the first trimester, crown-rump length and average sac diameter are the most dependable, BPD in the second trimester, and FL in the third trimester[3]. Fetal kidney length (FKL) has been suggested as a consistent indicator for assessing FGA and EDD, especially when combined with other fetal measurements[4]. Given that kidney development starts by the fourth week of gestation and it becomes operational around the 10th or 11th week, FKL measurements can begin from the 12th week. Nonetheless, FKL's utility in age estimation is primarily documented in the later stages of pregnancy, between the 20th and 41st weeks[5].

Al-Mlah and colleagues[6] investigated the effectiveness of using fetal kidney length to predict GA in single pregnancies. Their findings suggest a strong correlation between kidney size and GA, indicating that kidney measurements can be a reliable method for estimating GA, especially when menstrual histories are unclear. In the third trimester, both kidneys are readily observable via ultrasound, allowing for precise and distinct measurements of each kidney. They noted a consistent difference in size between the right and left kidneys throughout pregnancy, with the left kidney typically being larger. Therefore, they recommend measuring both kidneys, as the size of one cannot accurately represent the other. The average kidney length measurement proves to be a valuable tool in determining GA.

Akram and colleagues[7] evaluated the importance of FKL in estimating GA. They found FKL to be an easily identifiable and measurable parameter that is more accurate than other biometric indicators such as BPD, FL, AC, and HC for assessing GA during the second and third trimesters, particularly when other parameters are unreliable.

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This study aimed to explore the relationship between fetal kidney length in normal singleton pregnancies during the late second and early third trimesters (24–34 weeks) and GA determined from the last menstrual period (LMP), and to compare this with GA estimated from femur length.

PATIENTS AND METHODS

Study design and population

This study, designed as a prospective observational investigation, was conducted in the Obstetrical and Gynecological department of Benha University hospitals, including both inpatient wards and outpatient clinics, from January 2023 to January 2024. The study aimed to include 330 women attending the outpatient clinic for antenatal care, with selection criteria focusing on those between the ages of 20 and 35 years, having a Body Mass Index (BMI) less than 30 kg/m^2, and in the late second to early third trimesters of pregnancy (24 – 34 weeks). Eligible participants were those with regular menstrual cycles, confident in their LMP dates, supported by consistent cycle patterns in the three months preceding pregnancy without hormonal contraceptive use, and with pregnancy dates confirmed by first trimester ultrasound based on crown-rump length (CRL). Furthermore, participants were required to have a normal, uncomplicated, viable singleton pregnancy with both fetal kidneys clearly visible and no abnormal morphology detected on ultrasound.

Cases were excluded from the study if they were uncertain of their LMP, involved in multiple gestations, had pregnancy complications such as diabetes mellitus, hypertension, or intrauterine growth retardation, had conditions like polyhydramnios or oligohydramnios, or if there were indications of potential fetal chromosomal or congenital anomalies, including abnormal renal morphology (such as nephromegaly, agenesis, hypoplasia, cysts, polycystic kidney disease, hydronephrosis, or dilated renal pelvis greater than 4mm), or if the adrenal or renal borders were not well-defined.

Ethical considerations for the study included obtaining approval from the Ethical Scientific Committee of Benha University, securing informed written consent from all participants, and acquiring the necessary administrative permissions to conduct the research.

Methods

In the study, all participating women underwent a thorough evaluation process that included:

A) History Collection

A detailed history was gathered with a particular focus on the patient's menstrual history and the date of the LMP to confirm GA. The expected EDD was calculated using Naegle's formula, which adds 7 days and 9 months to the first day of the LMP.

B) Ultrasound Examination

Patients were examined using a GE Logiq P5 ultrasound machine. Routine sonographic evaluations were conducted from the first trimester onwards. The GA was estimated using Headlock's formula based on femur length and other fetal biometric indices, with all data meticulously recorded. Renal length measurements were also taken during these scans.

C) Kidney Length Measurement

The procedure for measuring kidney length involved first identifying a satisfactory transverse plane of the fetus at the level of the four heart chambers. The ultrasound probe was then moved caudally in a transverse section just below the abdominal circumference measurement level to locate the kidneys.

Upon locating the kidneys, the probe was rotated longitudinally until the full length of the kidney could be clearly seen for measurement.

The largest longitudinal image displaying both the superior and inferior outer poles of each kidney was captured and frozen on the monitor screen. Using electronic calipers, the kidney length was measured from the superior outer pole to the inferior outer pole.

Measurements were taken for both the right and left kidneys, with careful attention to exclude the adrenal glands from the measurements. (Figures 1,2).

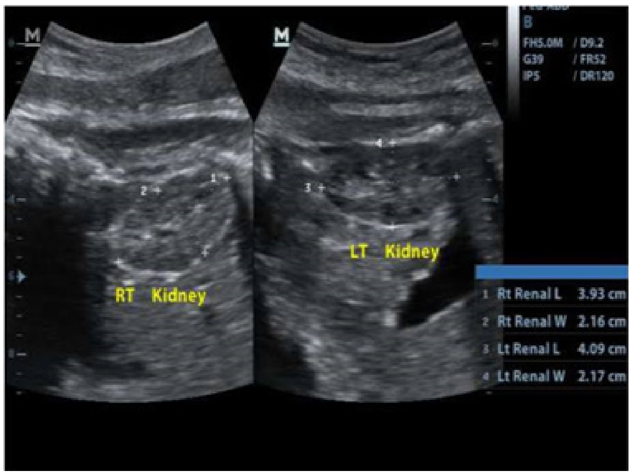

Fig. 1: Measurement of fetal kidney (left and right). BMC medical imaging

Fig. 2: 25 years 3rd GP2 NVD 32 weeks fetal kidney length 38.1 mm

These measurements were then compared to GAs determined by LMP and mean fetal kidney length, as well as other fetal biometric indices, to assess their correlation and accuracy in estimating GA.

Statistical Analysis

The collected data were verified and processed using Epi-Info software version 6 and SPSS for Windows version 8. The significance level for all statistical analyses conducted was set at a 5% threshold (*p-value*).

RESULTS

(Table 1) presents the demographic details and ultrasound findings of the participants in the study. Of the 330 individuals involved, 129 (39.09%) had no previous births (nulliparous), and 201 (60.91%) had given birth before (parous). The average age was 27.5 years, with a standard deviation (SD) of 4 years, spanning from 18 to 35 years. The average GA was 29 weeks, with an SD of 3 weeks, ranging from 24 to 34 weeks.

Table 1: Demographic and sonographic characteristics of the study population

Variable	Mean ± SD (range)
Age (years)	27.5 ± 4 (18-35)
Parity	
Nulliparous	129 (39.09%)
Parous	201 (60.91%)
Gestational age by CRL (weeks)*	29 ± 3 (24-34)
Femur length (mm)	67.5 ± 6 (54-79)
Right fetal kidney length (mm)	33.5 ± 3 (27-40)
Left fetal kidney length (mm)	34 ± 3 (27.4-40.6)
Average fetal kidney length (mm)	33.5 ± 3 (27-40.5)

SD = Standard Deviation, *Measured between 7 and 11 weeks

The average femur length measured was 67.5 mm, with an SD of 6 mm, and varied between 54 to 79 mm. The average lengths for the right and left kidneys, as well as the combined average kidney length, were 33.5 mm (SD = 3 mm, range 27 to 40 mm), 34 mm (SD = 3 mm, range 27.4 to 40.6 mm), and 33.5 mm (SD = 3 mm, range 27 to 40.5 mm) respectively.

(Table 2) compares the lengths of the right and left fetal kidneys, showing a statistically significant yet clinically negligible difference between them (mean difference = 0.5 mm, standard error (SE) = 0.01, 95% confidence interval (CI) = 0.48 to 0.52 mm).

Table 2: Comparison between right or left fetal kidney length

Variable	Right side	Left side	Mean difference	SE	95%CI	*p-value**
FKL (mm)	33.5 ± 2.8	34 ± 2.9	0.5	0.01	0.48 to 0.52	< 0.001

SE = Standard Error, 95CI = 95% Confidence Interval, *Paired-samples t-test

(Table 3) compares the precision of GA predictions using femur length versus average fetal kidney length. The results indicate a statistically significant difference (F = 1.59, $p = 0.01$), with the average fetal kidney length providing a more accurate estimation of GA than femur length.

Table 3: Comparison of the standard error of estimate for predicted gestational age using femur length or average fetal kidney length

Measure of accuracy	redictor			
	Femur length	Mean fetal kidney length	F	*p-value**
Standard error of the estimate	1.04	0.82	1.59	0.01

F= F-statistic, standard error of the estimate = Root Mean Square Error (RMSE) = SD of residuals, *Variance ratio test (F-test).

DISCUSSION

This research encompassed 330 participants, with 129 (39.09%) having no previous pregnancies (nulliparous) and 201 (60.91%) having had at least one pregnancy (parous). The participants' ages averaged 27.5 years, with a standard deviation (SD) of 4 years, ranging from 18 to 35 years, and their GAs averaged 29 weeks, with an SD of 3 weeks, spanning 24 to 34 weeks. Tawfik *et al*. conducted a similar investigation, focusing on the fetal kidney length in singleton pregnancies during the late second and early third trimesters, finding an average age of 26.31 years with a deviation of 4.87 years among the women studied[8].

Mahima Sophia and colleagues explored the use of FKL to determine GA across various stages of pregnancy, involving 160 women whose pregnancies ranged from 18 to 38 weeks. A significant portion of these women (127 out of 160, or 79.37%) were between 20 and 34 years old[1].

Our findings indicated that the average GA was 29 weeks, with an SD of 3 weeks, similar to Tawfik *et al*., who reported an average GA of 30.29 weeks with an SD of 3.34 weeks. In our study, the femur length averaged 67.5 mm (SD = 6 mm, range 54 to 79 mm), and the kidney lengths (right and left, as well as the overall average) measured consistently around 33.5 to 34 mm, with slight variations. In contrast, Tawfik *et al*. reported an average fetal kidney length of 29.88 mm with an SD of 3.33 mm[8].

Mahima Sophia and their team observed that the average FKL varied from 16.50 mm at the lowest to 38.20 mm at the highest, with weekly increments of approximately 1 mm from the 18th to the 35th week, demonstrating a steady and correlated growth. These findings were substantiated by significant statistical increases and positive correlations, particularly between the 18^{th} and 24^{th} weeks, in relation to femur length[1].

Our analysis revealed that the average fetal kidney length, with an R-squared value of 0.92, offers a more precise estimate of GA in the third trimester compared to femur length, which has an R-squared value of 0.87. Although we observed a statistically significant difference in size between the right and left kidneys, the slight variance (0.5 mm) was deemed too minor to hold clinical significance, with the left kidney generally being slightly larger than the right.

Our findings align with those of Konje *et al*., who assessed the use of kidney length measurements for estimating GA from weeks 24 to 38, comparing its precision against other fetal biometric markers. Their study concluded that fetal kidney length offers a more accurate estimation of GA compared to traditional measurements like biparietal diameter, head circumference, abdominal circumference, and femur length. They noted that the standard deviation for fetal kidney length was 10.29 days, compared to 10.96 days for femur length, highlighting the superior accuracy of fetal kidney length[9].

However, our results diverged from Konje *et al*. concerning the differences in length between the right and left kidneys; they found no significant disparity, contrasting with our observation of a statistically significant yet clinically negligible difference[9]. Mahima Sophia and colleagues observed that fetal kidney length consistently increases until 30 weeks of gestation, supporting its utility in accurately estimating GA[1].

In our research, although we identified a significant difference between the lengths of the right and left kidneys, the difference was deemed too minor for clinical relevance. Echoing our findings, Shivalingaiah and team discovered a strong correlation between fetal kidney length and GA across trimesters, including in cases of IUGR, with a correlation coefficient (r) of 0.85. They demonstrated that kidney length had the smallest mean deviation from GA when compared to all other parameters, affirming its accuracy in GA estimation as nearly equivalent to the collective accuracy of all ultrasound biometric measurements[10].

Manasvi and colleagues assessed the precision of using average fetal kidney length to estimate GA in the third trimester. They discovered that the mean fetal kidney length closely correlates with GA, significantly more so than other metrics, evidenced by a highly significant *p-value* ($p < 0.0001$). Their findings suggest that mean fetal kidney length could serve as a reliable sole indicator for determining GA during the third trimester. The primary distinction between their study and ours lies in the basis for calculating GA; they used the LMP, whereas our study utilized the crown-rump length (CRL)[11].

Das *et al*. conducted research to define standard ranges for FKL during the third trimester and examined its accuracy against traditional biometric measurements. After assessing conventional biometrics, they measured FKL and analyzed its correlation with GA, comparing its effectiveness to other metrics[2]. They reported a Pearson's correlation coefficient of 0.907 between FKL and GA, indicating a very strong correlation. AC came close with a correlation of 0.901, and TL had a correlation of 0.879 with GA, suggesting all these parameters strongly correlate with GA, with FKL being the most accurate single measure. However, their findings contrast with the current Canadian Obstetric Ultrasound guidelines, which advocate FL as more precise than AC in the third trimester[12].

Differing from our findings, Kumar *et al*. conducted a study comparing the effectiveness of fetal kidney length, BPD, and FL for estimating GA. They determined that the best model for predicting fetal GA ranked FL as the most accurate, followed by kidney length, and then BPD, with standard errors of 3.85 days, 8.04 days, and 8.75 days, respectively. Notably, their research spanned a broad gestational period from 18 to 38 weeks, in contrast to our focus solely on the third trimester starting from 28 weeks[13].

Moreover, Kumar *et al*. identified FL as the most precise single measurement for estimating GA, which contrasts with the Canadian Obstetric Ultrasound guidelines[13]. According to Butt and Lim, HC is the most accurate in the second trimester, a parameter Kumar *et al*.'s study did not evaluate. They also found BPD to be the least accurate measurement, a conclusion at odds with our research[12].

Goyal *et al*.[14] also examined fetal kidney length, both as a standalone measure and in conjunction with other biometric parameters, aligning with Kumar *et al*.'s conclusion and differing from ours by suggesting FL as the most accurate single parameter, followed by FKL, with BPD ranked as the least accurate. Their study paralleled Kumar *et al*.'s in terms of the GA range covered but showed variations in the standard deviation of accuracy for each parameter[13]. Additionally, Goyal *et al*. concluded that the most precise GA estimates result from combining FKL with FL and BPD[14].

Joshi *et al*. observed that FKL measurements in millimeters matched the gestational week during the first and early second trimesters, exemplified by a 22 mm measurement at 22 weeks[15]. Edevbie and Akhigbe noted that FKL measurements corresponded with gestational weeks from 20 to 36, yet found no matching FKL values towards the end of gestation. Ugur *et al*. identified a positive correlation between FKL and GA, deeming it a reliable indicator for predicting delivery dates in later stages of pregnancy[5]. Conversely, Cohen *et al*. discovered no correlation between FKL and GA when calculating the expected EDD, emphasizing the necessity for accurate FKL measurements to rule out abnormal fetal growth[16].

Shivalingaiah *et al*. demonstrated that FKL was strongly correlated with all standard fetal biometric parameters, except AC, highlighting that FL at 24 weeks and BPD at 36 weeks did not correlate with FKL[10]. Edevbie and Akhigbe further stated that GA as estimated by FKL showed a linear correlation with ages calculated from BPD, FL, AC, and HC[5].

Akintomide and Efanga found positive correlations between HC, FL, and FKL in estimating the EDD[17]. Toosi and Rezaie-Delu conducted a cross-sectional study with 92 pregnant women to assess normal fetal kidney length and its relationship with GA. Through univariate and multivariate linear regression analyses, they developed a predictive model using KL alongside other fetal biometry parameters to estimate GA. They concluded that the most accurate prediction of GA was achieved by a composite measure incorporating HC, fetal BPD, femur length, and KL, demonstrating that combining KL measurements with other fetal biometrics could enhance the precision of pregnancy age predictions[18].

Shivalingaiah and colleagues highlighted a strong link between fetal kidney length and GA in the later stages of pregnancy, including in fetuses with IUGR, with a correlation coefficient of 0.85. Their research focused on 60 pregnant women between 24 and 36 weeks of gestation, all of whom had their pregnancies precisely dated by an early scan. Measurements of the closer kidney were taken every four weeks in the longitudinal axis, alongside other biometric indices. Their findings revealed that kidney length had the smallest mean deviation from the GA across all weeks, indicating a strong correlation between measured kidney length and the assigned GA, comparable to the combined accuracy of all ultrasound biometric parameters[10].

Mahima Sophia and co-researchers found that including FKL with standard fetal biometrics, such as FL, significantly improves the precision of FGA and expected EDD calculations during the early second trimester. This approach was also useful in the early detection of fetal anomalies[1].

Our analysis demonstrated that the average fetal kidney length offers greater precision than femur length in predicting GA. Tawfik *et al*. observed a significant correlation between GA determined by date and both FL and FKL, with the latter explaining up to 93% of the variance in GA (R2= 0.93), compared to FL's 89% (R2= 0.89). The mean fetal kidney length showcased the most accurate predictive model, characterized by the highest slope (0.97), the lowest intercept (1.56), and the highest adjusted R2 (0.93). Consequently, they concluded that mean fetal kidney length, particularly when used alongside femur length, serves as a highly accurate new metric for estimating GA, especially in the late second and early third trimesters[8].

Nasr AdDeen and colleagues conducted a study to evaluate the precision of using fetal kidney length compared to FL for estimating GA during the third trimester. Their findings indicated that the GA estimated from FL had an accuracy within ±1.04 weeks and showed a good fit overall. Meanwhile, the GA derived from mean kidney length (MKL) demonstrated a higher accuracy, within ±0.82 weeks, and also showed a good overall fit. The study concluded that fetal kidney length exhibits a strong correlation with GA in the later stages of pregnancy[19].

CONCLUSIONS

In summary, accurately determining FGA is crucial for obstetricians to predict the expected date of delivery, identify congenital abnormalities, and ensure high-quality maternal care. Beyond traditional fetal biometric measurements, FKL emerges as a valuable metric during ultrasound and prenatal visits, particularly in the later second and early third trimesters, from the 24th to the 34th weeks. FKL has proven to be a reliable predictor of the expected date of delivery.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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