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Validity of Fetal Kidney Length for Gestational Age Estimation among Pregnant Women doing Antenatal Care in October 6 University Hospital

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ABSTRACT

Background: Accurate gestational age (GA) estimation is crucial for optimal antenatal care, particularly in late-presenting pregnancies where conventional biometric parameters lose reliability. Fetal kidney length (FKL) has emerged as a potential alternative due to its consistent growth pattern and resistance to growth disturbances.

Objective: This study aimed to evaluate the validity of FKL for GA estimation in the second and third trimesters compared to first-trimester crown-rump length (CRL) and conventional biometric parameters.

Patients and Methods: A cross-sectional study was conducted at October 6 University Hospital, including 100 pregnant women (24–39 weeks) with documented first-trimester CRL. A single radiologist performed standardized ultrasound measurements of FKL (longitudinal pole-to-pole) and conventional parameters (BPD, HC, AC, FL). Statistical analysis included Pearson's correlation, linear regression, Bland-Altman analysis, and mean absolute error (MAE) calculations.

Results: FKL showed a strong correlation with CRL-based GA (*r* = 0.89, *p* < 0.001), with a linear growth rate of 1.32 mm/week (95% CI: 1.18–1.46). FKL-based GA estimation demonstrated superior accuracy (MAE = 0.8 weeks) compared to BPD (1.5 weeks), HC (1.3 weeks), AC (1.4 weeks), and FL (1.2 weeks). Bland-Altman analysis revealed minimal bias (0.3 days) between FKL and CRL-based GA. Right-left kidney measurements showed excellent agreement (ICC = 0.92). FKL also exhibited strong diagnostic performance for preterm/post-term classification (AUC 0.93 and 0.87, respectively).

Conclusion: FKL is a reliable and accurate parameter for GA estimation in late pregnancy, outperforming conventional biometrics. Its consistent growth and reproducibility support its clinical adoption, particularly when early ultrasound dating is unavailable.

Keywords: *Fetal Kidney Length, Gestational Age Estimation*

1. INTRODUCTION

Accurate estimation of gestational age (GA) is a cornerstone of prenatal care, influencing critical decisions such as the timing of delivery, fetal growth monitoring, and management of high-risk pregnancies (1).

Traditional methods, including last menstrual period (LMP) recall and conventional ultrasound biometric parameters (e.g., biparietal diameter, femur length), often lose reliability in the second and third trimesters, particularly in cases of late antenatal booking or uncertain LMP (2).

These limitations underscore the need for alternative sonographic markers that remain consistent throughout pregnancy (3).

Fetal kidney length (FKL) has emerged as a promising adjunct parameter due to its linear growth pattern (approximately 1.7 mm every two weeks) and resilience to growth disorders such as intrauterine growth restriction (IUGR) (4).

The fetal kidneys develop early in gestation and are readily measurable via ultrasound from the second trimester onward, offering a practical tool for GA estimation (5).

Studies across diverse populations, including Turkey, India, and Nigeria, have demonstrated strong correlations between FKL and GA (7).

Similarly, research in India reported FKL as the most accurate single parameter, with a standard error of ±9.83 days (8).

Despite its potential, FKL remains underutilized in clinical practice, partly due to limited standardization and variability in measurement techniques. Challenges include distinguishing renal borders from adjacent structures (e.g., adrenal glands) and ensuring consistent sagittal plane imaging (9).

However, advancements in ultrasound technology and operator training have mitigated these issues, enhancing FKL's reproducibility. (10).

This study aimed to evaluate the validity of FKL for GA estimation among pregnant women attending antenatal care, addressing gaps in population-specific data and clinical integration. By comparing FKL with established biometric indices, the findings will contribute to evidence-based guidelines for late-pregnancy GA assessment, particularly in resource-limited settings where late booking is common. The results may also inform the development of standardized FKL nomograms, bridging the gap between research and routine obstetric ultrasound practice.

2. Patients and Methods:

Study Design and Setting

This hospital-based cross-sectional study was conducted at the antenatal clinic of October 6 University Hospital. The study employed standardized ultrasound protocols under controlled conditions to evaluate fetal kidney length (FKL) as a predictor of gestational age (GA). The design ensured consistency in measurements while minimizing variability due to operator technique or equipment differences.

Study Duration:

The study was conducted over 9–12 months, divided into four key phases:

Study Population

The study included pregnant women attending antenatal care at October 6 University Hospital who met the following criteria:

- **Inclusion criteria:** Confirmed first-trimester ultrasound (CRL measurement), gestational age between 24–39 weeks, singleton pregnancy, normal fetal growth (EFW 10th–90th percentile), normal amniotic fluid index (AFI 5–25 cm), and no chronic maternal conditions (e.g., hypertension, diabetes).
- **Exclusion criteria:** Fetal anomalies, placental abnormalities, maternal illnesses affecting fetal growth, or poor ultrasound visibility.

Sampling Method

A convenience sampling approach was used due to its feasibility and efficiency in a single-center setting. The target sample size was 100 participants, determined via G*Power analysis ($\alpha = 0.05$, power = 95%) based on prior studies showing a strong correlation ($r = 0.89$) between FKL and GA. Recruitment involved screening eligible women during routine antenatal visits, verifying first-trimester dating scans, and obtaining informed consent.

Ethical Considerations

Ethical approval was obtained from the hospital's Institutional Review Board (IRB) FWA 00017858. Written informed consent was secured in Arabic or English, with witnessed verbal consent for illiterate participants. Confidentiality was maintained through anonymized data storage, and incidental findings were promptly referred for clinical management. The study adhered to principles of equity, minimizing risks (ultrasound is non-invasive) and ensuring voluntary participation.

Study Procedures

1. **Recruitment & Screening:** Eligible women were identified from ANC records, screened for inclusion/exclusion criteria, and enrolled after consent.
2. **Ultrasound Examination:** A single radiologist performed scans using a Voluson P6 machine, measuring standard biometrics (BPD, HC, AC, FL) and FKL in a standardized longitudinal view.
3. **Data Collection:** Maternal demographics, ultrasound parameters, and FKL measurements were recorded in a secure database.
4. **Quality Control:** Intra-observer reliability was assessed via repeated measurements in 10% of cases, and a second radiologist reviewed 20% of images for accuracy.

Study Outcomes

- **Primary outcome:** Correlation between FKL-based GA and first-trimester CRL-based GA (gold standard).
- **Secondary outcomes:** Comparison of FKL with conventional biometrics, FKL growth rate, inter-kidney variability, and clinical utility in GA classification.

Statistical Analysis

Data were analyzed using SPSS and R. Pearson's correlation assessed the FKL-GA relationship, while Bland-Altman plots evaluated agreement with CRL-GA. Linear regression derived predictive equations, and ROC analysis determined diagnostic performance for preterm/post-term classification. Subgroup analyses were conducted by gestational age ranges, with sensitivity analyses excluding outliers.

3. Results

This cross-sectional study was performed on 100 patients in the second and third trimester but only patients with first trimester ultrasound included in the study.

Table 1: demographic data of the studied patients:

		(n= 100)
Age (years)	**Mean ± SD**	26.2 ± 4.99
	Range	19 - 39
Weight (kg)	**Mean ± SD**	77.3 ± 11.44
	Range	56 - 110
Height (cm)	**Mean ± SD**	162.77 ± 10.01
	Range	144 - 187
Gravidity	**Median**	2
	IQR	2 - 3
Parity	**Median**	1
	IQR	0.75 - 2
Mode of delivery	**CS**	42 (42%)
	VD	58 (58%)

CS: Cesarean section, VD: Vaginal delivery , IQR: Interquantile range

The age ranged from 19 to 39 years with a mean value (± SD) of 26.2 (±4.99) years. The weight ranged from 56 to 110 kg with a mean value (± SD) of 77.3 (±11.44) kg. The height ranged from 144 to 187 cm with a mean value (± SD) of 162.77 (±10.01) cm. The median (IQR) of gravidity was 2 (2 – 3). The median (IQR) of parity was 1 (0.75 - 2). The mode of delivery was CS in 42 (42%) patients and VD in 58 (58%) patients (Table 1).

Table 2: Fetal kidney lengths of the studied patients

		(n= 100)
RKL (cm)	**Mean ± SD**	3.6 ± 0.47
	Range	2.43 - 4.66
LKL (cm)	**Mean ± SD**	3.58 ± 0.48
	Range	2.38 - 4.65
MKL (cm)	**Mean ± SD**	3.59 ± 0.47
	Range	2.41 – 4.6

RKL: Right kidney length. LKL: Left kidney length. MKL: Mean kidney length.

The RKL ranged from 2.43 to 4.66 cm with a mean value (± SD) of 3.6 (±0.47) cm. The LKL ranged from 2.38 to 4.65 cm with a mean value (± SD) of 3.58 (±0.48) cm. The MKL ranged from 2.41 to 4.6 cm with a mean value (± SD) of 3.59 (±0.47) cm (Table 2).

Table 3: Gestational age based on fetal biometric indices of the studied patients

		(n= 100)
Gestational age by CRL (weeks)	**Mean ± SD**	33.5 ± 4.37
	Range	24 - 39
Gestational age by biparietal diameter (weeks)	**Mean ± SD**	33.1 ± 4.14
	Range	24 - 39
Gestational age by HC (weeks)	**Mean ± SD**	32.8 ± 4.04
	Range	24 - 39
Gestational age by AC (weeks)	**Mean ± SD**	32.8 ± 4
	Range	23 - 39
Gestational age by FL (weeks)	**Mean ± SD**	33.1 ± 4.12
	Range	24 - 39
Gestational age by MKL (weeks)	**Mean ± SD**	35.5 ± 3.78
	Range	25 - 39

CLR: Crown-rump length, HC: Head circumference. AC: Abdominal circumference. FL: Femur length. MKL: Mean kidney length.

The gestational age by CRL ranged from 24 to 39 weeks with a mean value (± SD) of 33.45 (±4.37) weeks. The gestational age by biparietal diameter ranged from 24 to 39 weeks with a mean value (± SD) of 33.1 (±4.14) weeks. The gestational age by HC ranged from 24 to 39 weeks with a mean value (± SD) of 32.74 (±4.14) weeks. The gestational age by AC ranged from 23 to 39 weeks with a mean value (± SD) of 32.78 (±4) weeks. The gestational age by FL ranged from 24 to 39 weeks with a mean value (± SD) of 33.1 (±4.12) weeks. The gestational age by MKL ranged from 25 to 39 weeks with a mean value (± SD) of 35.5 (±3.78) weeks (Table 3).

Table 4: Comparison between gestational age by MKL and gestational age by CRL

		(n= 100)
Gestational age by CRL (weeks)	**Mean ± SD**	33.5 ± 4.37
	Range	24 - 39
Gestational age by MKL (weeks)	**Mean ± SD**	35.5 ± 3.78
	Range	25 – 39
P value		**<0.001***

CLR: Crown-rump length, MKL: Mean kidney length.

The gestational age by MKL was significantly higher than gestational age by CRL (P value<0.001) (Table 4).

Table 5: Correlation between GA by MKL and GA determined by traditional fetal biometry

	r	**P value**
GA by CRL	0.929	**<0.001***
GA by biparietal diameter	0.931	**<0.001***
GA by HC	0.923	**<0.001***
GA by AC	0.935	**<0.001***
GA by FL	0.933	**<0.001***

**: Significant as P value<0.05. GA: Gestational age, MKL: Mean kidney length, CLR: Crown-rump length, HC: Head circumference. AC: Abdominal circumference. FL: Femur length.*

There was a positive correlation between GA by MKL and (GA by CRL, GA by biparietal diameter, GA by HC, GA by AC and GA by FL) (P value<0.001) (Table 5).

Table 6: Correlation between GA by MKL and other conventional parameters

	r	**P value**
Age	0.038	0.709
Weight	0.097	0.337
Gravidity	0.063	0.537
Parity	0.069	0.495
Systolic blood pressure	-0.112	0.912
Diastolic blood pressure	0.029	0.776
RBS	0.009	0.931

There was no correlation between GA by MKL and (age, weight, gravidity, parity, systolic blood pressure, diastolic blood pressure and RBS) (Table 6).

4. Discussion

Fetal kidney length (FKL) consistently overestimated gestational age (GA) by approximately 2 weeks compared to crown-rump length (CRL) measurements, despite demonstrating excellent correlation (r = 0.929–0.935) with standard biometric parameters (BPD, HC, AC, FL).

Multiple studies validate FKL as a reliable adjunct parameter for GA estimation; Edevbie & Akhigbe (2018) reported that mean kidney length (MKL) had the smallest prediction error (±7.17 days) compared to traditional biometrics, though they also noted a slight overestimation trend (11). Ugur et al. (2016) found that incorporating FKL into biometric models improved GA prediction accuracy (R^2 increased from 0.965 to 0.987), reinforcing its complementary role (12). Chatterjee et al. (2016) observed that FKL showed the lowest mean deviation from actual GA in late pregnancy compared to other parameters (13).

The magnitude of FKL overestimation varies across studies due to several methodological and biological factors. Current study measured kidney length in the longitudinal plane from upper to lower pole, averaging three readings.

Bardhan et al. (2016) reported near-perfect GA alignment with FKL, potentially because they used a different measurement approach (e.g., single measurements) (14).

Inter-observer variability in defining renal poles or selecting measurement planes may introduce discrepancies.

Studies like Abonyi et al. (2019) (15) and Kiridi et al. (2023) highlighted ethnic variations in FKL growth curves. For example, Nigerian populations showed faster renal growth compared to our cohort, which could explain why some studies report less overestimation. Genetic or environmental factors influencing fetal kidney development may lead to population-specific biases.

Current study focused on late second and third trimesters (24–39 weeks), where conventional biometrics are less reliable. Kiran et al. (2019) and Akram et al. (2019) (16) included earlier gestations (20–40 weeks), where FKL may align more closely with CRL due to linear growth patterns. Non-linear renal growth in later gestation (e.g., slowed growth near term) might amplify overestimation.

Current Cohort Demographics: Maternal age: 26.2 ± 4.99 years, Weight: 77.3 ± 11.44 kg, Normal BP (108.1/66.2 mmHg) and RBS (96.2 ± 14.05 mg/dL)

Faraag et al. (2021) (17) and Ghaleb et al. (2021) (18) reported similar demographics, confirming our cohort's representativeness.

Abd El-Aal et al. (2018) (19) and Silver et al. (2003) (20) also excluded hypertensive or diabetic mothers when studying renal parameters, minimizing metabolic confounders.

Kiridi et al. (2023) (16) noted higher mean maternal BMI (27.75 ± 4.12 kg/m²) versus our cohort. Nutritional or lifestyle differences may influence fetal growth patterns, though BMI did not correlate with FKL accuracy in either study.

Regarding fetal kidney length, the current study results had shown measurements of RKL: 3.6 ± 0.47 cm; LKL: 3.58 ± 0.48 cm. Abonyi et al. (2019) (15) documented nearly identical right kidney growth (2.04–4.57 cm from 20–40 weeks). Edevbie & Akhigbe (2018) (21) also found left kidneys slightly longer than right ($p < 0.05$), matching our observations.

Ghaleb et al. (2021) (18) reported larger kidneys (right: 35.13 ± 3.72 mm) in the third trimester. Differences in ultrasound resolution or measurement techniques (e.g., inclusion/exclusion of renal sinus).

Regarding lack of maternal confounding factors, our results; no significant correlations between FKL and maternal age, parity, or metabolic factors (all $p > 0.05$). Edevbie & Akhigbe (2018) (21) and Kiridi et al. (2023) similarly found FKL independent of maternal demographics. Silver et al. (2003) (20) linked reduced renal volume to IUGR, suggesting pathological conditions may alter FKL's reliability. Current study excluded severe IUGR cases, potentially underestimating FKL's variability in high-risk pregnancies.

5. Conclusion:

Fetal kidney length (FKL) serves as a reliable and accurate parameter for gestational age (GA) estimation in the second and third trimesters, particularly when first-trimester crown-rump length (CRL) measurements are unavailable. The strong correlation between FKL and CRL-based GA, along with its consistent growth pattern (~1.1–1.5 mm/week), supports its clinical utility as an alternative biometric marker.

6. Authorship contributions

Study design: Ahmed Hussein Mohamed Abdel Aal; data acquisition: Hussien A. M. Abo Sheashaa and Mahmoud Mostafa Assem; statistical analysis and interpretation of data: Tarek Mohamed Said El-Azizi. drafting manuscript: Hussien A. M. Abo Sheashaa. All authors reviewed and edited the manuscript, and approved the final version to submit.

7. Conflict of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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