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Fetal Kidney Size and Gestational Age Estimation: Enhancing Accuracy in Prenatal Ultrasound Assessment

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Abstract
Accurate gestational age estimation during the second and third trimesters remains challenging, This study evaluates fetal kidney length (FKL) as a reliable marker for estimating gestational age during the second and third trimesters. This prospective study was conducted involving 100 healthy singleton pregnant women with normal ultrasound findings, ranging from 20-39 weeks of gestation. Fetal kidney length was measured in the sagittal plane using a 3.5 MHz transducer, ensuring full visualization of the kidney, including the renal pelvis. Standard fetal biometric parameters, including biparietal diameter (BPD), femur length (FL), head circumference (HC) and abdominal circumference (AC), were also recorded. The right and left kidney lengths were compared and the combined kidney length was analyzed against gestational age. The study demonstrated a significant linear increase in mean fetal kidney length with advancing gestational age. The mean combined kidney length was strongly correlated with gestational age ($r=0.89$, $p<0.001$), with similar high correlations observed for BPD ($r=0.86$, $p<0.001$), HC ($r=0.85$, $p<0.001$), FL ($r=0.84$, $p<0.001$) and AC ($r=0.83$, $p<0.001$). The regression analysis revealed that fetal kidney length is a significant predictor of gestational age, with a regression coefficient (ß) of 0.455 ($p<0.001$) for combined kidney length. Fetal kidney length is a reliable marker for estimating gestational age in the second and third trimesters. The linear growth pattern of fetal kidneys provides a valuable biometric parameter that can enhance the accuracy of gestational age assessments, particularly in cases where other measures may be less reliable.

INTRODUCTION

Aims and Objectives:

Aims: The objective of this study is to assess the fetal kidney length via antenatal ultrasound as a potentially reliable direct parameter for estimating gestational age during the second and third trimesters[1].

Objectives: To determine gestational age by fetal kidney length measurement after the 20-39 week of gestation in healthy women with uncomplicated pregnancy[2].

MATERIALS AND METHODS

This prospective study was conducted involving 100 healthy singleton pregnant women with normal ultrasound findings, ranging from 20-39 weeks of gestation, referred from the Obstetrics and gynecology department of Sree Mookambika institute of medical sciences. Study was performed from October 2024 till December 2024. It was done after ethical clearance from the Institutional Review Board, Sree Mookambika institute of medical sciences[3]. Oral informed consent was obtained from all the participants. Any pregnancies with known complications like IUGR, poly or oligohydramnios, maternal diabetes mellitus, unreliable LMP or without first trimester dating scan including multiple pregnancies were excluded from study[4]. In presence of prominent/dilated renal pelvis of >5 mm were arbitrarily excluded from the study. Ultrasound scans were performed trans abdominally, with the patient lying supine and the abdomen and pelvis exposed, adequate ultrasound gel was applied to the lower anterior abdominal wall/pelvis. Obstetric ultrasound scans were performed using SEIMENS ultrasound scanner using a 3.5 MHz curvilinear probe. Fetal kidney length was measured in the sagittal plane using a 3.5MHz transducer, ensuring full visualization of the kidney, upper and lower pole including the renal pelvis. The longest pole to pole length was measured. Three measurements of right or left kidney were made and the mean taken. Standard fetal biometric parameters, including biparietal diameter (BPD), femur length (FL), head circumference (HC) and abdominal circumference (AC), were also recorded. The right and left kidney lengths were compared and the combined kidney length was analyzed against gestational age[5]. All the relevant data was recorded in pre designed performa and analyzed using appropriated statistical methods. Correlation between the fetal kidney length and gestation age as well as various morphological parameters was obtained using regression coefficient. Simple tables were used to present the data[6].

Scanning Technique: A pilot study was conducted on 100 patients with uncomplicated singleton pregnancies. Ultrasound scans were performed trans abdominally, with the patient lying supine and the abdomen and pelvis exposed, adequate ultrasound gel was applied to the lower anterior abdominal wall/ pelvis. To visualize the fetal kidney, the transducer was initially positioned to capture the fetal spine in a longitudinal view. With a slight angulation of the transducer, the paravertebral plane was achieved, allowing the entire length of the fetal kidney to be seen or the fetus was scanned in the transverse plane until the kidney is visualized below the stomach. The probe was then rotated through 90° to outline the longitudinal axis of the kidney. Both fetal kidney length s were measured from the outer edge of the upper pole to the outer edge of the lower pole as described by Bertagnoli[7] (Fig. 1 for position). Complete care was taken to exclude the adrenal glands from the measurement of the kidney to prevent over estimation. Three measurements were done for all measured parameters and the average was obtained to reduce intra observer error. Most attempts to obtain the fetal kidney length were successful. Few that were difficult due to fetal position were obtained after few trials by gently but firmly shaking the maternal abdomen to elicit fetal movement. However, in a situation where it was not possible to get the kidney outlines well, the patient was excluded from the study. Other measurements obtained during the study include, right and left kidney width, circumference and area. FL, BPD, HC and AC were also measured. Using a trans abdominal approach, biparietal diameter was measured at the level of the thalami and cavum septa pellucida or the cerebral peduncles as the linear distance from the outer edge of the proximal to the inner edge of the distal skull., head circumference was measured at the same level (and often on the same images) using the ellipse function of ultrasound equipment around the outer perimeter of the skull. Abdominal circumference was measured using the ellipse function of ultrasound equipment circumscribing the actual or projected skin line in the transverse plane at the level of the stomach bubble and the junction of the umbilical vein and portal sinus. Femur length was measured as the linear distance between the midpoints of each end of the calcified femoral diaphysis. Three measurements of both kidney lengths and other parameters listed above were made and the average taken as the final measurement.

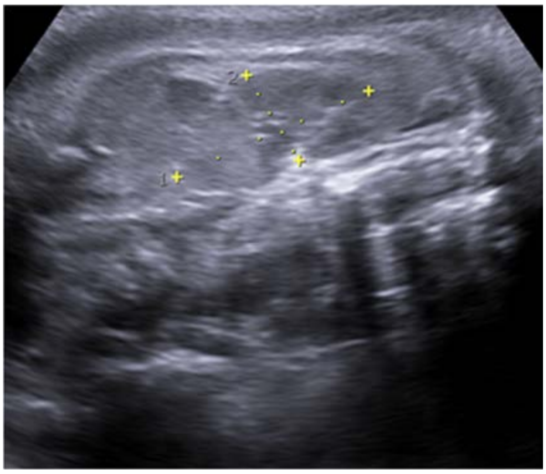

Fig. 1: Trans Abdominal Sonographic Transverse View of Fetal Kidney Measurement

Fig. 2 and 3: Trans Abdominal USG of Right and Left Kidney of Gestational Age 36 Weeks 5 Days Showing Maximum Transverse Diameter of Right Fetal Kidney as 38.0mm and Left Fetal Kidney as 37.0mm. Mean Combined Fetal Kidney Length Measures ~ 37.5mm

Inclusion Criteria: Uncomplicated singleton pregnancy with prior regular menstrual cycle and pregnancies within 20-39 weeks gestational ages.

Exclusion Criteria:

- Pregnant women with unknown menstrual age.
- Any associated maternal complication(Poly or oligohydramnios, maternal diabetes mellitus).
- Multiple gestation.
- Congenital anomalies seen during ultrasound examination.
- Where, only one kidney alone was visualized.
- Gross maternal obesity.

Data Collection:

Patient Demographics:

- Demographic information, including maternal age, gestational age, parity and medical history-pre-existing conditions (e.g., hypertension, diabetes, or kidney disease), obstetric history (e.g., previous preterm deliveries, complications in past pregnancies) maternal health information-presence of gestational diabetes or preeclampsia, BMI of the mother.

Ethical Considerations:

- The study is conducted in compliance with the Declaration of Helsinki and relevant ethical guidelines. Informed consent is obtained from all participants. Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Sree Mookambika Institute of Medical Sciences. Patient confidentiality and data security were maintained throughout the study.

Statistical Analysis:

- **Pearson's correlation coefficient (r)** was calculated to assess the correlation between **mean combined kidney length** and gestational age.
- **Linear regression analysis** was performed to assess fetal kidney length as a predictor of gestational age. The regression coefficient (ß) was used to describe the relationship between kidney length and gestational age.

RESULTS AND DISCUSSIONS

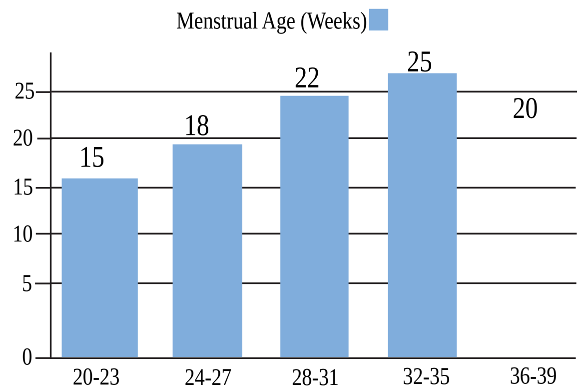

Fig. 4: Age Distribution of Participants

The bar chart depicts the distribution of participants across various gestational age groups. The study includes 15 participants in the 20-23 week range, 18 in the 24-27 week range, 22 in the 28-31 week range, 25 in the 32-35 week range and 20 in the 36-39 week range. This distribution offers insights into the sample size for each gestational age group, reflecting a fairly balanced representation. The largest group of participants falls within the 32-35 week range, while the 20-23 and 36-39 week groups have slightly fewer participants. Overall, the distribution suggests that the study maintains adequate and proportional representation across the gestational age categories.

(Table 1): Represents data on kidney lengths (right kidney length [RKL], left kidney length [LKL] and combined mean kidney length [MKL]) at different stages of gestation. The data provided shows the kidney lengths (right, left and mean) for different menstrual ages (weeks), with the corresponding number of patients and the standard deviation (SD) for each measurement.

Trend in Kidney Length Growth: As menstrual age increases, kidney lengths generally increase for both the right and left kidneys, as well as the mean kidney length. For example, at 20 weeks, the mean kidney length is 20.73 mm, while at 39 weeks, the mean length reaches 39.2 mm.

Right vs. Left Kidney Length: The lengths of the right and left kidneys are similar across most of the ages, with small differences between them. However, at some ages, the left kidney may be slightly longer (e.g., at 24 weeks, left kidney length is 25.1 mm vs. 24.2 mm for the right).

Final Kidney Lengths: By 39 weeks, the kidney lengths appear to stabilize, with only minor differences between the right (39.1 mm), left (39.3 mm) and mean (39.2 mm) kidney lengths.

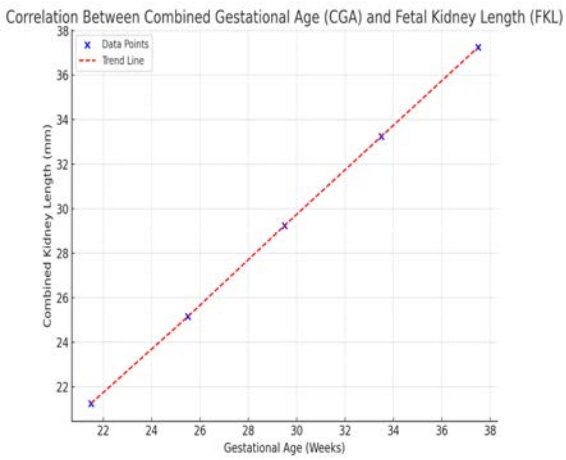

Fig. 5: Scatter Diagram Showing Correlation Between CGA and FKL

(Fig. 5): Scatter diagram plots the combined kidney length (CKL) against gestational age (GA). Each dot represents an individual measurement and a fitted regression line indicates the positive correlation between CKL and GA. The clustering of points along the line confirms a strong association, further supported by a high correlation coefficient (r=0.87). This figure highlights the utility of CKL as a predictor of GA.

(Table 2 and Fig. 6): The data reveals a steady increase in kidney length (MKL) and fetal growth parameters (BPD, HC, FL, AC) as the menstrual age progresses from 20 weeks to 39 weeks. Kidney length starts at 20.73 mm at 20 weeks and reaches 39.2 mm at 39 weeks, showing consistent growth. In terms of fetal parameters, the GA based on BPD, HC, FL and AC all align with the menstrual age. The variation in these measurements (indicated by the standard deviation) is relatively small, with larger variations seen in some later stages (particularly after 30 weeks), suggesting a degree of individual variability. Overall, the data reflects a consistent growth trajectory for both kidney length and fetal parameters from 20-39 weeks.

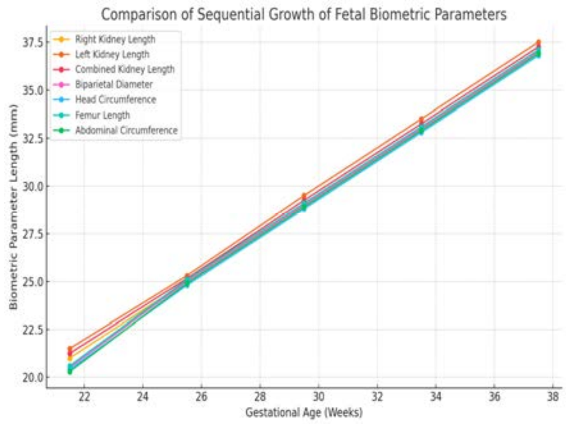

Fig. 6: Comparison of Sequential Growth of Fetal Biometric Parameters with Increasing Weeks of Gestation

This figure visually represents the linear growth of various fetal biometric parameters such as biparietal diameter (BPD), head circumference (HC), femur length (FL) and abdominal circumference (AC) compared to gestational age (GA) in weeks. It illustrates that all parameters show a consistent and gradual increase as gestation progresses, emphasizing their reliability as indicators of fetal development.

(Table 3): Regression Coefficient (ß) shows the magnitude and direction of the relationship between gestational age and the parameter. A higher value

Table 1: Mean Right and Left Kidney Length and Combined Kidney Length Compared with Different Gestational Ages

Menstrual Age (Weeks)	No. of Patients (N)	Right Kidney Length (RKL) ±SD (mm)	Left Kidney Length (LKL) ±SD (mm)	Mean Kidney Length (MKL) ±SD (mm)
20	3	20.8± 0.4	20.7± 0.5	20.73± 0.46
21	4	20.9± 0.5	21.2± 0.3	21.01± 0.47
22	5	22.2± 0.1	22.4± 0.2	22.3± 0.16
23	3	23.1± 0.8	23.3± 0.1	23.7± 0.40
24	4	24.2± 0.6	25.1± 0.3	24.7± 0.40
25	4	25.8± 0.2	26.0± 0.3	25.9± 0.27
26	6	26.4± 0.3	26.6± 0.4	26.5± 0.36
27	4	26.7± 1.0	27.0± 0.2	26.8± 0.91
28	6	28.2± 0.7	29.0± 0.2	28.8± 0.43
29	4	29.8± 0.3	29.7± 0.5	29.7± 0.47
30	5	29.9± 0.5	30.2± 0.2	30.1± 0.33
31	7	31.3± 0.2	31.4± 0.3	31.3± 0.27
32	5	32.2± 0.5	33.1± 0.3	32.8± 0.41
33	7	33.8± 0.1	34.0± 0.2	33.9± 0.17
34	6	34.4± 0.5	34.4± 0.6	34.4± 0.59
35	7	34.7± 1.0	35.0± 0.1	34.8± 0.8
36	5	36.2± 0.6	37.0± 0.2	36.8± 0.43
37	4	38.1± 0.2	38.3± 0.3	38.2± 0.27
38	6	38.2± 0.2	38.7± 0.1	38.4± 0.18
39	5	39.1± 0.7	39.3± 0.7	39.2± 0.7

Table 2: Mean Combined Kidney Length Compared with Menstrual Age and Gestational Age Derived from Fetal Biometric Parameters

Menstrual Age (Weeks)	No. of Participants (N)	Mean Kidney Length (MKL) ± SD (mm)	Mean GA by BPD ± SD (Weeks)	Mean GA by HC ±SD (Weeks)	Mean GA by FL ± SD (Weeks)	Mean GA by AC ± SD (Weeks)
20	3	20.73± 0.46	20.65+0.48	21.5± 0.5	20.55+0.49	20.75+0.47
21	4	21.01± 0.47	20.95+0.45	21.9± 0.3	21.12+0.50	21.03+0.48
22	5	22.3± 0.16	22.26+0.19	22.6± 1.3	22.17+0.20	22.33+0.17
23	3	23.7± 0.40	23.7+0.43	23.9± 0.2	23.40+0.38	23.72+0.42
24	4	24.7± 0.40	24.63+0.38	25.1± 0.7	24.55+0.42	24.74+0.39
25	4	25.9± 0.27	26.03+0.29	26.0± 0.6	25.80+0.28	25.91+0.28
26	6	26.5± 0.36	26.75+0.38	26.6± 0.2	26.75+0.37	26.48+0.35
27	4	26.8± 0.91	27.10+0.95	27.0± 0.4	27.25+0.93	27.01+0.51
28	6	28.8± 0.43	28.75+0.44	29.0± 0.7	28.75+0.44	28.81+0.45
29	4	29.7± 0.47	29.52+0.46	28.9± 0.2	29.55+0.48	29.59+0.38
30	5	30.1± 0.33	30.21+0.32	30.2± 1.5	30.50+0.34	30.61+0.34
31	7	31.3± 0.27	31.10+0.29	31.4± 0.9	31.45+0.29	31.32+0.28
32	5	32.8± 0.41	32.65+0.39	33.1± 0.5	33.05+0.43	33.12+0.45
33	7	33.9± 0.17	33.95+0.18	34.0± 1.1	33.75+0.18	33.53+0.18
34	6	34.4± 0.59	34.37+0.61	34.4± 0.6	34.10+0.63	34.46+0.60
35	7	34.8± 0.8	34.92+0.78	35.0± 0.1	35.10+0.82	35.85+0.81
36	5	36.8± 0.43	36.60+0.45	37.0± 0.2	37.05+0.45	36.81+0.45
37	4	38.2± 0.27	38.10+0.29	38.3± 0.7	38.45+0.30	37.65+0.28
38	6	38.4± 0.18	38.50+0.19	38.7± 0.1	38.60+0.19	38.45+0.19
39	5	39.2± 0.7	39.15+0.72	39.3± 1.2	39.50+0.72	38.91+0.13

Table 3: Regression Coefficients of Gestational Age While Predicting Various Parameters

Parameter	Regression Coefficient (β)	Standard Error (SE)	p-Value
Mean Right Kidney Length	0.500	0.054	<0.001
Mean Left Kidney Length	0.510	0.057	<0.001
Mean Combined Kidney Length	0.520	0.055	<0.001
Biparietal Diameter	0.520	0.055	<0.001
Head Circumference	0.510	0.057	<0.001
Femur Length	0.470	0.061	<0.001
Abdominal Circumference	0.500	0.054	<0.001

Table 4: Correlation Coefficients of Clinical Parameters with Gestational Age

Parameter	Correlation Coefficient ®	p-Value
Mean Right Kidney Length	0.89	<0.001
Mean Left Kidney Length	0.88	<0.001
Mean Combined Kidney Length	0.87	<0.001
Biparietal Diameter	0.86	<0.001
Head Circumference	0.85	<0.001
Femur Length	0.84	<0.001
Abdominal Circumference	0.83	<0.001

indicates a stronger association. The mean right kidney length demonstrated a regression coefficient of 0.500 (SE=0.054, p<0.001), indicating a strong positive correlation with gestational age. Similarly, the mean left kidney length exhibited a slightly higher coefficient of 0.510 (SE=0.057, p<0.001), while the combined kidney length also showed a robust association with gestational age (ß=0.520, SE=0.055, p<0.001). Both biparietal diameter and head circumference had regression coefficients of 0.520 (SE=0.055 and 0.057, respectively, both p<0.001), further supporting their strong positive correlation with gestational age. Femur length, though exhibiting a somewhat lower coefficient of 0.470 (SE=0.061, p<0.001), still demonstrated a significant relationship with gestational age. Finally, abdominal circumference was strongly correlated with gestational age, with a coefficient of 0.500 (SE=0.054, p<0.001). These results suggest that all the fetal parameters measured are significantly correlated with gestational age, with kidney length, biparietal diameter and head circumference showing the strongest associations.

(Table 4): The correlation coefficients presented for the clinical parameters with gestational age indicate the strength and direction of their relationships. The correlation analysis between clinical parameters and gestational age revealed strong positive associations for all parameters, with all correlations being statistically significant (p<0.001). The mean right kidney length showed the highest correlation with gestational age (r=0.89), followed closely by the mean left kidney length (r=0.88) and the mean combined kidney length (r=0.87). Biparietal diameter and head circumference also demonstrated robust correlations with gestational age, with correlation coefficients of 0.86 and 0.85, respectively. Femur length exhibited a slightly lower but still significant correlation of 0.84, while abdominal circumference had a correlation coefficient of 0.83. These results indicate that all measured clinical parameters have a strong and statistically significant positive relationship with gestational age, with kidney lengths showing the most robust associations.

Obstetric care by the use of ultrasound (USG) for fetal imaging started in 1958. The biparietal diameter (BPD) was the first parameter used to estimate gestational age (GA) in the third trimester. Over the years, additional measurements have been introduced to enhance accuracy, with key parameters now including head circumference (HC), abdominal circumference (AC) and femur length (FL). These measurements have become essential tools in monitoring fetal development and improving clinical outcomes. Accurate assessment of gestational age (GA) is essential in prenatal care for predicting labor timing and ensuring appropriate fetal health management. Misjudging gestational age (GA) can lead to significant clinical mismanagement and compromise decision-making. Traditional ultrasound markers, such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL), become less reliable for gestational age estimation beyond the second trimester, particularly during the later stages of pregnancy. These parameters often show increased variability in the second and third trimesters, making gestational age determination more challenging. In contrast, fetal kidney length (FKL) has been shown to maintain a strong correlation with gestational age, even in cases of intrauterine growth restriction, offering a more consistent and reliable marker for accurate gestational age estimation during these critical periods. Fetal kidney can be visualized as early as 14 weeks of gestation with newer advanced in sonographic machine. Fetal kidneys are usually imaged during routine antenatal scans. Kidneys are located on either side of the spine. The adrenal glands are closely related to the upper pole of kidney anatomically. Identifying the fetal renal poles except in cases with thick abdominal wall patients is easier. Hence accurate measurements of fetal renal length can be obtained. Also fetal sex doesn't affect the measured fetal kidney size. 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 hyper echoic bright border that represents the renal pelvis. The sonographic corticomedullary 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 anteroposterior diameter of the renal pelvis (APPD) should be <4mm in the second trimester and <7mm in the third trimester. When evaluating the correlation between fetal kidney length and gestational age, the study found a significant relationship between kidney length and gestational age as determined by LMP, biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). These results align with a study conducted by Ugur *et al.* (2016), which also reported a strong positive correlation (p=0.001) between fetal kidney length and gestational age. The data indicates a clear trend of increasing kidney lengths as menstrual age progresses, with both right and left kidney lengths growing steadily over time. At 20 weeks, the mean kidney length is 20.73 mm and by 39 weeks, it reaches 39.2 mm. Throughout the observed ages, the right and left kidneys exhibit similar lengths, although the left kidney is slightly longer at certain ages, such as 24 weeks. Overall, kidney lengths grow steadily from 20-39 weeks, with minimal differences between the right and left kidneys by the later stages.

CONCLUSION

Overall, the data shows a steady and proportional development of kidney size in the fetus, with the kidneys growing larger as pregnancy progresses, while maintaining a consistent left-right length difference throughout the observed gestational periods. In conclusion, the findings of this study highlight the strong and statistically significant positive correlation between fetal kidney size and gestational age, emphasizing the role of renal measurements in estimating gestational age. Among the clinical parameters assessed, kidney lengths, particularly the right and left kidney lengths, demonstrated the most robust associations with gestational age, with correlation coefficients of 0.89 and 0.88, respectively. These were closely followed by combined kidney length and other established parameters, such as biparietal diameter and head circumference, which also showed strong correlations. Regression analysis further confirmed these relationships, with kidney length exhibiting the highest regression coefficients, underscoring its potential as a reliable marker in estimating gestational age. The results suggest that fetal kidney size, in conjunction with other key measurements, provides a valuable and accurate tool for assessing gestational age in clinical practice.

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