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Fetal Kidney Diameter as a Parameter for Determination of Fetal Gestational Age in Apparently Healthy Nigerian Women

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Abstract **Original Research Article**

Background: Accurate determination of gestational age (GA) is vital in obstetric management, as incorrect dating may result in preterm or post-term delivery, both of which are associated with adverse perinatal outcomes. Conventional ultrasound parameters such as Biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are commonly used for gestational age estimation; however, their accuracy declines in the late second and third trimesters. This study investigated the relationship between fetal kidney antero-posterior diameter (APD) and gestational age and sought to establish baseline reference values among Nigerian women.

Materials and methods: A prospective cross-sectional study was conducted among 208 apparently healthy pregnant women between 20 and 40 weeks of gestation who attended the Radiology Department of the Federal Medical Centre, Jalingo, Taraba State. Standard fetal biometric parameters (BPD, HC, AC, and FL) as well as fetal renal antero-posterior diameters were measured using a GE Logic 7 ultrasound machine equipped with a 3.5 MHz convex transducer. Statistical analyses, including Pearson correlation and linear regression, were performed using SPSS version 30.0 to determine the strength of association between gestational age and fetal kidney diameter and to derive regression equations for gestational age prediction.

Results: The results showed mean right and left fetal renal antero-posterior diameters of 19.87 ± 4.88 mm and 20.09 ± 4.94 mm, respectively. Both parameters demonstrated a strong positive correlation with gestational age ($r = 0.928$ and $r = 0.927$, $p < 0.001$) and a high coefficient of determination ($R^2 = 0.86$). The regression model indicated that fetal kidney antero-posterior diameter increases by approximately 0.74 mm for each advancing week of gestation.

Conclusion: The fetal renal antero-posterior diameter correlates strongly with gestational age and can serve as a reliable adjunct parameter for gestational age estimation, particularly when conventional biometric indices are limited. The established baseline reference values provide useful population-specific data for Nigerian women and support broader clinical application in obstetric sonography.

Keywords: Fetal kidney diameter, Gestational age, Ultrasound biometry, Nigerian women, Antero-posterior diameter.

INTRODUCTION

Accurate dating of pregnancy by obstetricians is crucial, as failure to do so can lead to either premature delivery or post-maturity of the fetus, both of which may result to increased perinatal morbidity and mortality. Ultrasound scan is an important imaging modality of choice in the determination of fetal gestational age (GA), in which various biometric parameters such as crown-rump length (CRL), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are used as common indicators [1]

However, the accuracy abd reliability of these parameters defers from trimester to trimester especially in the first trimester and early second trimester. The accuracy of these parameters can be influenced by conditions such as oligohydramnios, multiple gestations, breech presentations, polyhydramnios, and intrauterine growth restriction (IUGR)[2].. As pregnancy progresses, especially into the late second and third trimesters, these measurements become increasingly unreliable for estimating gestational age [2].

Consequently, there is ongoing research into alternative, non-traditional sonographic parameters for GA estimation. These include transverse cerebellar diameter, fetal foot length, epiphyseal ossification centers, amniotic fluid volume, placental grading, fetal kidney diameter, and fetal kidney length (FKL). Among these, fetal kidney length has shown a strong correlation with GA and has been reported to provide more accurate estimates than BPD, FL, HC, and AC beyond 24 weeks of gestation[3].

Fetal organ measurements may also aid in the early detection of abnormalities. The increasing use of prenatal ultrasonography enables early diagnosis of renal defects, which may manifest as enlarged or malformed kidneys. Such abnormalities, including Finnish syndrome, infantile polycystic kidney disease, Meckel's syndrome, and posterior urethral valve obstruction, are often linked to abnormal kidney size and may be fatal[2]. Conditions like achondroplasia (characterized by short limbs and a bulging forehead) can cause discrepancies in BPD and FL measurements, leading to incorrect GA estimations. In cases like hydrocephalus or anencephaly, traditional measurements such as BPD may be misleading or unusable. Therefore, relying on alternative parameters like fetal kidney diameter especially when more traditional metrics are compromised may enhance dating accuracy.

Sonographic measurement of the fetal kidney diameter can be done easily, yet there is a lack of established baseline values fit for different populations. Most available data are originated from Caucasian populations, which may not be applicable to Nigerian populations due to potential racial and ethnic variations. Ozo *et al[4]*.,and Okeke and Ukoha *et al[5]*.,have highlighted such disparities in adult renal measurements, which likely extend to prenatal metrics as well. This study aims to establish baseline reference values for fetal kidney diameter in Nigerian women and to assess its correlation with gestational age.

MATERIALS AND METHODS

1. Research Design

A cross-sectional prospective hospital;-based study was conducted among 208 singleton apparently healthy pregnant Nigerian women came for a routine antenatal ultrasound scan between April 2025 to August 2025 at Federal Medical Center Jalingo, Taraba State, Nigeria.

2 Area of Study

The study was conducted in the Ultrasound scan unit of the Radiology Department, Federal Medical Center, Jalingo, Taraba State, Nigeria. located in the Northern eastern region of Nigeria. It is a federal government facility and one of the leading healthcare providers in the state. The center operates 24 hours a day and serves as a referral center for all primary and secondary healthcare facilities in the state.

3 Study populations

Apparently healthy pregnant Nigerian women with singleton pregnancies, who presented themselves for routine antenatal ultrasound scan in their second and third trimesters, which were referred for obstetric ultrasonography in Radiology Department from the antenatal clinic of Federal Medical Center Jalingo. Taraba State, Nigeria.

4 Sample size and Sampling Techniques

Two hundred and eight (208) singleton apparently healthy pregnant Nigerian women formed the sample size for this study and they were selected using convenient sampling technique after obtaining both ethical approval and their consents.

5 Selection Criteria

Primary data was obtained from sonographic measurements of:

Fetal Kidney Diameter (FKD)

Biparietal Diameter (BPD)

Abdominal Circumference (AC)

Femur Length (FL)

Head Circumference (HC)

Secondary data was retrieved from antenatal clinic record sheets.

6.1 Inclusion Criteria

1. Participant should have singleton pregnancies at the 20th weeks of pregnancy to term at time of this study
2. Participantmust be a Nigerian citizen and apparently healthy
3. No fetal kidney abnormal

6.2 Exclusion Criteria

1. Pregnant women with fetuse having fetal anomaly,
2. Fetus with intra-uterine growthretardation (IUGR),
3. Pregnant women with multiple gestations,
4. Fetuses with unclear renal margin on sides,
5. Pregnant women with history of drug abuse

7 Method of data collection

7.1 Instrumentation

GE Logiq 7 4D ultrasound machine with 3.5 MHz convex probe was use for performing all the ultrasound examinations on the pregnant women and ultrasound gel to be applied on the surface of the abdomen before the examination.

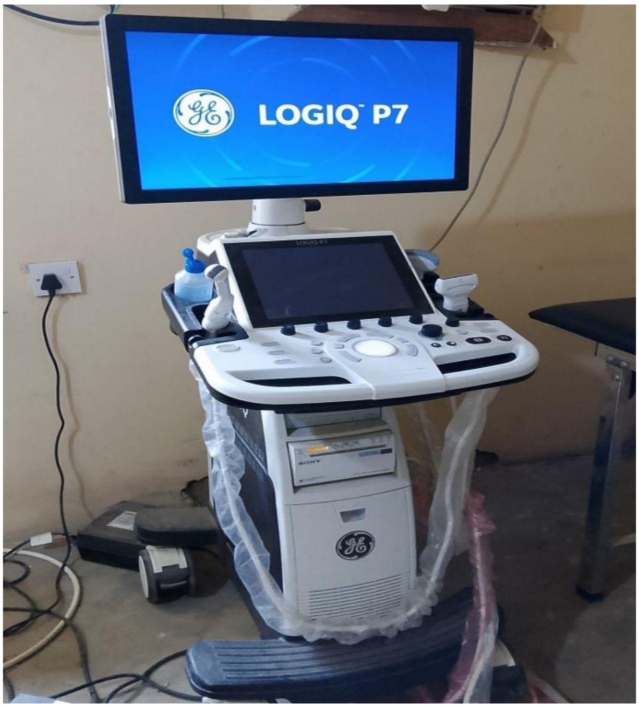

Plate 1: GE Logiq P7 ultrasound equiptment with linear, curve linear and trans-vaginal probes

7.2 Procedures for data collection

All participants met the inclusion criteria and the ultrasound examinations were conducted on them after explaining the procedure clearly to them and their consent sought and properly obtained using informed consent form. The participants were asked to lay on the examination bed in supine position or left lateral. Ultrasound gel was applied to the anterior abdominal wall, multiple longitudinal and transverse cross-sectional images of the kidneys was obtained and measured in their anteroposterior diameters of both kidneys.

Gestational age (GA) was assessed using measurements of BPD, HC, FL, and AC. An average of BPD, HC, FL, and AC were referred to as the composite gestational age, which was compared with gestational age estimated from fetal kidney Diameter.

The measurements of the kidneys was obtained by placing the electronic callipers at the outer margins of kidneys. On sonography, foetal renal structures cannot be reliably imaged during the early embryologic events of the first trimester. However, some of the fetal kidneys was well visualized in the early second trimester. The kidneys were visualized on transverse scans of foetal abdomen as paired hypoechoic structures adjacent to foetal spine, the antero-posterior diameter measurement was obtained. Both left and right kidney dimensions were taken. Only the kidneys with complete outline were measured. Unclear adrenal or renal borders, abnormal renal morphology, and renal pelvic dilatation greater than 4mm in antero-posterior diameter was grounded for exclusion in the measurements. The measurement of the BPD was taken in transverse axial plane. Intracranial landmark that was utilized for the BPD include visualization of falx cerebri posteriorly, the cavum septipellucidi anteriorly and paired thalami in the midline with a sylvian fissure laterally. The HC was measured directly by placing the ellipse around the outside of the skull bone echoes. The AC was measured in the transverse section of the foetal abdomen (as circular as possible), umbilical vein at the level of the portal sinus and stomach was visualized, kidneys was not visible at the level. The FL was measured with the bone across the beam axis. The strong acoustic shadow behind the femoral shaft and the visualization of both cartilaginous ends indicated the image plane was on the longest axis.

8 Method of data analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 30.0 (IBM, USA). Initial analysis assessed data normality through histogram plots. Since GA and parity are expected to be non-normally distributed, both parametric and non-parametric statistics were employed. Both descriptive statistical tools(mean, standard deviation and tables, first quartile, median, and third quartile) and inferential statistical tools such as Pearson correlation and Linear regression analysis was performed to predict gestational age based on fetal kidney diameter (FKD). The level of statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSIONS

A total of 208 cases were analyzed. Each record included right and left kidney antero-posterior diameters (RKAPD and RKAD), from which the mean fetal kidney diameter (FKD mean) was computed. Gestational age (GA) was expressed in completed weeks, derived from obstetric ultrasound measurements.

Table 1. Descriptive statistics for gestational age (weeks)

Variable	Minimum	Maximum	Mean ± SD	Mode	Median
Gestational age (weeks)	20.00	41..00	32.03 ± 6.18	34.60	33.14

The table above shows that the mean gestational age from this study was 32.03 ± 6.18 weeks, with the minimum gestational age being 20 weeks and the maximum 41 weeks

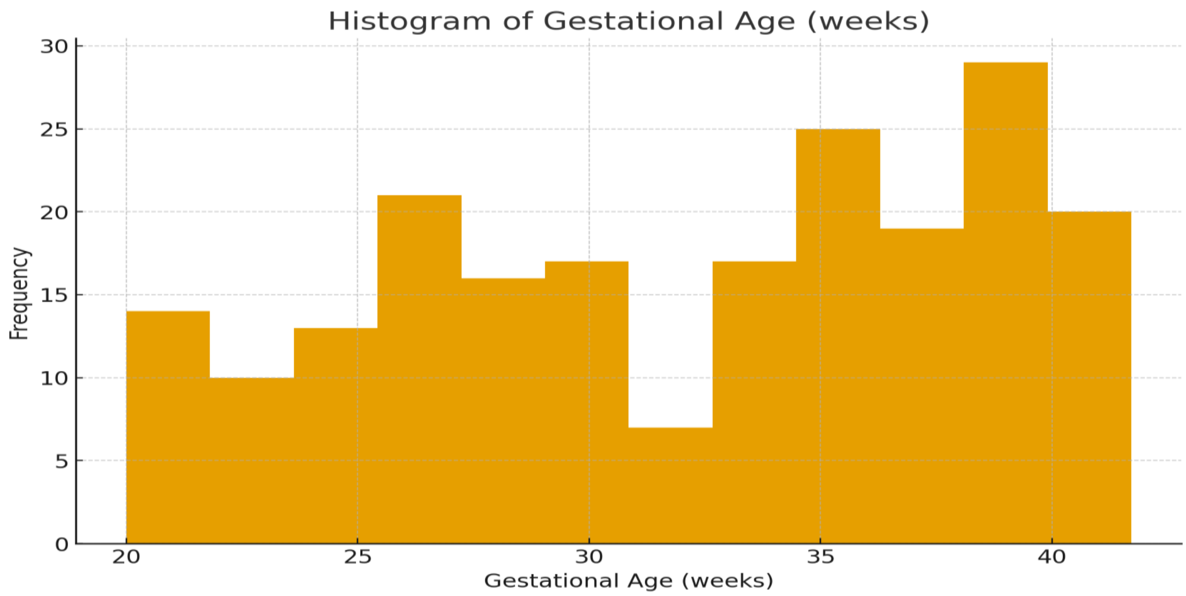

Figure 1. Histogram of gestational age (weeks)

The histogram shows a unimodal distribution centered in the late second to third trimester window. The mean and median are close, suggesting limited skewness; the percentile spread indicates adequate representation across late gestation weeks.

Table 2. Descriptive statistics for BPD, HC, AC, FL (mm) and EFW (g)

Variable	Mean±SD	Median	Mode	Min	Max	P5	P25	P75	P95
BPD	81.03±14.79	87.6	87.60	51	108.00	55.00	66.60	94.00	100.00
HC	288.56±50.77	310.0	311.0	68	360.00	208.00	244.00	333.00	352.00
AC	255.39±56.74	282.0	283.0	122	338.00	172.00	199.75	304.00	328.00
FL	62.50±13.90	67.7	68.0	38	82.10	39.00	50.50	76.00	79.79
EFW	1903±940	1954	1954	406	4297	515	1034	2664	3215

From table 2 above, the mean and standard deviation values for BPD, HC, and FL are 81.03±14.79, 288.56±50.77 and 62.50±13.90 respectively. The P25 value for BPD, HC and FL are 66.60, 244.00 and 50.50 respectively.

Table 3: Descriptive statistics for RKL, RKAPD, LKL and LKAPD (mm)

Variable	Mean±SD	Median	Mode	Min	Max	P5	P25	P75	P95
RKL	35.70± 8.87	36.40	45.00	16.50	52.50	21.28	28.10	43.85	49.16
RKAPD	19.87± 4.88	21.15	16.00	10.83	27.00	11.67	15.88	24.00	26.30
LKL	35.79± 8.81	36.35	22.10	16.50	52.80	21.88	28.38	43.92	49.20
LKAPD	20.09± 4.94	21.43	16.00	10.83	27.92	11.80	16.00	24.16	26.42

From table 3 above, the mean Right Kidney Length (RKL) was 35.70± 8.87mm and the mean Right Kidney Anteroposterior Diameter was 19.87± 4.88mm. The Left Kidney Length (LKL) was 35.79± 8.81mm and the Left Kidney Anteroposterior Diameter (LKAPD) was20.09± 4.94mm. The proximity of mean and median across variables suggests limited skewness; percentile ranges indicate adequate coverage across clinically relevant sizes for modelling and centile creation.

Table 4. Correlation and simple linear regression for GA vs kidney AP diameters

Comparison	n	r	95% CI (r)	p-value	Slope (mm/week)	Intercept (mm)	R^2	SEE (mm)
GA (weeks) vs RKAPD (mm)	208	0.928	[0.907, 0.945]	0.0000	0.733	-3.612	0.862	1.816
GA (weeks) vs LKAPD (mm)	208	0.927	[0.905, 0.944]	0.0000	0.741	-3.652	0.859	1.858
GA (weeks) vs Mean APD (mm)	208	0.928	[0.907, 0.945]	0.0000	0.737	-3.632	0.862	1.829

The correlation between the Gestational Age and the mean Anteroposterior diameters was strongly positive with r = 0.928. This implies that as Gestational Age increases APD also Increases and this was also significant with p = 0.000(table 4).

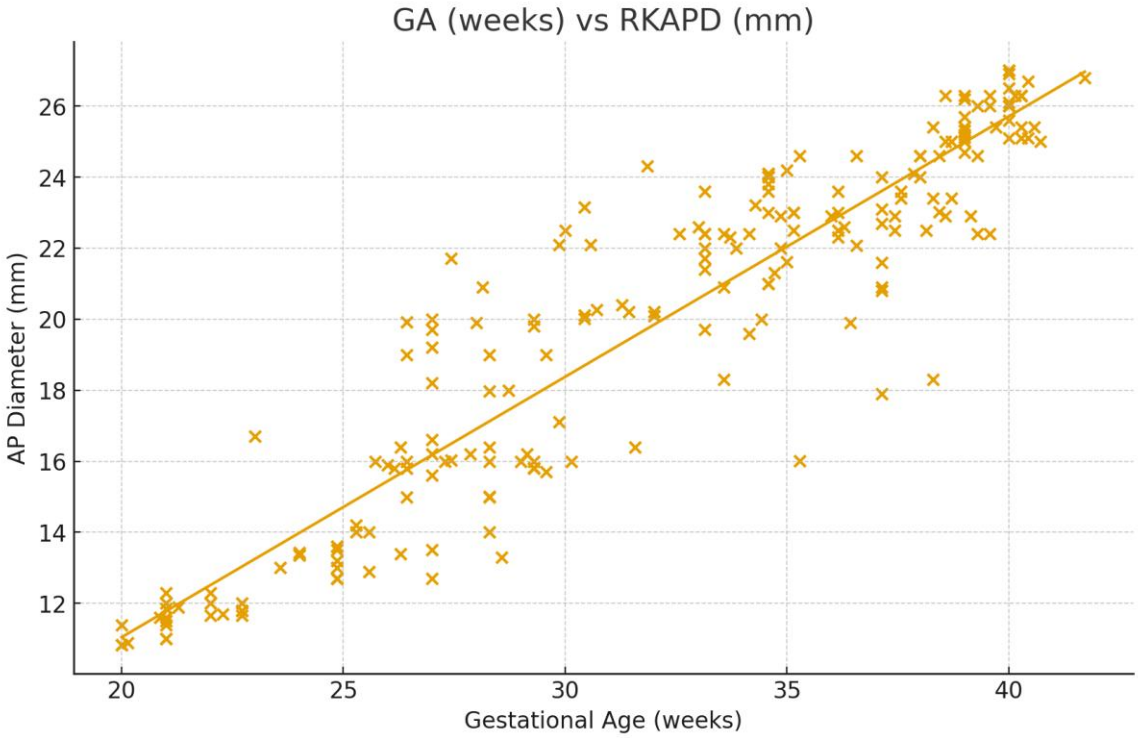

Figure 1 above shows a scatter plot indicate a linear progression of both Gestational age and APD uniformly.

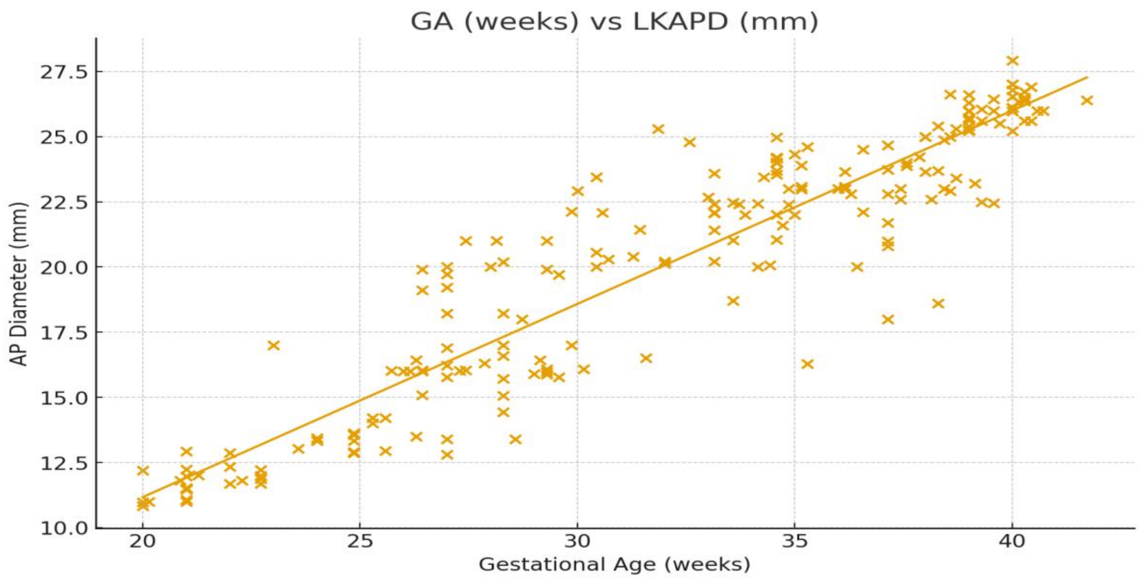

Figure 2: GA (weeks) vs LKAPD (mm)

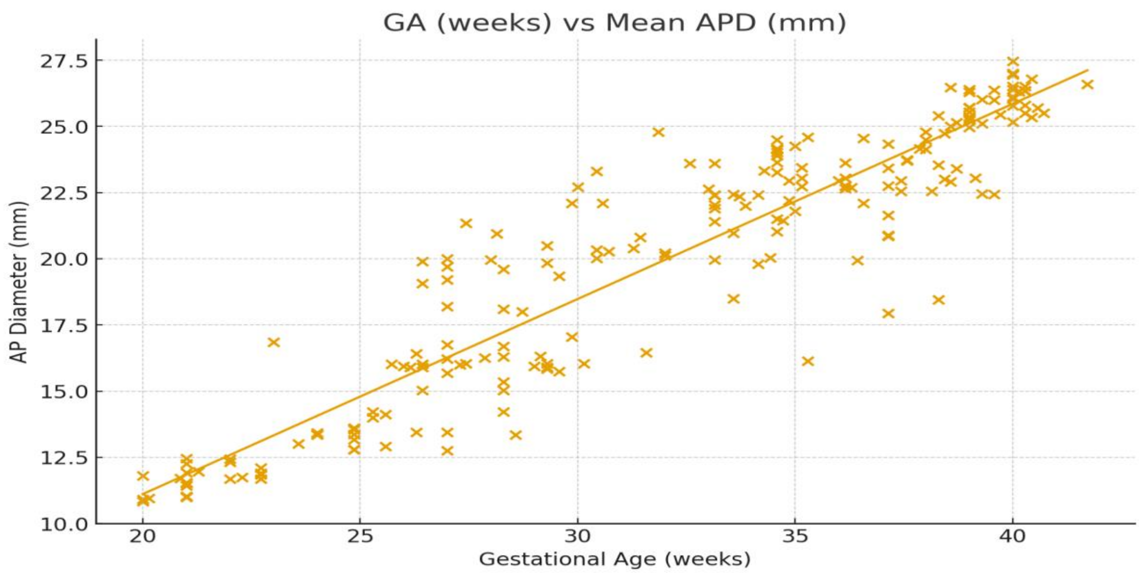

Figure 3: GA (weeks) vs Mean APD (mm)

Renal antero-posterior diameters (right, left, and their mean) show positive associations with gestational age. Effect sizes (r) and slopes (mm/week) indicate that AP diameter increases with advancing gestation, with goodness-of-fit (R^2) quantifying the proportion of variance in AP diameter explained by GA. Confidence intervals that exclude zero support statistical robustness.

Table 5: Weekly reference for RKAPD (mm): N, Mean, SD, and centiles (P5, P10, P50, P90, P95)

GA_week	N	Mean	SD	P5	P10	P50	P90	P95
20.00	4.00	10.99	0.28	10.83	10.83	10.87	11.25	11.32
21.00	10.00	11.62	0.42	11.00	11.00	11.60	12.03	12.17
22.00	4.00	11.92	0.30	11.67	11.68	11.85	12.21	12.26
23.00	5.00	12.79	2.19	11.70	11.72	11.80	14.82	15.76
24.00	4.00	13.29	0.20	13.05	13.11	13.37	13.42	13.42
25.00	10.00	13.32	0.55	12.70	12.70	13.35	14.02	14.11
26.00	12.00	15.84	2.04	13.18	13.46	15.85	18.74	19.41
27.00	12.00	17.12	2.70	13.14	13.71	16.41	19.97	20.76
28.00	10.00	17.04	2.30	14.45	14.90	16.30	20.00	20.45
29.00	9.00	16.77	2.14	14.30	15.30	16.00	19.84	19.92
30.00	9.00	19.52	2.79	15.82	15.94	20.01	22.63	22.89
31.00	4.00	20.75	0.91	20.22	20.23	20.34	21.59	21.84
32.00	4.00	20.25	3.23	16.95	17.51	20.16	23.07	23.69
33.00	9.00	22.02	1.07	20.38	21.06	22.40	22.80	23.20
34.00	9.00	21.24	1.63	18.82	19.34	22.00	22.57	22.89
35.00	20.00	22.69	1.94	20.75	21.00	23.00	24.11	24.22
36.00	7.00	22.40	1.18	20.62	21.34	22.60	23.24	23.42
37.00	11.00	22.10	1.82	19.35	20.80	22.50	24.00	24.30
38.00	12.00	23.46	1.81	20.61	22.55	23.80	24.60	24.96
39.00	19.00	24.86	1.17	22.85	22.90	25.00	26.22	26.30
40.00	21.00	25.90	1.00	25.10	25.10	26.10	26.90	27.00
41.00	2.00	25.20	0.28	25.02	25.04	25.20	25.36	25.38
42.00	1.00	26.80	Nan	26.80	26.80	26.80	26.80	26.80

From table 5 above, the table above presents a baseline mean Right Kidney Anteroposterior Diameter for all gestational ages from 20 weeks to term from the data obtained from the study.

Table 6: Weekly reference for LKAPD (mm): N, Mean, SD, and centiles (P5, P10, P50, P90, P95)

GA_week	N	Mean	SD	P5	P10	P50	P90	P95
20.00	4.00	11.25	0.64	10.85	10.88	10.98	11.84	12.02
21.00	10.00	11.75	0.57	11.03	11.06	11.66	12.30	12.61
22.00	4.00	12.17	0.55	11.70	11.72	12.07	12.71	12.79
23.00	5.00	12.95	2.27	11.73	11.76	11.99	15.09	16.04
24.00	4.00	13.29	0.17	13.08	13.13	13.34	13.40	13.42
25.00	10.00	13.46	0.47	12.87	12.87	13.57	14.02	14.12
26.00	12.00	15.94	2.02	13.25	13.57	16.00	18.85	19.48
27.00	12.00	17.11	2.58	13.13	13.64	16.56	19.97	20.45
28.00	10.00	17.45	2.29	14.72	15.00	16.80	20.28	20.64
29.00	9.00	16.95	2.32	14.39	15.38	16.08	20.12	20.56
30.00	9.00	19.73	2.89	15.90	16.03	20.01	23.02	23.23
31.00	4.00	21.05	0.86	20.32	20.33	20.91	21.89	21.99
32.00	4.00	20.54	3.62	17.05	17.59	20.18	23.78	24.54
33.00	9.00	22.41	1.28	20.70	21.18	22.41	23.84	24.32
34.00	9.00	21.39	1.54	19.22	19.74	22.00	22.66	23.05
35.00	20.00	23.00	1.91	20.80	21.54	23.62	24.35	24.62
36.00	7.00	22.65	1.20	20.84	21.68	23.00	23.32	23.49
37.00	11.00	22.26	1.90	19.40	20.80	22.60	24.50	24.59
38.00	12.00	23.66	1.80	20.80	22.64	23.94	25.00	25.18
39.00	19.00	25.18	1.24	22.88	23.14	25.60	26.36	26.60
40.00	21.00	26.16	1.05	25.22	25.50	26.36	27.00	27.00
41.00	2.00	26.00	0.00	26.00	26.00	26.00	26.00	26.00
42.00	1.00	26.40	Nan	26.40	26.40	26.40	26.40	26.40

Table 6 above, presents a baseline mean Left Kidney Anteroposterior Diameter for all gestational ages from 20 weeks to term from the data obtained from the study.

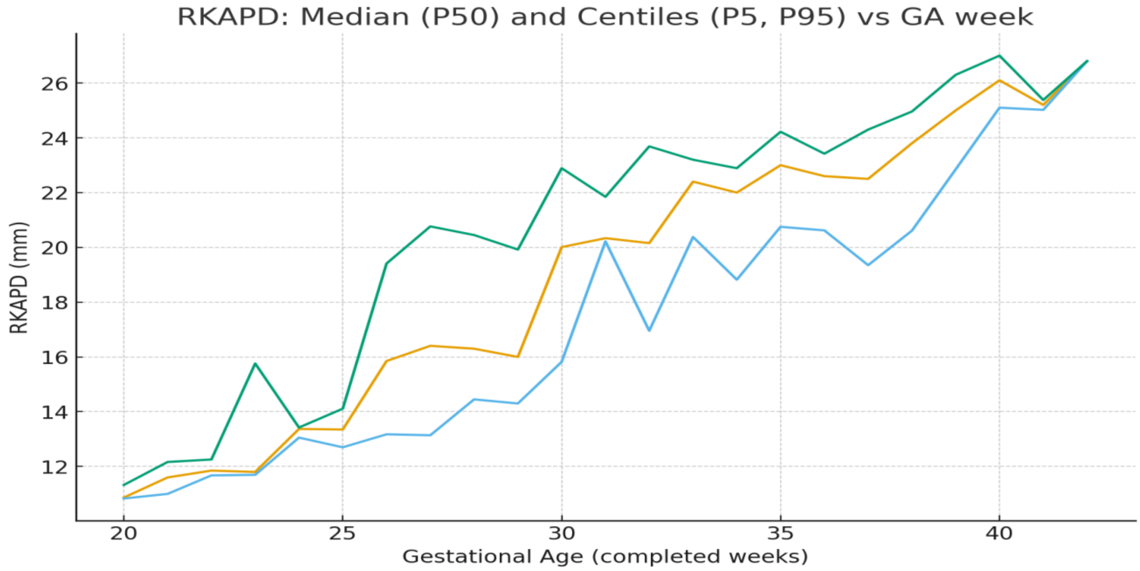

Figure 4.4: RKAPD — Median (P50) with P5 and P95 by completed GA week

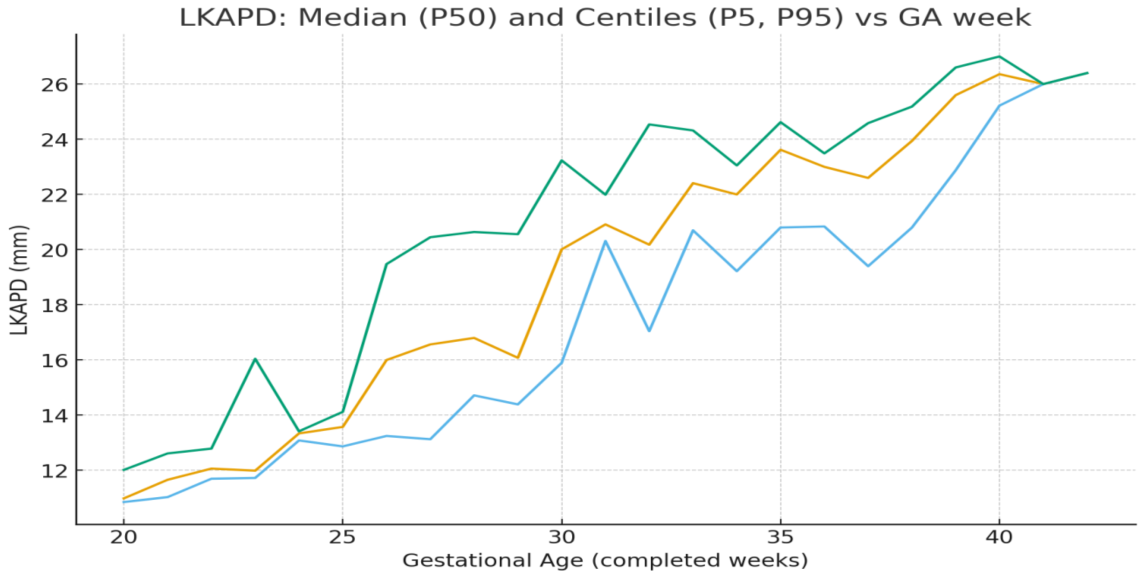

Figure 5: LKAPD — Median (P50) with P5 and P95 by completed GA week

Both kidneys exhibit increasing AP diameters with advancing gestation. These week-by-week centiles provide a baseline reference to compare individual measurements. Values below P5 or above P95 warrant closer review in clinical context (measurement quality, fetal position, hydration/physiology, and coexistent findings). For weeks with limited sample size, consider borrowing strength from adjacent weeks or using smoothed centile curves.

Table 7: Linear models predicting GA from renal AP diameters and standard biometry

Model	n	Slope	95% CI (Slope)	Intercept	95% CI (Intercept)	R^2	SEE (weeks)
GA ~ RKAPD	208	1.176	[1.111, 1.241]	8.668	[7.346, 9.990]	0.862	2.301
GA ~ LKAPD	208	1.159	[1.095, 1.224]	8.741	[7.408, 10.074]	0.859	2.323
GA ~ MeanAPD	208	1.169	[1.105, 1.233]	8.676	[7.353, 10.000]	0.862	2.303
GA ~ BPD	208	0.412	[0.402, 0.421]	-1.326	[-2.133, -0.519]	0.971	1.058
GA ~ HC	208	0.113	[0.107, 0.119]	-0.622	[-2.423, 1.178]	0.865	2.277
GA ~ AC	208	0.101	[0.096, 0.107]	6.138	[4.712, 7.564]	0.867	2.258
GA ~ FL	208	0.439	[0.430, 0.449]	4.592	[3.983, 5.202]	0.976	0.966

Hold-out performance (Mean APD model, 20% test): RMSE = 2.679 weeks; MAE = 1.944 weeks.

The table above 7 shows that marginal error from predicting gestational age using APD of the kidneys is possibly by ± 1.9 weeks.

Table 8: Nomogram: Predicting GA (weeks) from Mean APD (mm) with 95% PI

Mean APD (mm)	Predicted GA (weeks)	Lower 95% PI	Upper 95% PI
10	20.11	15.69	24.52
11	21.29	16.89	25.70
12	22.48	18.08	26.87
13	23.66	19.28	28.05
14	24.85	20.47	29.23
15	26.03	21.66	30.41
16	27.22	22.85	31.59
17	28.40	24.04	32.77

18	29.59	25.22	33.95
19	30.77	26.41	35.13
20	31.96	27.60	36.32
21	33.14	28.78	37.50
22	34.33	29.96	38.69
23	35.51	31.14	39.88
24	36.69	32.32	41.06
25	37.88	33.50	42.25
26	39.06	34.68	43.44
27	40.25	35.86	44.64
28	41.43	37.04	45.83

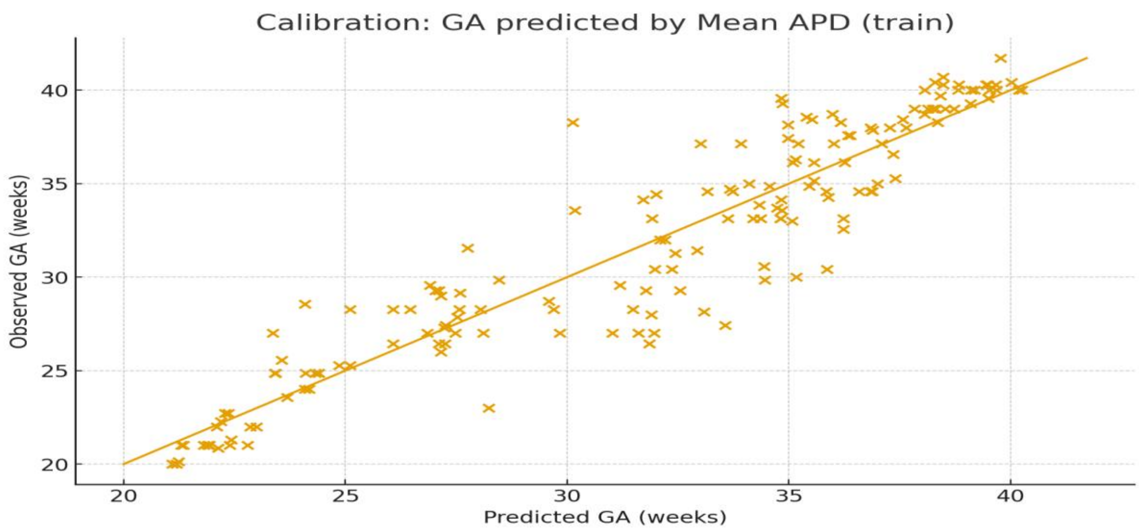

Figure 6: Calibration plot (train): Predicted vs Observed GA (Mean APD model)

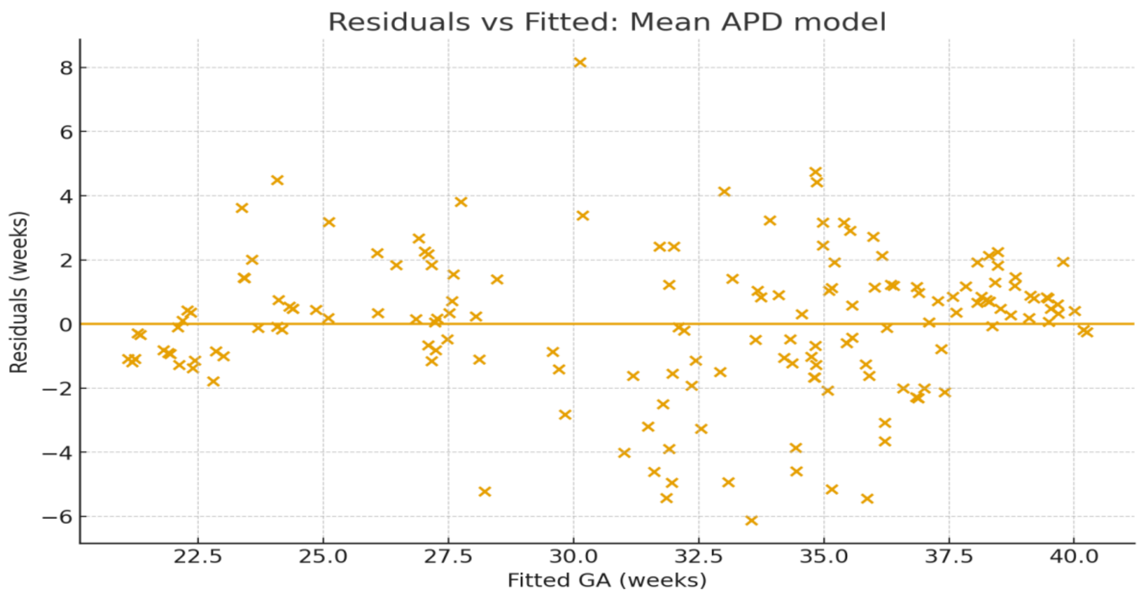

Figure 7: Residuals vs Fitted (Mean APD model)

All renal AP diameter models exhibited high explanatory power (R^2), with the Mean APD model performing comparably to single-parameter standard biometry models. The slopes indicate a ~linear increase in GA per mm increase in AP diameter. Calibration and residual checks did not reveal gross mis-specification. Out-of-sample error (RMSE/MAE) for the Mean APD model suggests clinically interpretable accuracy within the sampled GA range.

Comparison of Mean Fetal Kidney AP Diameters with Caucasian Reference [6]

Overall study means (mm): RKAPD = 19.87, LKAPD = 20.09, Mean APD = 19.98 (N = 208).

Table 9. Per-week comparison against Caucasian median (p50) from van Vuuren et al[6]

GA_week	RKAPD_mean	LKAPD_mean	MeanAPD_mean	Ref_APD_p50	Δ MeanAPD vs Ref_p50 (mm)
20	10.99	11.25	11.12	12.10	-0.98
21	11.62	11.75	11.68	12.90	-1.22
22	11.92	12.17	12.04	13.60	-1.56
23	12.79	12.95	12.87	14.40	-1.53
24	13.29	13.29	13.29	15.10	-1.81

25	13.32	13.46	13.39	15.80	-2.41
26	15.84	15.94	15.89	16.50	-0.61
27	17.12	17.11	17.11	17.20	-0.09
28	17.04	17.45	17.25	17.80	-0.55
29	16.77	16.95	16.86	18.40	-1.54
30	19.52	19.73	19.63	19.00	0.63
31	20.75	21.05	20.90	19.60	1.30
32	20.25	20.54	20.40	20.10	0.30
33	22.02	22.41	22.22	20.60	1.62
34	21.24	21.39	21.32	21.10	0.21
35	22.69	23.00	22.85	21.50	1.35
36	22.40	22.65	22.53	22.00	0.53
37	22.10	22.26	22.18	22.40	-0.22
38	23.46	23.66	23.56	22.80	0.76
39	24.86	25.18	25.02	23.10	1.92
40	25.90	26.16	26.03	23.40	2.63
41	25.20	26.00	25.60	23.80	1.80

The Weighted mean difference (Mean APD – Reference p50) between this study an a Caucasian Study by Van Vuuren (2012) was 0.35 mm (weighted by week-specific sample size).

DISCUSSIONS

Gestational Age

Findings from this study showed that the mean gestational age for pregnancies in the study was 32.03±6.18. This implies that the gestational age distribution is centered in the late second and third trimesters. Second–third trimester cohorts often cluster around routine scan windows, producing distributions concentrated within 24–38 weeks [7,8]. A broad GA spread enhances the precision of correlation and regression when evaluating adjunct predictors—such as fetal kidney dimensions—by reducing extrapolation risk and stabilizing slope estimates[9,10]. The observed range and percentiles are consistent with reference series used to derive biometric standards, supporting the planned analyses.

This distribution also suits the construction of gestation-specific nomograms, where adequate sampling across weeks is essential to obtain reliable centiles and to test for non-linearity, especially in late gestation [10,11].

Fetal Biometry

Findings from the study showed a mean Bi-parietal Diameter (BPD) of 81.03±14.79mm, mean Head Circumference (HC) of 288.56±50.77mm, mean Abdominal Circumference (AC) of 255.39±56.74mm, mean Femur Length (FL) of 62.50±13.90mm and mean Estimated Fetal Weight (EFW) of 1903±940g, which are typical of a mid second and third trimester fetal biometry.

The descriptive profile broadly aligns with classical biometric references, where BPD, HC, AC and FL increase near-linearly across mid-gestation before moderating later in the third trimester [7,10,12]. EFW centiles in this range are similarly consistent with international standards [8,10]. These distributions support valid correlation and regression analyses comparing fetal kidney parameters with standard biometry and weight estimates.

Fetal Renal Dimensions

For the renal lengths, this study showed that the mean Right Kidney Length (RKL) was 35.70± 8.87mm and the mean Left Kidney Length (LKL) was 35.79± 8.81mm. then for the Antero-posterior diameters, this study showed that the mean Right Kidney Antero-Posterior Diameter (RKAPD) was 19.87± 4.88mm and the Left Kidney Antero-Posterior Diameter was 20.09± 4.94mm.

Fetal renal dimensions increase progressively with gestational age, and their distributions within mid-to-late gestation cohorts tend to be unimodal with moderate dispersion—features that are suitable for deriving reference ranges and for assessing correlations with GA and other biometric indices (e.g., BPD, HC, AC, FL). Methodologically, stable central tendency with limited skew strengthens regression and agreement analyses, particularly when evaluating renal measures as adjunct predictors of GA or growth status [7,10].

Correlation between Gestational Age and Renal Anteroposterior Diameter

We observed very strong positive correlations between gestational age (GA) and renal anteroposterior diameters (APD) on the right and left, and for the mean of both kidneys ($r \approx 0.927$–0.928; slopes ≈ 0.74 mm/week; n = 208). These effect sizes indicate that APD increases steadily with advancing gestation and that GA explains a large share of the variability in APD ($R^2 \approx 0.86$).

Published fetal kidney charts and nomograms consistently show strong growth relationships between renal dimensions and GA, particularly for fetal kidney length (FKL). Contemporary and classic series report high correlations for FKL with GA (for example, $r \approx 0.94$–0.99), with linear trends through mid- and late gestation [13-17]. Although our primary parameter is APD rather than length, the direction and magnitude of association we observed are consistent with the general renal growth pattern described in those references. Large prospective datasets and international standards also document steady renal growth with advancing gestation and advocate deriving gestation specific reference ranges[6,11].

It is important to distinguish the parenchymal kidney AP diameter used in our study from the anteroposterior diameter of the renal pelvis used to screen for hydronephrosis. The latter (renal pelvic APD) has well established normal cut offs that are typically <4 mm before 28 weeks and <7 mm at ≥28 weeks[18,19]. Our measured APD values are substantially larger than renal pelvic APD norms, confirming we assessed renal parenchymal APD rather than pelvic dilation; therefore, direct numerical comparison with hydronephrosis threshold literature is not appropriate. Nonetheless, both literatures agree that measurements tied to renal anatomy exhibit GA related trends, with increasing dimensions across gestation.

Most existing studies focus on FKL rather than parenchymal APD. Head- to- head reports quantifying GA–APD correlations are relatively scarce compared with FKL reports. Our effect sizes ($r \approx 0.93$) are on par with or slightly below the highest FKL–GA correlations reported (often ≥0.95–0.99), which is plausible given anatomical measurement axes and caliper reproducibility. This highlights an opportunity to expand nomograms for parenchymal APD alongside length based charts, and to evaluate reproducibility and clinical utility across trimesters.

The concordance of our findings with the renal growth literature supports using APD as a biologically meaningful marker that scales with GA. In practice, APD could complement FKL and standard biometry when evaluating growth trajectories or constructing gestation specific centiles. Future work can benchmark APD performance against FKL and standard indices (BPD, HC, AC, FL) using multivariable models and assess calibration with external datasets.

Weekly Reference for Renal Diameters

We constructed week-by-week baseline references (P5–P95) for right and left renal anteroposterior diameters (RKAPD, LKAPD). The centiles rise monotonically with gestational age (GA), and the interpercentile spread remains relatively narrow across mid–late gestation—both features match the expected physiology of renal growth and mirror patterns seen in established kidney size charts. For example, classic and contemporary references document steady increases in fetal kidney dimensions with GA and advocate GA specific centile charts to contextualize individual measurements [6,11].

Most of the published literature emphasizes fetal kidney length (FKL) rather than parenchymal AP diameter. Numerous studies have shown very strong linear relationships between FKL and GA—often reporting correlations in the $r \approx 0.94$–0.99 range—supporting the biological plausibility of a tight, week-by-week relationship between renal size and gestation [14,15]. Although our reference is built on parenchymal AP diameter (rather than length), the week-by-week medians and centile bands we observed are consistent with those renal growth curves; thus, our tables fill a useful gap by providing parenchymal APD centiles that can complement the more widely available FKL charts in research and clinical audit.

It is essential to distinguish parenchymal AP diameter from the anteroposterior diameter of the renal pelvis used to screen for hydronephrosis. Consensus guidance for urinary tract dilation (UTD) treats pelvic APD as a threshold based marker (e.g., <4 mm before 28 weeks; <7 mm at ≥28 weeks) and classifies risk using standardized antenatal/postnatal grading, which is a different clinical application from organ growth centiles [18]. Accordingly, numerical comparison between our parenchymal APD centiles and pelvic APD cut offs is not appropriate; however, both literatures agree that kidney related measurements demonstrate GA linked changes across gestation.

Methodologically, per week centiles with adequate sample coverage are consistent with best practice in constructing fetal organ charts. van Vuuren et al[6] noted that longitudinally derived centiles can exhibit narrower percentile bands than older references—an observation that supports our use of completed week aggregation and suggests that smoothed centile curves (e.g., polynomial/LOESS) could be reported alongside raw week specific values for publication grade presentation.

Accuracy of Fetal Kidney Diameter to Estimate Gestational Age

Using linear models, gestational age (GA, weeks) showed tight, approximately linear relationships with renal anteroposterior diameters (APD)—right, left, and their mean—with $R^2 \approx 0.86$ and standard error of estimate (SEE) around 2.3 weeks. As expected, single parameter models based on standard biometry (especially femur length, FL) performed even better (e.g., GA~FL: $R^2 \approx 0.976$, SEE ≈ 0.97 weeks), followed by HC and BPD, with AC close to APD performance. These patterns are consistent with the broader obstetric sonography literature.

Classic and contemporary references consistently demonstrate that individual biometric parameters (FL, BPD, HC, AC) are strongly associated with GA, with FL typically yielding the tightest fit in the second–third trimesters due to its reproducibility and relatively stable measurement plane. The observed hierarchy in our benchmark models—FL > HC ≈ BPD > AC—accords with widely used charts and standards [8,10,12]. Our GA~FL model's very high R^2 (≈0.976) and low SEE (≈0.97 weeks) are in line with these reports, while HC and BPD models also showed strong performance ($R^2 \approx 0.93$–0.94).

Most renal growth studies emphasise fetal kidney length (FKL), which often exhibits correlations with GA approaching $r \approx 0.95–0.99$. Our APD based models delivered R^2 values (≈0.86) comparable to AC and slightly below HC/BPD, which is plausible given that APD samples a different axis of renal growth and may be more sensitive to fetal position and caliper placement than the long-axis FKL. Even so, the linear slopes (~1.17 weeks per mm for Mean APD) and low residual error support APD as a biologically meaningful adjunct predictor—especially when standard planes are suboptimal or when renal morphology is under concurrent evaluation [9,14,16].

APD-based GA estimation, while not intended to replace standard biometry, can complement routine dating/growth assessment and may be particularly useful in sensitivity analyses or in populations where specific biometric planes are challenging. Multivariable models that combine Mean APD with conventional indices (e.g., FL+HC or FL+AC) can plausibly reduce error further, as suggested by integrative growth-standards programmes [10]. For clinical deployment, models should be calibrated and validated on independent cohorts, with attention to measurement reproducibility, inter-observer variability, and GA coverage.

Direct comparison between APD and length based renal parameters should account for measurement axis, fetal posture, and acoustic window—all of which affect precision. Unlike renal pelvic AP diameter (hydronephrosis screening), parenchymal APD reflects organ size rather than collecting-system dilation; numerical thresholds in the hydronephrosis literature are therefore not comparable to APD based growth models[18]. Finally, single parameter linear models assume near linearity and homoscedasticity; residual diagnostics in our analysis did not reveal gross misspecification, but smoothing or non-linear terms can be explored if future residuals suggest curvature at GA extremes.

Comparison of Kidney diameters to Caucasian Studies

Mean parenchymal AP diameters in this cohort are compared by completed week to a Caucasian reference derived from a prospective, predominantly European population. Across overlapping weeks, the mean differences are small to moderate in magnitude, indicating broad concordance of renal AP diameter growth between populations, with any deviations likely explained by GA mix, measurement axis, and sampling. This is consistent with kidney-growth literature showing steady, monotonic increases of parenchymal dimensions across gestation and supporting GA-specific centiles [6,11].

CONCLUSION

This study provides robust evidence that fetal renal parenchymal AP diameter increases predictably with GA and correlates strongly with gestation ($r \approx 0.93$), enabling week-specific reference centiles and adjunct GA estimation.

While standard biometry (especially FL) remains the primary and most precise GA predictor, APD-based charts and models offer complementary value—particularly when standard planes are challenging or when renal assessment is already indicated.

The close alignment with a Caucasian reference and the small weighted difference (~+0.35 mm) support physiological concordance and potential cross-population applicability, pending external validation.

Overall, the outputs (centiles, regression equations, and nomogram) are fit for clinical audit and research use, with next steps focused on smoothing, reproducibility, and multicentre validation to finalize publishable standards.

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