Original Article

Ultrasound Measurement of Fetal Kidney Length in Normal Pregnancy and Correlation with Gestational Age

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Abstract

Background: Belated booking for antenatal care remains a common practice among pregnant women in developing countries. Many of the existing conventional ultrasonographic indices used for assessing gestational age (GA) become increasingly unreliable beyond the 2nd trimester. **Materials and Methods:** A prospective cross-sectional study of booked healthy pregnant women with regular menstrual cycles and certain last menstrual period (LMP) were examined using ultrasound over a 6-month period. Fetal kidney length (FKL) was measured, beginning from 20 to 41 weeks of gestation. **Results:** A total of 400 pregnant women were examined. The mean left FKL was slightly but significantly higher than the mean right FKL across the various weeks of gestation ($P < 0.05$). The mean combined FKL (MKL) was 32.18 ± 5.96 mm, with a reference range of 20.87 ± 0.75 mm to 41.41 ± 0.07 mm from 20 to 41 weeks of gestation. There was strongly positive significant correlation between MKL in millimeters and GA by the LMP in weeks ($r = 0.997$, $P = 0.000$). The standard error of prediction (SE) of GA was least for MKL (±7.17 days), followed by femur length (FL) (±8.38 days), head circumference (HC) (±9.02 days), abdominal circumference (AC) (±9.14 days), and biparietal diameter (BPD) (±10.36 days). The best multiple regression model for predicting GA included the five variables such as MKL, FL, BPD, HC, and AC, with a SE of prediction of (±6.31 days). **Conclusion:** FKL can serve as an additional reliable parameter for accurate dating of GA during obstetric scan.

Keywords: *Fetal kidney length, gestational age, pregnant women, ultrasound*

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Introduction

An accurate gestational age (GA) is vital to the diagnosis of fetal growth disorders and the timing of elective delivery, failure of which could either result in iatrogenic prematurity or postmaturity, with their attendant perinatal morbidity and mortality. In developing countries, a significant number of pregnant women tend to seek antenatal care late in pregnancy, a number of who are unable to recall their precise last menstrual period (LMP).[1]

Compared with the traditional methods of dating pregnancy using LMP and clinical measurement, ultrasonographic dating has been recognized as the most accurate method of assessing GA.[2-7] The biometric parameters used include gestational sac volume, gestational sac diameter, and crown-rump length (CRL) measurements, which are most commonly used in 1st-trimester pregnancy dating.[8,9] By the end of the 1st trimester, measurements of biparietal diameter (BPD) become more accurate than the CRL, which by that time reflects errors associated with fetal flexion and extension.

BPD and femur length (FL) are commonly used for 2nd-trimester pregnancy dating.[10] To a lesser

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degree, biometric indices such as transcerebellar diameter,[11,12] foot length,[13] and clavicular length[14] have also been used. The sonographic parameters used in the 3rd trimester are BPD, FL, abdominal circumference (AC), and head circumference (HC). Between the 12th and 26th weeks of gestation, BPD has been shown to be able to predict GA within 6–11 days, but after 26 weeks, the accuracy of BPD measurement progressively decreases, with a standard error (SE) of ±3 weeks near term.[15] Similarly, HC, FL, and AC have also been reported to get increasingly unreliable beyond the 2nd trimester.[16-19]

This study sonographically measured the length of both fetal kidneys in normal singleton pregnancies. Measurements were then correlated with GA derived from the 1st day of patients' known LMP and compared with GA derived from the other conventional biometric methods (BPD, HC, FL, and AC). Its predictive accuracy in GA dating was also determined and compared with those of other biometric methods.

Materials and Methods

This was a prospective cross-sectional study of fetal renal length which was carried out in the ultrasound unit of the Department of Radiology, University of Benin Teaching Hospital (UBTH), Benin City between May and October 2013. The maternal inclusion criteria were viable normal singleton gestation, pregnant women in their late 2nd and 3rd trimesters (beginning from the 20th week) at the time of examination who had regular 28-day menstrual cycle and were certain of their LMP, and those with first trimester obstetric scan in the index pregnancy which was dated using the CRL.

The maternal exclusion criteria were multiple gestations, history of diabetes or hypertension in pregnancy, uncertainty of LMP in index pregnancy, maternal history of cigarette smoking, and difference between GA by LMP and composite GA (CGA) by the Hadlock's chart of >2 weeks. Fetal exclusion criteria included suspected intrauterine growth restriction, polyhydramnios, indistinct adrenal or renal borders, abnormal renal morphology, gross fetal hydronephrosis, and fetal structural abnormality.

The sample size (N) for this study was calculated from the Fisher's formula[20] for a sample population >10,000, given as $N = (Z/D)^2 P (1 - P)$, where Z is the standard normal deviation (with a value of 1.96 corresponding to 95% confidence level), D the degree of accuracy desired (which for this study was set at 0.05), and P the proportion in the target population estimated to have a particular characteristic (50% for this study). With these values, the required minimum sample size for this study was 384. This was approximated to 400 to broaden the study.

Measurement technique

Measurements of all fetal biometric parameters were obtained using a real-time, grayscale, 3.5–5.0 MHz curvilinear array transducer of a Sonoace X4 (Medison Inc, Korea 2010) ultrasound machine. A structured questionnaire was administered to participants to document sociodemographic data and other relevant clinical information. Maternal height (meters) and weight (kilograms) were obtained.

A satisfactory transverse plane of the fetus was first defined at the level of the four chambers of the heart, following which transverse scanning was continued in a cephalocaudal direction until the fetal kidneys were visualized, often at the level of the stomach, or just below it. The probe was then oriented through 90° to obtain the longitudinal axis of each kidney on either side of the midline tubular anechoic abdominal aorta. The largest longitudinal image showing both superior and inferior outer poles of each kidney was painstakingly obtained and frozen on the monitor screen. Using electronic calipers, kidney length was measured from the superior outer pole to the inferior outer pole as described by Bertagnoli *et al*.[21] Three measurements were taken per kidney to minimize intraobserver error, and the average value in millimeters was recorded in a worksheet. Care was taken to exclude the adrenal glands (AGs) from the measurements [Figure 1].

Menstrual age (MA) in weeks was determined from the patient's LMP using Naegele's rule,[22] thus representing GA by LMP, while the estimated GA was determined from the Hadlock's chart of predicted fetal measurements at specific menstrual weeks for BPD, HC, FL, and AC, using well-defined reference points.[23] The CGA in weeks, derived as an average of the measured biometric indices (BPD, HC, FL, and AC), was similarly documented in the worksheet. Each measurement was done thrice and the average computed and recorded as the mean value.

Data were analyzed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). Statistical tests of significance of hypotheses were done using Student's *t*-test, analysis of variance, and Pearson's correlation coefficient at $P \leq 0.05$ and 95% confidence interval. Regression analyses of the biometric variables were also done and compared. Univariate/multivariate regression equations were derived.

Ethical clearance for this study was obtained from the Ethics and Research Committee of UBTH. Written informed consent was also obtained from each participant.

Results

A total of 400 pregnant women and 800 fetal kidneys were examined. About two-third of the participants (288, 72%) were in the third trimester, while the remaining one-third (114, 28.5%) were in late second trimester. The age range of participants was 18–44 years, with a mean age of 29.90 ± 0.22 years. Table 1 shows the mean RKL, LKL, and MKL with their respective standard deviations at specific GAs beginning from the 20th week, representing the nomograms for fetal kidney length (FKL) in this study. There was a progressive increase in RKL, LKL, and MKL in millimeters as the GA increased in weeks. The MKL increased from a value of 20.87 ± 0.75 mm to 41.41 ± 0.07 mm at 20 weeks and 41 weeks of gestation, respectively.

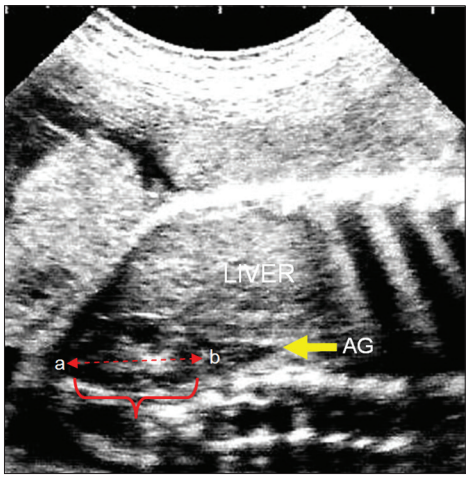

Figure 1: Coned longitudinal sonogram of the fetal right kidney with the fetus in supine position. The kidney is seen as an elliptical structure with a central echogenic sinus and hypoechoic cortex. The broken red arrow shows the measurement of the kidney length from superior outer pole to inferior outer pole, between points a and b. The yellow arrow points to the fetal adrenal gland, seen as an inverted V-shaped hypoechoic structure located adjacent to the superior pole of the kidney

The LKL was significantly higher than the RKL across the different weeks of gestation (P = 0.000) [Table 1]. There was strong positive correlation between RKL (mm) and MA in weeks (r = 0.983, P = 0.000), LKL (mm), and MA in weeks (r = 0.983, P = 0.000), as well as MKL (mm) and MA (weeks) (r = 0.985, P = 0.000). There was no significant correlation between maternal height and RKL (r = 0.067, P = 0.178), LKL (r = 0.076, P = 0.132), MKL (r = 0.072, P = 0.153), and MA (r = 0.077, P = 0.125). The maternal weight showed very weak positive correlation with RKL (r = 0.209, P = 0.000), LKL (r = 0.209, P = 0.000), MKL (r = 0.209, P = 0.000), and MA (r = 0.207, P = 0.000). Table 2 shows the MKL values and their standard deviations obtained per week of gestation, along with the corresponding mean GAs obtained by BPD, HC, FL, and AC. There was progressive linear increase in the MKL as GA determined by other parameters increased.

Table 1: Mean right kidney length, left kidney length, and combined kidney length compared with menstrual age

Menstrual age (weeks)	Number of patients (*n*)	RKL±SD (mm)	LKL±SD (mm)	Difference (mm)	MKL±SD (mm)
20	17	20.70±0.91	21.04±0.63	0.34	20.87±0.75
21	10	20.86±0.43	21.05±0.45	0.19	20.96±0.41
22	18	22.06±0.60	22.49±0.46	0.43	22.27±0.44
23	18	23.59±0.85	23.99±1.13	0.40	23.79±0.94
24	13	25.13±1.36	25.53±1.32	0.40	25.33±1.32
25	18	25.83±1.28	26.11±1.43	0.28	25.97±1.31
26	10	26.90±0.67	28.04±0.71	1.14	27.47±0.68
27	9	27.31±1.28	27.77±1.09	0.46	27.54±1.17
28	14	29.36±0.62	29.56±0.74	0.20	29.46±0.63
29	14	30.00±0.96	30.69±1.19	0.69	30.34±1.02
30	18	31.59±0.89	32.07±0.77	0.48	31.83±0.74
31	23	31.66±0.99	32.08±1.07	0.42	31.87±1.00
32	18	33.51±0.97	33.69±1.02	0.18	33.60±0.88
33	26	34.13±1.34	34.48±1.30	0.35	34.31±1.26
34	18	34.92±0.84	35.21±1.02	0.29	35.06±0.86
35	29	35.76±1.34	35.96±1.16	0.20	35.86±1.19
36	45	36.52±1.04	37.20±1.03	0.68	36.86±0.99
37	34	38.15±1.41	38.21±1.08	0.06	38.18±1.14
38	25	38.58±1.14	38.96±1.15	0.38	38.77±1.05
39	11	39.35±1.14	39.45±0.92	0.09	39.40±0.99
40	6	39.80±0.68	40.83±1.75	1.03	40.32±0.54
41	6	40.80±0.63	42.02±0.76	1.22	41.41±0.07
Total	400	31.99±5.98	32.38±5.98		32.18±5.96

RKL=Right kidney length; LKL=Left kidney length; MKL=Mean combined fetal kidney length; SD=Standard deviation

Table 2: Mean combined kidney length compared with menstrual age and gestational age derived from fetal biometric parameters (biparietal diameter, head circumference, femur length, and abdominal circumference)

Menstrual age (weeks)	Number of participants (*n*)	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	17	20.87±0.75	20.73±0.88	20.79±0.81	20.57±0.81	21.23±0.83
21	10	20.96±0.41	21.43±0.62	21.30±0.53	21.67±0.53	21.73±0.49
22	18	22.27±0.44	22.56±0.35	22.49±0.82	22.63±0.49	22.76±0.68
23	18	23.79±0.94	23.50±1.16	23.20±0.93	23.33±1.15	23.26±1.01
24	13	25.33±1.32	25.46±1.15	25.48±1.00	24.83±1.37	25.09±1.12
25	18	25.97±1.31	25.02±1.10	25.48±0.98	25.11±0.78	25.29±0.85
26	10	27.47±0.68	26.71±1.18	27.31±1.50	27.23±0.57	27.29±0.98
27	9	27.54±1.17	26.75±0.52	26.89±0.50	26.95±0.84	26.24±0.43
28	14	29.46±0.63	28.38±0.98	28.96±1.27	28.39±1.10	29.23±1.19
29	14	30.34±1.02	29.54±0.85	29.29±1.21	29.68±1.06	29.74±0.83
30	18	31.83±0.74	31.22±0.94	31.43±0.84	30.73±1.61	30.75±1.00
31	23	31.87±1.00	31.53±1.11	32.02±1.06	31.54±0.92	31.61±1.53
32	18	33.60±0.88	32.54±1.22	33.44±0.66	33.22±1.27	32.00±1.64
33	26	34.31±1.26	33.57±1.25	34.14±0.81	33.92±1.39	33.75±1.54
34	18	35.06±0.86	34.02±1.72	35.07±0.77	34.79±1.08	35.10±1.02
35	29	35.86±1.19	35.17±0.90	35.47±1.10	35.93±1.47	35.55±1.58
36	45	36.86±0.99	35.64±1.76	36.02±1.56	36.45±1.35	36.22±1.45
37	34	38.18±1.14	36.15±1.65	37.17±1.43	37.66±1.64	37.15±1.08
38	25	38.77±1.05	37.10±1.60	37.79±1.50	38.43±1.50	37.66±1.06
39	11	39.40±0.99	38.16±1.23	38.31±1.16	38.77±0.35	37.91±0.83
40	6	40.32±0.54	37.62±2.10	40.00±0.34	39.57±0.22	38.29±0.56
41	6	41.41±0.07	38.38±1.64	39.05±1.38	39.76±1.04	39.14±0.68
Total	400	32.18±5.96	31.27±5.48	31.72±5.72	31.77±5.91	31.59±5.62

MKL=Mean combined fetal kidney length; SD=Standard deviation; GA=Gestational age; BPD=Biparietal diameter; HC=Head circumference; FL=Femur length; AC=Abdominal circumference

Table 3: Comparison between mean combined fetal kidney length in the present study and mean combined fetal kidney length in other studies at specific gestational ages

GA (weeks)	MKL (mm) in present study (2014)	MKL (mm) (Nirmala *et al*., 2013)	MKL (mm) (Indu *et al*., 2012)	MKL (mm) (Kansaria *et al*., 2009)	MKL (mm) (Konje *et al*., 2002)
24	25.3	24.1	25.7	23.9	24.2
28	29.5	28.2	31.5	27.0	29.0
32	33.6	32.8	36.5	30.8	33.2
36	36.9	36.5	40.6	34.3	38.2

GA=Gestational age; MKL=Mean combined fetal kidney length

A comparison between MKL at specific GAs in the present study and MKL in other studies is shown in Table 3.

BPD showed the least accuracy as a single parameter for predicting GA (SE of 10.36 days), whereas MKL was the best single accurate parameter (SE of ± 7.17 days). The simple linear regression equations derived from each FKL parameter (RKL, LKL, and MKL) as a function of GA are shown below:

1. MA (weeks) = 0.661 + 0.969 RKL (mm)
2. MA (weeks) = 0.264 + 0.969 LKL (mm)
3. MA (weeks) = 0.326 + 0.973 MKL (mm).

Different multiple regression models consisting of two or more variables were also derived. The model consisting of MKL, FL, BPD, HC, and AC was found to be the most accurate in predicting GA, with a SE of ± 6.30 days.

Discussion

With the advent of high-resolution real-time ultrasound, the ability to image various organs *in utero* has dramatically improved. This is certainly true for the fetal kidney.[1,24] In the course of conducting this research, both fetal kidneys were easily identified and examined in all 400 recruited cases, contrary to the observations of Cohen *et al*.[25] and Aremu[26] but in consonance with those of other authors.[25,27-29,30] This was aided by manipulations of the transducer and angle of insonation relative to the fetal kidney plane, regardless of fetal presentation, lie, and position.

The resolution of the ultrasound machine used in this study was sufficient to enable adequate delineation of the adjacent fetal AG, and therefore its exclusion from FKL measurements. The weak positive correlation between maternal weight and MA in this study suggests that maternal body habitus in this environment may significantly affect the correctness of GA determination using the LMP predicated on Naegele's rule, an observation that may be due to dietary and genetic peculiarities among this study population.

Cohen *et al*.[25] and Nahid *et al*.[31] found no significant correlation between maternal height and FKL as was the case in this study; however, the observation of both investigators that maternal weight showed no correlation with FKL is incongruous with that of this study, which showed a weak positive correlation between both variables. Cohen *et al*.[25] worked with maternal weights recorded before pregnancy, as against this study in which maternal weights were measured at the same time of measurement of FKL. The research by Nahid *et al*.[31] was a prospective longitudinal study among an Asian population, whereas this study is a prospective cross-sectional study among an African population.

The linear increase in FKL in millimeters as the GA increased in weeks in this study concurs with the observations of Aremu[26] and other authors.[27,28,31] Values of MKL obtained in millimeters in the report of Nirmala *et al*.[32] were closer to the actual GAs when compared with this study. However, only one of the fetal kidneys (the proximal kidney) was measured in their study, whereas both kidneys were measured in this present study.

The statistically significant difference in length observed in the present study between both kidneys, in favor of the left kidney, is consistent with the report of Seilanian Toosi and Rezaie-Delui[29] and Fitzsimons.[33] The latter author ultrasonographically measured the lengths of 115 kidneys in neonatal life and found LKL slightly and significantly higher than the RKL. Adult left kidneys have also been found to be marginally longer than their counterpart right kidneys by about 1.5 cm.[34] Konje *et al*.[27] and Kansaria and Parulekar[28] found no significant difference between the right and left kidney lengths. These investigators carried out their measurements in fewer participants (70 and 73 participants, respectively), compared with 400 participants in the present study. The research by Kansaria *et al*. was a longitudinal study in which consecutive measurements were done at 2 weekly intervals in each participant (in an Asian population), as against the cross-sectional approach in the present study in which measurements were taken in each participant at just one visit (in an African population). Genetic and socioeconomic factors may have also been contributory to the variation in observations regarding right and left kidney lengths in the present study compared with other differing previous studies. Although Ahmadi *et al*.[35] found no difference between RKL and LKL ($P = 0.843$) in an examination of 557 fetuses, they found mean right kidney width longer than the mean left kidney width ($P = 0.004$). Fetal kidney width was not measured in this study as this has been reported to be smaller in fetuses who are small-for-GA (unlike FKL which was found to be similar in both appropriate- and small-for GA fetuses),[36,37] hence its unsuitability as a dependable parameter for GA assessment *in utero*.

The strongly positive significant correlation between MKL in millimeters and GA in weeks as predicted by BPD, HC, FL, and AC in this study supports the findings of several other researchers.[25,27-31,38] Aremu in Ilorin, Nigeria[26] found very strong correlation observed between FKL and estimated GA by LMP ($r = 0.997$). Joylene *et al*.[39] found a high degree of correlation ($r = 0.860$) between MKL and GA in an examination involving only third-trimester participants.

Konje *et al*.[27] and other investigators[28-30] reported MKL as the most accurate single parameter for predicting GA as was found in this study. The increasing unreliability of BPD in GA determination beyond early 2nd trimester has earlier been reported by O'Brien *et al*.[17] and may be due to fetal skull engagement and molding that occurs with most vertex-presenting intrauterine fetuses as pregnancy progresses toward term, when it becomes difficult to obtain the standard plane for BPD measurement.

The SE in estimating the mean CGA from multiple variables has been shown in this study to be less than the SE obtained when any single variable is used. This concurs with the observations and recommendations by many authors for sonographic estimation of GA to be done using the composite measurement of multiple fetal biometric variables.[15,18,40-42]

Conclusion

This study has been able to establish a nomogram for mean right and left FKL per week, between the 20th and 41st weeks of gestation in a South-South Nigerian population, with MKL of 20.87 ± 0.75 mm and 41.41 ± 0.07 mm at 20 and 41 weeks, respectively.

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Conflicts of interest

There are no conflicts of interest.

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