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Fetal kidney measurement — additional biometric parameter for accurate gestational age assessment

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ABSTRACT

Objectives: Ultrasound examination — recommended in the prenatal period — allows for an assessment of fetal anatomy and well-being and for monitoring its growth trend. Determining gestational age is important in monitoring the developing fetus. Research is increasingly being conducted in search of further biometric components that may improve ultrasound techniques in terms of predicting the gestational age. It should be noted that a fairly large number of publications focus on the accessibility of fetal kidneys to diagnostic imaging during routine ultrasound examination. The reported study was an attempt to answer the question whether fetal kidney dimensions correlated with gestational age. The obtained results are presented as fetal kidney normograms for particular weeks of gestation.

Material and methods: The study covered by dissertation was conducted among patients hospitalized at the Provincial Specialist Hospital in Zgierz, Department of Gynecology, Obstetrics and Endoscopic Therapy, in the period from 1st April 2019 to 30th November 2019. The study group included patients in a single pregnancy. The control group was not included in the study. The ultrasound examinations, which are the basis of the study, were carried out using the PHILIPS

Affiniti 70 ultrasound device, with a frequency of 3.5 MHz transabdominal transducer. All data were subjected to statistical analysis using the Statistica 13.1 program.

Conclusions: Kidney dimensions strongly correlated with gestational age. Fetal kidney growth was a linear process in normal pregnancy. Fetal kidney measurements can provide additional biometric parameters for accurate gestational age assessment.

Key words: fetal anatomy; determining gestational age; fetal kidney; fetal kidney normograms; kidney dimensions; fetal kidney growth

INTRODUCTION

Ultrasound examination — recommended in the prenatal period — allows for an assessment of fetal anatomy and well-being and for monitoring its growth trend. Prenatal sonography is increasingly being used as a tool to determine the advancement of gestational age in unclear cases, such as those related to the unknown date of the last menstrual period. Determining gestational age is important in monitoring the developing fetus [1, 2].

In the absence of the ability to accurately determine the stage of pregnancy, a reliable prediction of the prenatal and postnatal fate is rather difficult to establish. The lack of both reliable data and precise and clear eligibility criteria in the area directly translates into higher rates of perinatal mortality, increased incidents of low birth weight or an elevated risk of preterm birth. Research is increasingly being conducted in search of further biometric components that may improve ultrasound techniques in terms of predicting the gestational age. Examples of such parameters include the transverse dimension of the cerebellum, the length of the foot or the width of the palate [3–5].

It should be noted that a fairly large number of publications focus on the accessibility of fetal kidneys to diagnostic imaging during routine ultrasound examination. Numerous efforts are underway to develop fetal renal normograms for different stages of pregnancy [6].

Aim of the study

The reported study was an attempt to answer the question whether fetal kidney dimensions correlated with gestational age. The obtained results are presented as fetal kidney normograms for particular weeks of gestation.

MATERIAL AND METHODS

The study was conducted at the Regional Specialist Hospital in Zgierz, Poland, Department of Gynecology, Obstetrics and Endoscopic Therapy, among female patients hospitalized between the 1st of April 2019 and 30th of November 2019, using a PHILIPS Affiniti 70 ultrasound system with a transabdominal 3.5 MHz probe. The concept of the study received approval of the Bioethics Committee. All examinations were performed individually by the author of the study during a routine ultrasound assessment of the fetus. Each patient was examined only once, not in individual trimesters.

The study group included patients with single pregnancy, in whom the duration of pregnancy had been calculated based on the first trimester examination, using the crown rump length (CRL) parameter or considering the date of the last menstrual period [7]. The exclusion criteria comprised undetermined pregnancy duration, multiparous pregnancies, pregnancies complicated by chronic diseases in an uncompensated phase, *i.e.*, diabetes (including gestational diabetes), hypertension and collagenosis.

In addition, patients with congenital fetal anomalies and those with any sonographic abnormalities identified in the fetal kidneys were not included in the study. Sonographic examinations were performed in the enrolled pregnant women between the 18th and 40th weeks of gestation. No control group was considered in the study. First, fetal well-being was determined (with an assessment of fetal growth trend, peripheral flows and amniotic fluid volume). In a subsequent stage of the study, an attempt was made to visualize fetal kidneys, which was carried out according to the accepted standard for studies of indicated structures, used, among others, in the publication by Edevbie JP et al. [8]. A satisfactory transverse plane of the fetus was first defined at the level of four chambers of the heart, followed by a transverse scanning continued caudally until fetal kidneys were visualized, often at the level of the stomach or immediately below it. The probe was then rotated by 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 meticulously obtained and frozen on screen [8]. Using electronic calipers, kidney length was measured from the superior outer pole to the inferior outer pole — KD 1 (Kidney Dimension 1) as the greatest kidney dimension in longitudinal axis and KD 2 (Kidney Dimension 2) as the greatest dimension perpendicular to the previous axis. As a rule, three measurements per kidney were taken. The average value in millimeters was recorded in a worksheet (Fig. 1). It is important to notice that once the measurement in the longitudinal axis is taken, it is necessary to obtain a transverse scan of the spine and both kidneys (spine located at 6 or 12 o'clock) in order to record the largest dimension of the fetal kidneys (KTD — kidney transverse dimension) in an axis parallel to a hypothetical line between the spine and the sternum.

In order to eliminate erroneous measurements, US imaging was repeated three times in each patient and for each fetal kidney separately. To receive the most reliable results, the study population was divided into relatively homogeneous subpopulations.

Statistical analysis

A statistical analysis was performed by means of the Statistica 13.1 software. The received results were expressed as arithmetic means ± standard deviations and mini- mum and maximum values. The Shapiro-Wilk test ($\alpha < 0.05$) was applied to check the normality of the distribution of variables. The Pearson correlation analysis was used for continuous variables with normal distribution. Student's t-test was used to compare the values of variables with normal distributions in two groups. If normal distribution was not found, further analysis was performed, using non-parametric tests. The Spearman correlation analysis was employed for continuous variables without normal distribution.

RESULTS

The study involved 265 pregnant women with an average age of 29 years. The ultrasound examination was performed between the 17th and 42nd weeks of pregnancy and the mean gestational age of the examined population was 29 + 5. Female sex was identified in 122 fetuses and male sex in 143 ones. See Table 1 for mean kidney dimensions at particular weeks of gestation (Tab. 1). See Tables 2–7 for normal kidney dimensions, expressed as the 5th, 10th, 50th, 90th and 95th percentile for each week of gestation (Tab. 2–7). The same data are also presented for the studied population in the form of percentile grids. The 5th, 10th, 50th, 90th and 95th percentiles were calculated for each week of gestation. Connecting simple regression lines were drawn for particular percentiles. The results are presented as percentile charts (Fig. 2–7). Based on the results of Mann-Whitney U test, no statistical difference was found between the weeks of gestation in the group of male and female fetuses ($p > 0.05$). The same test showed no difference between male and female fetuses in terms of particular kidney dimensions during pregnancy.

DISCUSSION

Knowing the correct fetal age is crucial for prenatal management planning from the first trimester until delivery [9]. Three parameters are needed to determine the duration of pregnancy in the first trimester examination: the size of the gestational sac (GS), crown rump length (CRL) and detection of the yolk sac (YS) [10, 11]. In the case of the second and third trimesters, the following parameters are considered: the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL) and humerus length (HL) [12].

It arises from available reports, that precise timing of pregnancy reduces unnecessary procedures, including the induction of labor for post-term pregnancy indications [13]. Exceeding specified time- frames in a particular medical procedure may result, among others, in ineffectiveness of therapeutic measures, such as prenatal stimulation of pulmonary respiratory system growth with recommended steroids, which should be administered between the 24th and 34th weeks of gestation [14–16]. The accuracy of establishing the gestational age is also important to determining delivery time. Some obstetric pathologies, such as gestational diabetes or untreatable hypertension, require induced labor [17]. Another advantage of accurate pregnancy timing is that it enables performing certain prenatal diagnostic tests. An example may be ultrasound imaging in the second trimester, which falls between the 18th and 22nd weeks of pregnancy [18, 19].

Additional biometric parameters helpful in determining the gestational age include: “floating particles” in the amniotic fluid — inhomogeneous amniotic fluid with hyperechoic inclusions, the cerebellar dimensions, visible ossification points in long bones, the scapula length, the foot length, the fetal chest to abdomen ratio, the sacral bone length, the hard palate width, echogenicity of the large intestine and the large bowel loop width. A complete diagnostic parameter should be characterized by easy detection, repeatability of measurements, independence from additional factors, *e.g.* chronic diseases accompanying pregnancy, and stability despite concomitant growth trend disorders. The innovative biometric parameters undoubtedly include the fetal kidney length, which correlates with the gestational age [20–25].

Romero R et al. [26] were among the pioneers of fetal kidney normogram development. The very few authors attempting to use the fetal kidneys for gestational age assessment not only provide evidence for a relationship between the fetal kidney linear growth and pregnancy duration, but also try to establish normograms for that organ [27]. In their publication, Lawson TL et al. [28] proposed methodology for the optimal measurement of fetal kidneys. They recommend that the whole procedure should individually visualize each of the kidneys; however, if it is difficult to visualize both fetal kidneys, the assessment may exceptionally address only one. Similarly, Edevbie JP et al. [8], due to subtle size differences between the left and right kidney, consider only one dimension in certain cases.

The size of the study population is undoubtedly of high significance to statistical reliability. In the study by Edevbie JP et al. [8], as many as 400 fetuses were examined, while in many reports, the number is below 100. In our study, 265 fetuses were assessed.

Similar findings were reported by Mete GU et al. [29] and Toosi FS et al. [30]. The above mentioned authors emphasize that fetal kidney measurements may be an excellent tool for pregnancy duration assessment in the third trimester. What is more, Konje JC et al. conducted observations between the 24th and 38th weeks of gestation and concluded that the fetal kidney length was a more predictive parameter for determining pregnancy duration than other parameters, such as the biparietal dimension, head circumference, abdominal circumference or femur length [31].

Fetal kidney dimensions can be a useful parameter in situations where it is either difficult or simply impossible to calculate pregnancy duration based on standard parameters. Examples may include: the unknown date of the last menstrual period, low fetal head position, impeded measurements of head dimensions, the lack of ultrasound records (from the first and the second trimester), impossible assessment by routine parameters due to malformations, such as achondroplasia, phocomelia, amelia, hepato- and splenomegaly, agenesis of the cranial bones, *etc*. In many cases, measurements are either impossible for the lack of properly formed structures or distorted by pathological organ sizes.

Summing up, the results of our study, supported by a fair amount of medical evidence and conclusions of other authors, imply that precise pregnancy duration establishment is of the key importance for both entire perinatal care and reduction of neonatal morbidity and/or mortality rates. Biometric dimensions of fetal kidneys may constitute an additional tool for gestational age prediction.

The very high repeatability of measurements, with no impact of fetal sex or the latitude of the studied population, ensure homogeneous results in parallel studies. The development of normograms will perhaps enable percentile grids to be implemented in ultrasound systems to improve calculations in terms of time and reliability.

A strong positive correlation between the fetal kidney dimensions and pregnancy duration period may provide a basis for the measurements to be used as an isolated additional biometric parameter employed to calculate the gestational age, also in combination with other more common parameters, such as the biparietal diameter, head circumference, abdominal circumference or femur length.

CONCLUSIONS

1. Kidney dimensions strongly correlated with gestational age. Fetal kidney growth was a linear process in normal pregnancy.
2. Fetal kidney measurements can provide additional biometric parameters for accurate gestational age assessment.

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Table 1. Kidney dimensions in particular gestation weeks

GESTATIONAL AGE		LKD 1	LKD 2	LKTD	RKD 1	RKD 2	RKTD
17–18	Mean average	18.63	8.70	8.38	18.30	8.14	8.85
	STD	0.30	0.68	0.95	0.34	0.97	0.84
19–20	Mean average	20.15	10.96	11.83	20.19	11.23	11.72
	STD	0.63	0.30	0.34	0.49	0.34	0.50
21–22	Mean average	22.11	10.56	11.44	22.35	11.05	11.56

	STD	0.47	0.46	0.39	0.54	0.36	0.51
23–24	Mean average	24.89	11.90	13.23	24.60	12.14	12.67
	STD	0.46	0.37	0.47	0.56	0.42	0.48
25–26	Mean average	27.24	13.37	16.15	27.08	13.28	14.77
	STD	0.44	0.13	0.75	0.30	0.09	0.29
27–28	Mean average	28.55	14.89	17.33	28.51	15.03	16.26
	STD	0.46	0.64	0.69	0.54	0.62	0.61
29–30	Mean average	31.08	16.01	18.85	31.09	15.96	17.43
	STD	0.90	0.40	0.72	0.75	0.38	0.46
31–32	Mean average	32.25	17.13	19.53	32.42	17.12	18.47
	STD	0.81	0.25	0.56	0.66	0.28	0.27
33–34	Mean average	34.57	17.53	19.42	34.32	17.35	18.72
	STD	0.60	0.50	0.46	1.12	0.36	0.40
35–36	Mean average	36.79	18.41	21.16	37.02	18.47	19.91
	STD	0.61	0.59	0.41	0.75	0.60	0.40
37–38	Mean average	38.61	19.82	21.70	38.73	20.09	21.03
	STD	0.64	0.60	0.60	0.66	0.93	0.85
39–40	Mean average	40.65	21.78	23.28	40.81	21.65	22.30
	STD	0.98	0.73	0.64	1.00	0.65	0.66

LKD — Left Kidney Dimension; LKTD — Left Kidney Transverse Dimension; RKD — Right Kidney Dimension; RKTD — Right Kidney Transverse Dimension; STD — Standard Deviation

Table 2. Consecutive percentiles for left kidney dimension 1 during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	18.11	18.13	18.72	18.89	18.96
19–20	19.13	19.14	20.53	20.73	20.73
21–22	21.50	21.67	22.10	22.67	22.67

23–24	24.25	24.42	24.85	25.47	25.59
25–26	26.43	26.70	27.43	27.57	27.58
27–28	27.58	28.07	28.57	29.13	29.16
29–30	29.25	29.56	31.48	31.83	31.86
31–32	31.31	31.40	32.00	33.50	33.55
33–34	33.83	33.83	34.52	35.31	35.74
35–36	36.01	36.07	36.72	37.58	37.73
37–38	37.58	37.63	38.72	39.38	39.47
39–40	39.45	39.62	40.48	42.33	42.45

Table 3. Consecutive percentiles for left kidney dimension 2 during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	8.04	8.08	8.43	9.92	10.00
19–20	10.63	10.67	11.03	11.19	11.23
21–22	9.94	10.09	10.47	10.89	11.13
23–24	11.38	11.50	11.90	12.23	12.49
25–26	13.15	13.20	13.40	13.50	13.52
27–28	14.17	14.18	14.90	15.71	15.79
29–30	15.46	15.63	15.98	16.65	16.70
31–32	16.78	16.89	17.05	17.47	17.61
33–34	16.71	16.82	17.62	18.00	18.33
35–36	17.61	17.68	18.42	19.07	19.30
37–38	19.03	19.03	19.90	20.41	20.83
39–40	20.45	20.75	21.95	22.42	22.83

Table 4. Consecutive percentiles for the left kidney transverse dimension during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	7.66	7.77	7.93	10.16	10.24
19–20	11.30	11.31	11.90	12.26	12.35
21–22	10.94	11.06	11.45	11.86	12.02
23–24	12.76	12.85	13.10	13.75	14.33

25–26	14.58	14.65	16.50	16.60	16.65
27–28	16.43	16.57	17.20	18.21	18.71
29–30	17.73	17.96	19.08	19.71	19.93
31–32	18.87	18.90	19.68	20.12	20.33
33–34	18.90	18.95	19.33	19.85	20.28
35–36	20.46	20.65	21.10	21.58	21.80
37–38	21.05	21.10	21.58	22.52	22.68
39–40	22.24	22.53	23.25	24.13	24.35

Table 5. Consecutive percentiles for right kidney dimension 1 during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	17.90	17.95	18.22	18.80	18.88
19–20	19.29	19.77	20.17	20.70	20.70
21–22	21.77	21.79	22.03	23.15	23.17
23–24	23.95	24.02	24.35	25.33	25.44
25–26	26.62	26.80	27.10	27.27	27.50
27–28	27.64	27.68	28.50	29.20	29.20
29–30	30.03	30.38	31.23	31.92	32.06
31–32	31.52	31.56	32.20	33.43	33.51
33–34	33.47	33.69	34.43	35.67	35.74
35–36	35.96	36.20	36.93	37.75	38.37
37–38	37.73	37.76	38.65	39.64	39.68
39–40	39.48	39.83	40.55	42.15	42.43

Table 6. Consecutive percentiles for right kidney dimension 2 during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	7.36	7.37	7.70	9.91	9.96
19–20	10.69	10.93	11.20	11.57	11.60
21–22	10.67	22.53	11.07	11.27	11.45

23–24	11.73	11.83	12.07	12.43	13.14
25–26	13.17	13.17	13.23	13.40	13.42
27–28	14.15	14.35	14.97	15.87	16.03
29–30	15.41	15.63	15.93	16.39	16.43
31–32	16.63	16.91	17.07	17.51	17.60
33–34	16.76	16.95	17.40	17.80	17.84
35–36	17.58	17.73	18.63	19.10	19.31
37–38	19.12	19.16	19.93	21.46	22.04
39–40	20.56	20.80	21.73	22.43	

Table 7. Consecutive percentiles for the right kidney transverse dimension during pregnancy

GESTATIONAL AGE	5. percentile	10. percentile	50. percentile	90. percentile	95. percentile
17–18	7.86	7.95	8.63	10.17	10.29
19–20	10.96	11.05	11.80	12.29	12.30
21–22	10.93	11.10	11.65	11.99	12.20
23–24	12.10	12.10	12.65	13.05	13.76
25–26	14.55	14.55	14.65	15.05	15.30
27–28	15.22	15.46	16.25	17.04	17.44
29–30	16.77	16.92	17.50	18.07	18.23
31–32	18.11	18.30	18.45	18.82	19.00
33–34	18.23	18.25	18.80	19.08	19.31
35–36	19.36	19.40	19.85	20.53	20.64
37–38	20.10	20.19	20.83	21.90	22.82
39–40	21.08	21.23	22.48	22.95	23.00

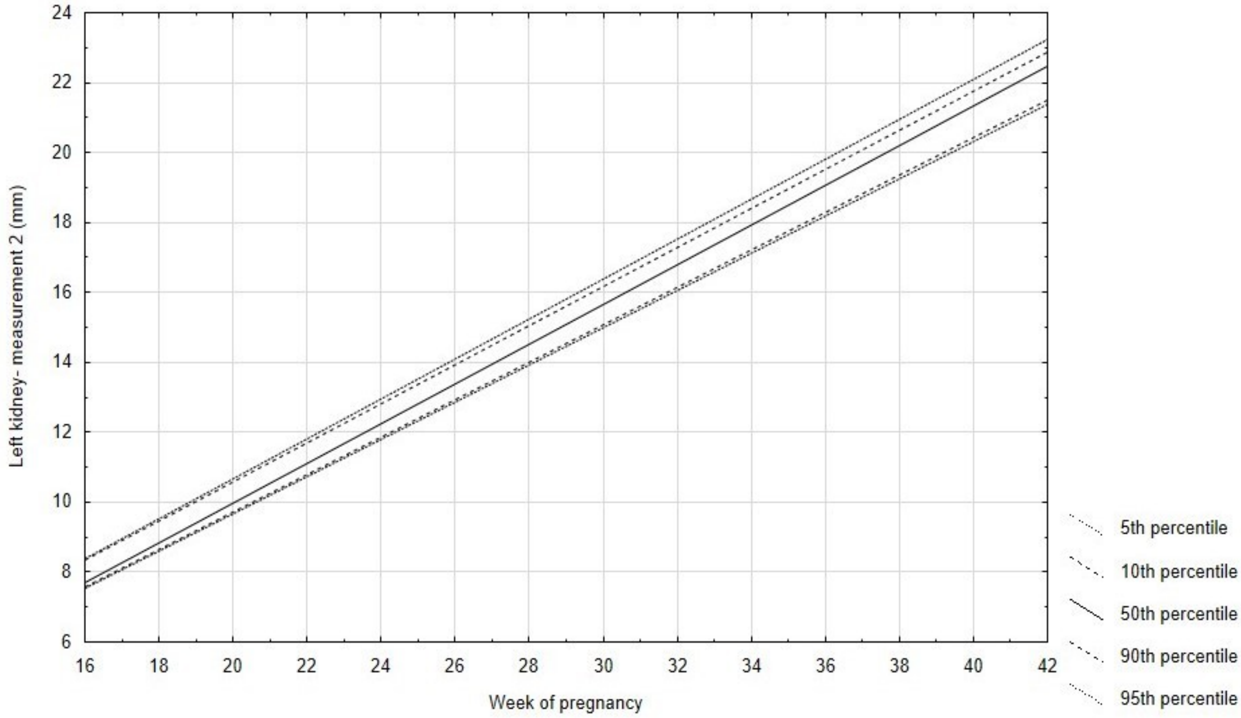

Figure 1. Percentile grid of left kidney dimension 1

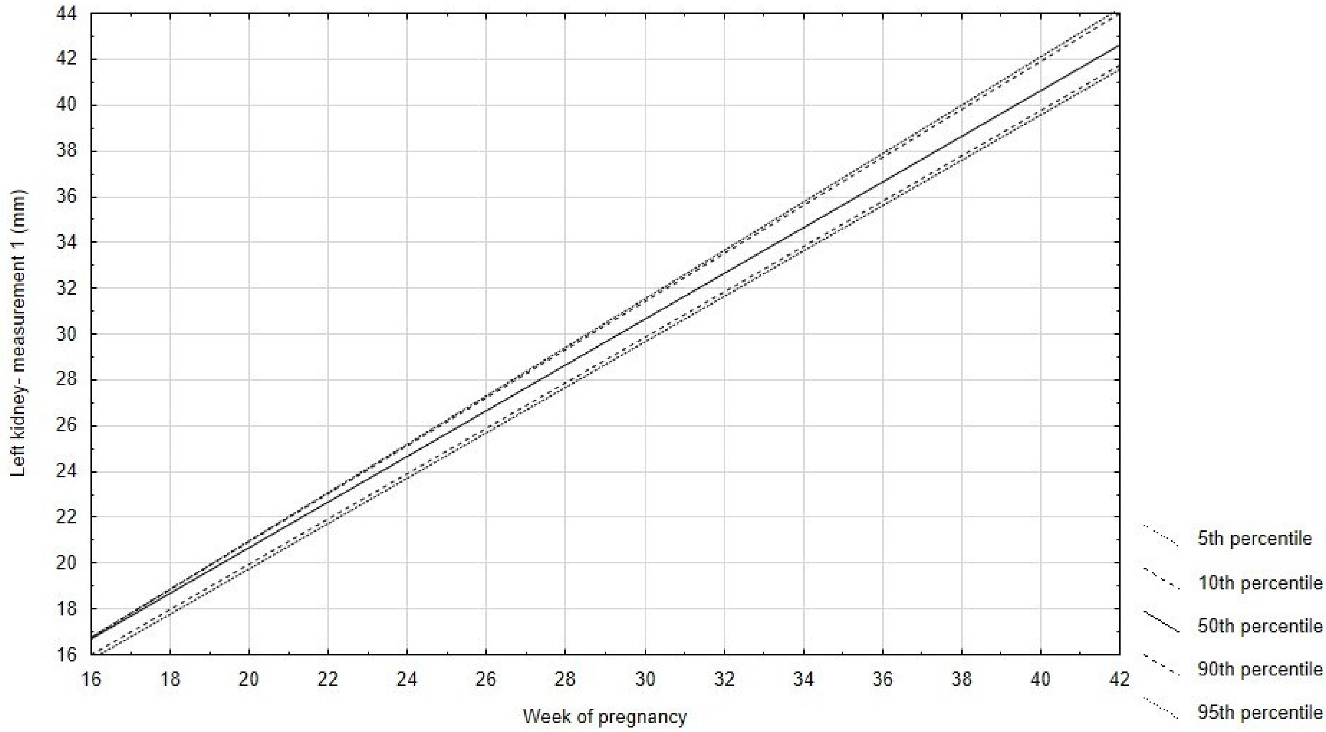

Figure 2. Percentile grid of left kidney dimension 2

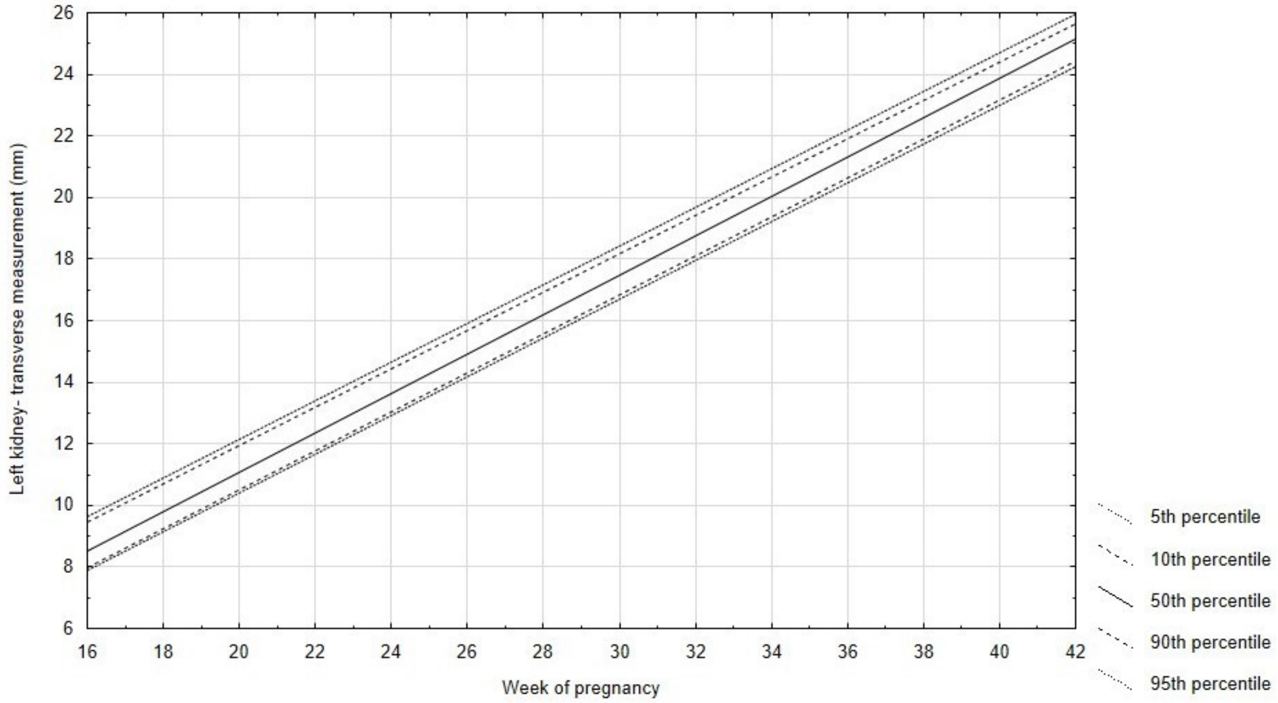

Figure 3. Percentile grid of the left kidney transverse dimension

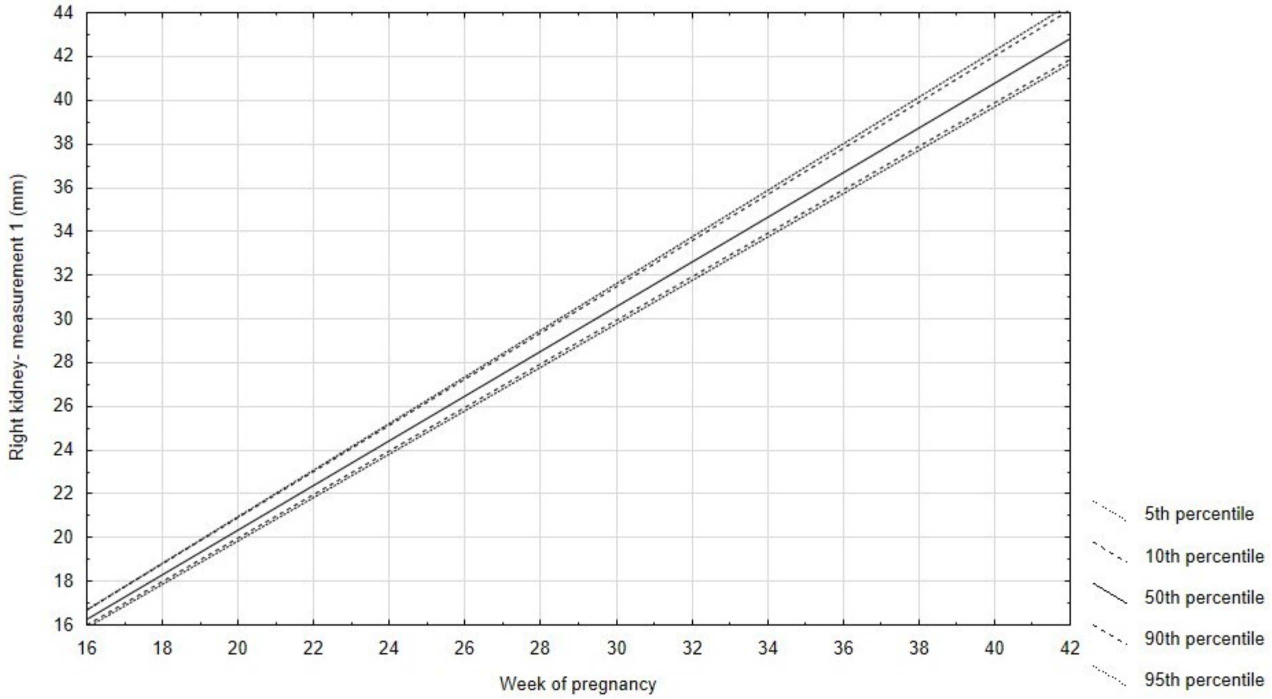

Figure 4. Percentile grid of right kidney dimension 1

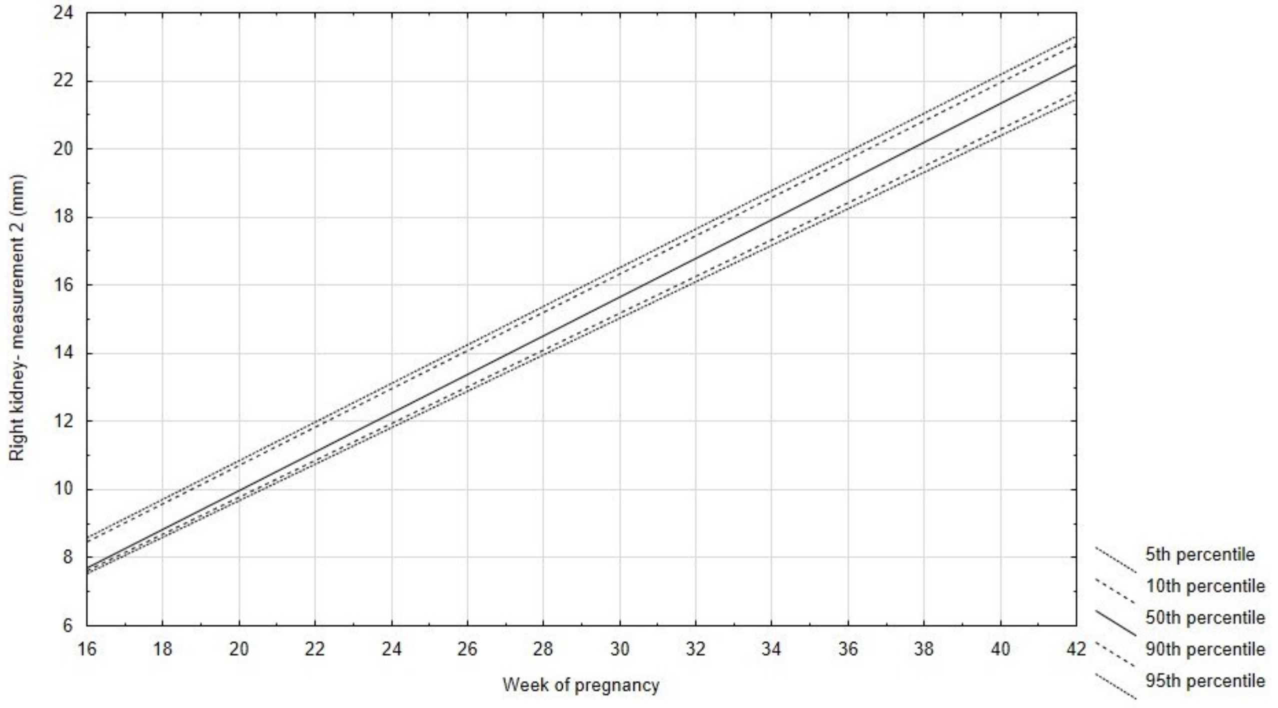

Figure 5. Percentile grid of right kidney dimension 2

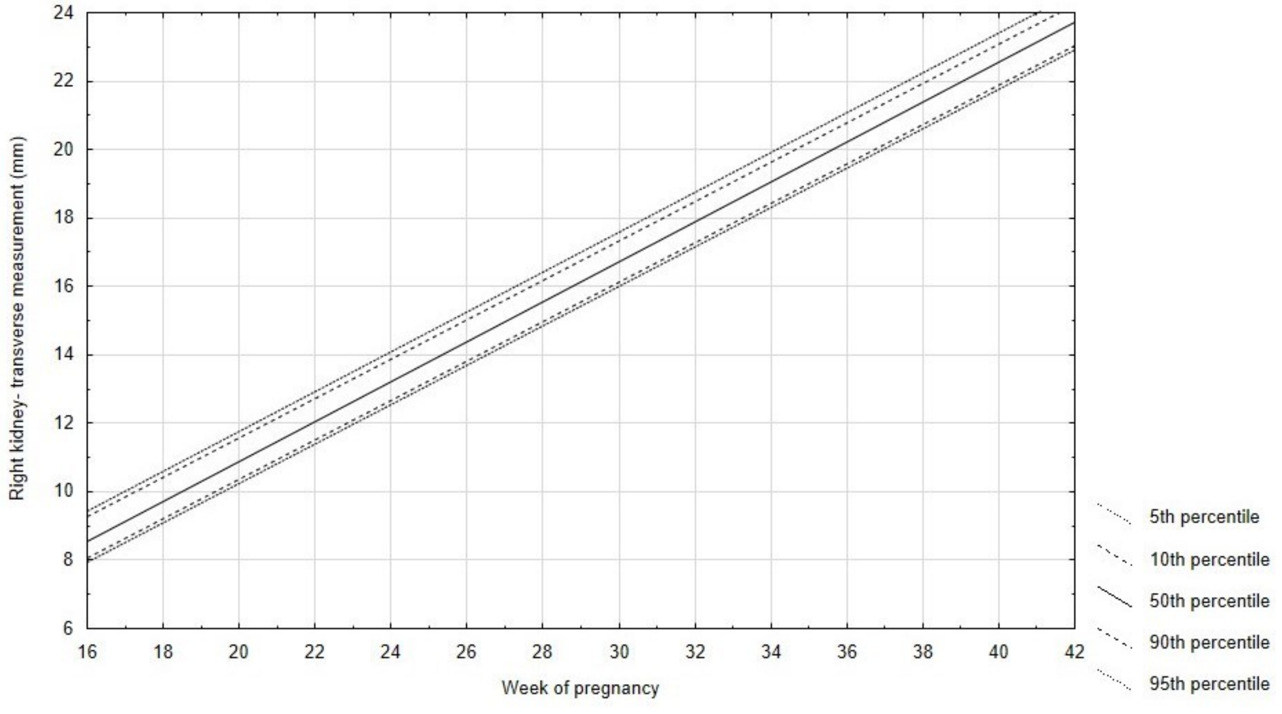

Figure 6. Percentile grid of the transverse dimension of the right kidney