THE AVERAGE VOLUME OF FETAL KIDNEY DURING DIFFERENT PERIODS OF GESTATION

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Early antenatal diagnostics and importance of genetic consultation are of great interest for echosonographical evaluation of normal fetus' anatomy. The research was carried out on kidneys of 100 fetuses of both sexes, ages ranging from IV to X lunar months. Each of the fourth and fifth lunar month was subdivided in two groups because of very progressive kidney growth. All fetuses were fixed in formaldehyde for a period of 30 days, at least. Macrodissection was used to extract both kidneys *en block*. After separation from the surrounding tissue, their volumes were measured by the method of sinking into the glass gauge. The corrections were made on the results of the procedure by means of the shrinkage factor.

Average volume of fetal kidney in the first half of IV lunar month was 0,33 ml and continually increased up to 8,68 ml (left kidney) and 9,53 ml (right kidney) in X lunar month.The kidney shows statistically significant ($p<0,05$) increase of volume in the second half of IV lunar month and in VI lunar month.

The highest value ratio volume/crown-rump length displays in X lunar month when the kidney is physically prepared for full taking over of all its functions after birth. *Acta Medica Medianae 2005; 44 (2): 47–50.*

***Key words**: fetal kidney, volume, lunar months*

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Introduction

Renal abnormalities are not uncommon in fetal life. Increasing importance of genetic consultation has great interest for echosonographical evaluation of normal fetus' anatomy. By prenatal ultrasound one can establish larger than normal kidney measurements in polycystic kidney, fetal hydronephrosis etc., and smaller than normal in dysplasia, hypoplasia, urethrocele etc (1,2,3). For some lethal anomalies, like polycystic kidney, renal dysplasia, bilateral renal agenesis etc., an early detection and termination of the pregnancy may be a better choice. Identification of either one or two kidneys by the ultrasound is possible in 90% of cases from the 17th until 22nd week of gestation, and that is the critical time for genetic consultation. After the 20th week, the kidneys are identificated in 95% of cases (4). Unfortunately, diagnosis of renal abnormalities appears relatively late in fetal life or postnatally. Nowadays, ultrasonography is used as the modality of choice for measuring a kidney size. The renal volume is calculated by supposing that kidney resembles an ellipsoid, by measuring its three axes (5). Because this method does not take into account the variability of the shape of the kidney, it could be quite inaccurate (6). The aim of this research was to quantify the volume of fetal kidney in particular phases of fetus' development, to determine its relation with crown-rump length of fetus and to establish periods of its most intensive growth.

Matherial and methods

The research was carried out on kidneys of 100 fetuses of both sexes, ages ranging from IV to X lunar months. They were analyzed being divided according to gestational ages and based upon temple to crown-rump length (CRL) (7). On the basis of preliminary research and due to intensive growth of kidney during these months, IV and V lunar months were divided into two subgroups,the first and second halftime. All fetuses were fixed in 10% solution of formaldehyde for a period or 30 days, at least. Macrodissection was used to extract both kidneys *en block* and they were separated from the surrounding tissue. Afterwards, the volume was measured by the process of fluid displacement by sinking into the glass gauge of 10 ml for small and 50 ml for big samples. Numerical values obtained were corrected by

shrinkage factor, established by measuring of volume of unfixed and fixed kidneys. This factor was determined as the ratio between these volumes. In the end, we calculated the quotient of the sum of average volumes of both kidneys and crown-rump length, which, in a specific way, shows quantity of kidney tissue per unit of fetus' largeness.

All parameters are statistically processed and graphically shown (8). The average values, standard deviation (SD), correlation with crown-rump length were established. The Student's t-test between adjacent groups was done.

Results

Table 1 displays the structure of examined fetuses according to gestational age from IV to X lunar month, crown-rump length and sex. The average kidney volume of fetuses of different sex is displayed in Table 2. The Student's t-test was done and no statistical significance ($p<0.05$) in kidney volume of certain age between different sexes was found.

The mean volume of left kidney continually increases from 0.330 ml in the first half of IV lunar month up to 8.680 in X lunar month. The mean volume of the right kidney increases from 0.337 ml up to 9.533 ml in X lunar month (Table 3). The left kidney volume shows statistically significant increase in the second half of IV lunar month and in VI lunar month ($p<0.05$) with high correlation with crown-rump length ($r=0.996$; $p<0.01$). Significant increase of the right kidney volume is in the second half of IV lunar month, in the first half of V lunar month and in VI lunar month ($p<0.05$). Coefficient of correlation is high ($r=0.98$; $p<0.01$).

Presented in percentage, the kidney most rapidly grows in the second half of IV lunar month and in the first half of V lunar month, namely, from the 14* to 18* week of intrauterine growth.

Table 1. Fetal structure (age; crown-rump length; sex)

Fetal age (lunar month)	Average crown-rump length (cm)	Sex		Σ
		Male	Female	
IV a	10.1	8	4	12
IV b	12.9	9	3	12
V a	15.5	8	4	12
V b	18.1	10	2	12
VI	21.2	7	5	12
VII	25.2	7	3	10
VIII	29.2	5	5	10
IX	31.0	6	4	10
X	36.0	5	5	10
Σ		65	35	100

Table 2. The average kidney volume of fetuses of different sex

Fetal age (lunar month)	Average kidney volume (ml) ± SD		Statistical significance
	Male	Female	
IV	0.505 ± 0.261	0.420 ± 0.265	$p=0.39>0.05$
V	1.524 ± 0.841	1.798 ± 0.586	$p=0.32>0.05$
VI	2.911 ± 1.516	2.810 ± 0.989	$p=0.79>0.05$
VII	3.900 ± 1.670	3.250 ± 0.395	$p=0.37>0.05$
VIII	5.500 ± 0.890	4.938 ± 0.886	$p=0.59>0.05$
IX	6.125 ± 0.530	5.417 ± 0.296	$p=0.30>0.05$
X	7.021 ± 3.909	6.531 ± 1.975	$p=0.82>0.05$

Table 3. The average volume ($\overline{V}$) of fetal kidney

Fetal age (lunar month)	N	Average volume (ml) ± SD			
		Left kidney	Increase (%)	Right kidney	Increase (%)
IV a	12	0.330 ± 0.16	—-	0.337 ± 0.13	—-
IV b	12	0.967 ± 0.53 *	193	0.870 ± 0.38 *	158
V a	12	1.794 ± 0.75	86	1.797 ± 0.72 *	107
V b	12	2.055 ± 0.57	15	2.087 ± 0.61	16
VI	12	3.430 ± 1.34 *	67	3.408 ± 1.41 *	63
VII	10	4.873 ± 1.49	42	4.721 ± 1.84	39
VIII	10	6.019 ± 1.06	24	5.709 ± 1.62	21
IX	10	6.634 ± 0.24	10	6.014 ± 0.60	5
X	10	8.680 ± 3.07	31	9.533 ± 4.01	59

* *Statistically significant increase ($p<0.05$) compared to previous period*

Quotient of the sum of average volumes of both kidneys and crown-rump length shows, in a specific way, the quantity of kidney's tissue per unit of fetus' largeness. This quotient increases from IV up to X lunar month, with transitory stagnation in thr second half of V lunar month. Its highest value in X lunar month clearly shows that kidney is phisically prepared for full taking over of all functions after birth (Table 4).

Table 4. Quotient of the sum of average volumes of both kidneys and crown-rump length

Fetal age	N	Average crown-rump length (CRL)	The sum of average volumes of both kidneys (ml)	Ratio: the sum of volumes/CRL (ml/cm)
IV a	12	10.1	0.667	0.066
IV b	12	12.9	1.837	0.142
V a	12	15.5	3.591	0.232
V b	12	18.1	4.142	0.229
VI	12	21.2	6.838	0.323
VII	10	25.2	9.594	0.381
VIII	10	29.2	11.728	0.402
IX	10	31.0	12.648	0.408
X	10	36.0	18.213	0.506

Discussion

It is very helpful to know the normal dimensions of fetal kidneys in order to diagnose renal abnormalities. Diagnostic tools are not completely adequate due to their imperfection (ultrasound) or cost (MRI). Ultrasonography has been established as a noninvasive imaging tool for the examination of fetal kidneys. Simple sonographic method, i.e., measurement of the kidney length, can detect a diagnosis of renal abnormality as early as 14 gestational weeks (9). Greater congenital anomalies of kidney, for example, infantile polycystical kidney disease, bilateral agenesis, fetal hydronephrosis etc., could be found by prenatal ultrasound observation. Dinkel et al. (10) concluded that size changes of ill child's kidney are better expressed in its volume than in its length. Probably, the same goes for a fetal kidney. Except in early diagnostics of fetal kidney's anomalies, measuring of their size can help in determination of gestational age, especially in cases where the date of the mother's last menstruation is unknown, and routine methods show contradictory results (11,12).

Many authors determined the volume of the child's kidney by measuring its dimensions in three axes and using the ellipsoid formula – "fetal renal volume formula" (10, 13,14). With this method, one assumes that kidney resembles an ellipsoid structure, but, in such a way, renal volume is systematically underestimated, because kidney is not an ellipsoid. The second reason for making a mistake is the existence of perirenal fatty tissue, measured by ultrasound together with kidney dimensions, which shows false, increased values. For these reasons, the voxel-count method, performed by magnetic resonance imaging (MRI) is much better (6) *in vivo* method, but the expense of MRI and lack of availability limits its usage. The fluid displacement method provided the "gold standard" for measuring kidney volume *in vitro*, as presented in our work.

The conclusion of Sampaio (13) that male fetuses presented kidney volumes significantly greater than female fetuses (found in 145 pairs of kidneys) is not in accord with our results where statistically significant difference in kidney volume between male and female fetuses during whole intrauterine life was not found.

One can conclude from Table 3 that in the second half of IV lunar month fetal kidney has almost three times bigger volume than in the first half of the same month. This fact clearly shows that from the 14th to 16th gestational week there is the period of the biggest growth of kidney. Differences in average volume of contralateral kidneys in the same period are not statistically significant.The left kidney has a little bit bigger volume than the right one from VI up to IX lunar month. Nevertheless, in X lunar month the right fetal kidney has bigger average volume than left one. Now, we can still guess why. One can suppose that fetal liver plays certain role in growth and development of the right kidney. We know that fetal liver is quite big and we can contemplate about its influence on the right kidney growth. Why does the right kidney grow faster than the left one in X lunar month and become bigger? It may be due to the loss of (haematopoethic or other?) role of fetal liver immediately before birth, when capacities of growth of the right kidney reach full expression. These presumptions should be checked on greater number of cases along with liver examination.

The ratio: sum of volumes of both kidneys/crown-rump length, in absence of other better data, shows, in a specific way, the quantity of kidney tissue per unit of fetus' largeness (in this case it is

crown-rump length). This ratio increases with fetal aging, except in the second half of V lunar month when it stagnates. This ratio displays the highest value in X lunar month, when it clearly shows that kidney is physically prepared for full taking over of all its functions after birth.

Conclusion

Average volume of fetal kidney continually increases from 0,33 ml in the first half of IV lunar month up to 8,68 ml (left kidney) and 9,53 ml (right kidney) in X lunar month. Kidney shows statistically significant ($p<0,05$) increase of volume in the second half of IV lunar month and in VI lunar month.

From the 14th to 16th gestational week there is the period of the biggest kidney growth.

The highest value ratio of volume/crown-rump length displays in X lunar month when kidney is physically prepared for full taking over of all its functions after birth.

Measuring of kidney size can help in determination of gestational age, especially in cases where the date of the mother's last menstruation unknown.

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PROSEČNA ZAPREMINA FETUSNOG BUBREGA U RAZLIČITIM PERIODIMA GESTACIJE

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Rana prenatalna dijagnostika i značaj genetskog savetovanja ima veliki interes za ultrazvučno praćenje normalne anatomije fetusa. U ovom istraživanju je ispitivano 100 pari bubrega fetusa oba pola, starosti od IV do X lunarnog meseca. Zbog veoma izrazitog rasta bubrega, IV i V lunarni mesec su podeljeni na po dve polovine, prvu i drugu. Svi fetusi su fiksirani u 10% formalinu za period od najmanje 30 dana. Oba bubrega su vađena u bloku metodom makrodisekcije. Posle odvajanja od okolnog tkiva njihova zapremina je merena metodom potapanja u menzuru. Vrednosti dobijene zapremine su korigovane množenjem sa koeficijentom skvrčavanja bubrežnog tkiva.

Prosečna zapremina fetusnog bubrega u prvoj polovini IV lunarnog meseca iznosi 0,33 ml i kontinualno raste do 8,68 ml (levi bubreg) i 9,53 ml (desni bubreg) u X lunarnom mesecu. Bubreg pokazuje statistički značajno ($p < 0,05$) povećanje zapremine u drugoj polovini IV lunarnog meseca i u VI lunarnom mesecu.

Najvišu vrednost odnosa zapremina/temeno-trtična dužina pokazuje u X lunarnom mesecu kada je bubreg i fizički spreman za puno preuzimanje svih svojih funkcija po rođenju.
Acta Medica Medianae 2005; 44 (2): 47–50.

Ključne reči: *fetusni bubreg, zapremina, lunarni meseci*