Renal Pelvic Diameters in Human Fetuses: Anatomical Reference for Diagnosis of Fetal Hydronephrosis

Marcio L. P. Lobo, Luciano A. Favorito, Marcelo Abidu-Figueiredo, and Francisco J. B. Sampaio

OBJECTIVE To evaluate renal pelvis diameters in human fetuses, to establish normative patterns of their growth and size during the second gestational trimester.

METHODS We studied 140 kidneys (70 fetuses; 38 male, 32 female) ranging in age from 12–25 weeks' postconception. The renal pelvis was dissected and the transverse and longitudinal diameters were measured. The renal length, width, and thickness were assessed. To compare the quantitative data in both sexes, Student's *t*-test was used ($P < .05$).

RESULTS The mean transverse diameter in male fetuses was 3.61 mm in the right side and 3.58 mm in the left. In female fetuses, it was 3.51 mm in the right side and 3.43 mm in the left. There was no statistical significant difference between the sides either in males ($P < .81$) or in females ($P < .33$). There was no significant difference in the mean transverse diameter between male and female fetuses ($P < .9$). The mean longitudinal diameter in male fetuses was 4.28 mm in the right side and 4.31 mm in the left. In female fetuses, it was 4.17 mm in the right side and 4.33 mm in the left. There was no significant statistical difference between the sides in either males ($P < .82$) or females ($P < .33$). There was no significant difference in the mean longitudinal diameter between male and female fetuses ($P < .9$).

CONCLUSIONS Transverse and longitudinal diameters are useful as parameters for assessment of the renal pelvis in human fetuses. UROLOGY 77: 452–457, 2011. © 2011 Elsevier Inc.

Congenital anomalies of the genitourinary tract are among the most frequently known anomalies, with an incidence ranging from 0.9% to 4%.[1-5] The extensive use of antenatal ultrasound screening has improved the diagnosis of genitourinary anomalies in early phases of fetal development. According to most recently reported studies, between 1% and 2% of the ultrasounds performed during the prenatal period demonstrate a dilation in the renal collecting system.[6,7]

Hydronephrosis is defined as a dilation of the renal pelvis and/or renal calyces and is the most common fetal urinary tract alteration, which is present in approximately 50% of the reported cases of genitourinary abnormalities.[8] The hydronephrosis of clinical significance has an incidence of 1/600, whereas the prevalence of the hydronephrosis detected during the gestational period is 1/50, suggesting that a number of patients resolve the hydronephrosis with development and without the need of active treatment.[9]

Supported by grants from the National Council of Scientific and Technological Development (CNPQ), Brazil) and Rio de Janeiro Foundation for Research Support (FAPERJ), Brazil.

From the Urogenital Research Unit, State University of Rio de Janeiro (UERJ), Rio de Janeiro, Brazil

Reprint requests: Luciano Alves Favorito, M.D., Ph.D., Rua Professor and Gabizo–Tijuca, Rio de Janeiro, RJ, Brazil 20271-062. E-mail: lufavorito@yahoo.com.br

Submitted: March 23, 2010, accepted (with revisions) June 27, 2010

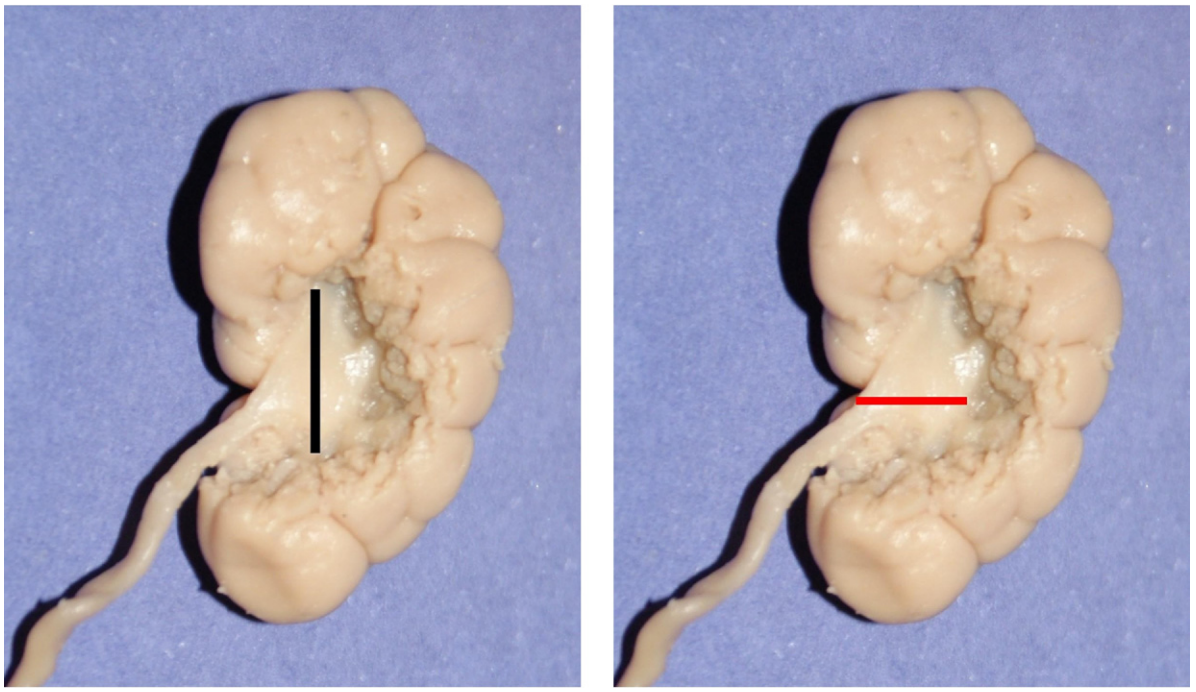
Fetal hydronephrosis diagnosis is performed with an ultrasound (US) examination, using as a parameter the anteroposterior diameter of the renal pelvis in the transversal plane (APDRP).[10] Another well-known parameter recognized by the Society for Fetal Urology considers the renal pelvis and renal calyces dilation with or without gauging of the renal parenchyma, although this classification has been previously described and is normally used for purposes of postnatal evaluation.[11]

The APDRP is the most commonly used parameter for US evaluation of prenatal hydronephrosis because of its technical simplicity and easy reproducibility. However, there are variations in the measurements considered normal by several authors.[12]

Magnetic resonance imaging (MRI) is an alternative approach for the analysis of the fetal urinary tract.[13] Previous studies have reported the significance of the definition of the normal limits of a fetal kidney in prenatal MRI,[14] although, in contrast to what occurs when using US, there are no better defined parameters of the fetal renal pelvis, which should be measured by MRI to more accurately evaluate the hydronephrosis.

The analysis of fetal kidney development is well known[15,16]; nevertheless, the analysis regarding the diameters of the renal pelvis and its development during

0090-4295/11/$36.00
doi:10.1016/j.urology.2010.06.049



A B

Figure 1. Evaluation of renal pelvis diameters in a fetus at 24 WPC. **(A)** Evaluation of the greatest longitudinal diameter (the distance between the upper most and lower most extremity) of the renal pelvis. The black line shows the longitudinal measurement of the renal pelvis. **(B)** Evaluation of the greatest transverse diameter of the renal pelvis. The red line shows the place where the measurement of the transverse diameter was taken: measure obtained between the distal extremity of the renal pelvis up to the confluence of the larger calyces. (Color version of figure available online.)

the human fetal period have not yet been well defined in the literature.

This paper attempts to evaluate the renal pelvis diameters in human fetuses, providing a normative pattern of their growth during the second gestational trimester, as well as to correlate the development of the renal pelvis with fetal growth and concomitant development of the kidney.

MATERIAL AND METHODS

The present work received institutional committee review and parental approval. This work was carried out in accordance with the ethical standards of the institutional committee responsible for human experimentation.

We studied 140 kidneys obtained from 70 human fetuses (38 male and 32 female) that died of causes not related to the urogenital tract. The fetuses were macroscopically well preserved and there was no evidence of congenital malformation. The gestational age of the fetuses was determined in weeks' postconception (WPC), according to the foot-length criterion, which presently is considered the most acceptable parameter used to calculate the gestational age.[17-20] The fetuses were also evaluated according to the crown-rump length and body weight immediately before dissection. All measurements were taken by the same observer.

After the measurements, the fetuses were carefully dissected with the aid of a stereoscopic lens with 16–25x magnification. The fetal kidneys were removed together with the ureters, bladder, and genital organs. After kidney dissection, we evaluated the following measurements: renal length, width of the renal hilum, width of the superior pole, width of the inferior pole, and renal thickness.

After taking the kidney measurements, the renal pelvis and the major calyces were carefully dissected, with removal of the renal parenchyma around the renal pelvis, whenever necessary, for accurate identification and measurement of these structures. The following fetal renal pelvis measurements were taken with the help of a magnifying lens and a digital paquimeter (calibrated in millimeters): transverse diameter of the renal pelvis (measurement obtained between the distal pelvis extremity and the confluence of the major calyces) (Fig. 1A) and the longitudinal diameter of the renal pelvis (distance between the 2 extremities of the pelvis, ie, uppermost and lowermost) (Fig. 1B).

Statistical Analysis

A statistical analysis was performed using GraphPad Prism software (GraphPad Software, Inc., La Jolla, CA). We also used Student's *t*-test, with a confidence interval of 95%, considering $P < .05$ as significant. We carried out a simple linear correlation between the dimensions of the renal pelvis in both sexes with renal measurements and gestational age.

RESULTS

The fetuses studied ranged in age from 12-35 WPC, weighed between 60 and 950 g, and the crown-rump length ranged from 8.5-24 cm (cm). The length of the right kidney ranged from 8.09-25.5 cm and the length of

Table 1. Parameters of male (M) and female (F) fetuses

Age (Sex)	Weight (g)	Crown-rump (cm)	RKL(cm)	LKL(cm)	LRRP (mm)	LLRP (mm)	WRRP (mm)	WLRP (mm)
12 (M)	230	17	18.17	20.27	5.74	5.16	4.42	4.4
12.1 (M)	220	15	16.83	17.7	3.1	4.2	3.3	3.2
13 (F)	60	9.5	8.09	8.28	1.46	1.9	1.32	1.38
13.4 (M)	60	10	9.7	11.4	2.8	2.9	2.6	2.32
14 (M)	100	12.4	12.44	12.29	2.96	2.72	2.02	1.7
14.5 (F)	105	12.5	14.57	12.41	3.17	2.8	2.82	2.8
14.5 (M)	90	12	10.83	12	3	2.3	2.2	1.8
14.7 (M)	165	13	14.25	15.8	3.5	3.6	2.4	2.66
15.3 (M)	125	13.3	14.59	15.79	4.57	4.16	5.1	4.5
15.4 (M)	170	13.5	18.48	17.18	4.4	4.6	3.7	3.9
15.5 (M)	190	13	17.44	15.21	4.6	4.2	2.8	2.57
15.6 (F)	180	15	15.72	16.32	3.2	3.84	2.64	3.25
15.7 (F)	180	13.5	13.29	15.1	3.79	4.16	2.76	3.64
15.7 (F)	260	15.5	19.16	17.36	4.14	4.32	4.36	3.46
15.7 (M)	200	14.5	15.7	15.8	2.8	2.9	2.2	2.5
15.9 (M)	185	14.5	16.9	15.1	3.5	3.2	2.7	2.6
16 (F)	200	16	19.75	19.08	3.5	4.3	3.2	2.6
16 (M)	230	15.5	17.22	13.99	3.7	3.96	2.9	3.07
16 (M)	195	15	18.12	16.9	5.08	4.38	4.11	3.47
16 (M)	170	12.5	13.6	13.2	4.79	4.74	3.26	3.5
16 (M)	170	14.5	18.2	18.8	4.4	3.8	4.1	3.1
16.4 (F)	155	14	18.59	17.33	5.7	4.9	4.8	3.78
16.4 (M)	245	16.5	21.43	21.72	4.25	4.58	2.89	3.01
16.4 (M)	220	15	13.3	18.32	3.8	4	2.4	2.9
16.5 (F)	300	16.2	20.28	18.27	4.22	3.6	3.14	2.92
16.5 (F)	220	16	20.74	17.22	4.38	4	3.72	2.76
16.5 (F)	270	16.5	19.7	19.5	3.6	4.2	3	3.4
16.6 (F)	225	16	17.18	16.84	2.9	4.2	2	2.7
16.6 (M)	150	14.5	15.19	17.83	2.3	2.7	2	2.1
16.6 (M)	185	15	14.95	14.62	3.7	3	3.08	2.58
16.9 (F)	135	14.5	14.45	16.76	4	3.4	2.4	2.5
17 (M)	300	7.3	19.44	19.83	4.27	3.97	4.03	3.2
17 (M)	255	16	18.33	17.01	5.01	4.92	4.11	4.2
17 (M)	280	17	18.06	16.13	5.04	4.22	3.87	3.2
17.3 (F)	140	14	17.99	16.67	4.74	4.13	3.42	3.9
17.4 (F)	280	16	18.93	18.88	4.57	4.94	3.17	3.3
17.4 (F)	290	17	18.95	20.6	5.05	5.2	4.7	4.03
17.4 (M)	260	16.5	17.14	16.45	3.5	4.1	3.24	2.86
17.5 (M)	245	15	20.55	20.79	3	3.17	2.46	1.99
17.6 (M)	190	16	17.44	18.7	4.3	5.1	3.9	4.5
17.7 (F)	280	16	16	17.7	4.5	4.6	3.8	4.2
17.8 (F)	370	17.3	24.19	21.21	5.13	3.76	4.49	3.21
17.8 (F)	280	15.5	15.56	17.34	3.03	3.48	2.61	3.11
18 (F)	300	16.5	21.74	18.45	5.5	5.07	4.36	4.13
18 (M)	335	17.3	18.01	17.4	7.11	6.12	5.7	7.26
18 (M)	280	7.5	16.47	17.15	2.86	3.24	3.57	2.64
18 (M)	345	8.3	19.42	17.15	4.83	6.01	5.3	7.23
18 (M)	365	18.5	22.84	18.37	6.89	5.48	5.85	4.43
18 (M)	280	16	17.63	17.58	5.68	4.6	3.83	3.69
18 (M)	300	15	20.04	17.99	4.9	3.95	3.24	3.5
18.2 (F)	285	15.3	17.41	17	4.6	4.63	4.2	4.25
18.2 (F)	405	18	19.7	19.9	3.9	3.2	3.7	3.2
18.4 (F)	350	17	15.36	16.77	3.18	3.6	3.43	2.6
18.4 (F)	325	16.5	22.6	23.5	4.85	5.2	3.7	4.2
18.5 (M)	245	15.5	17.4	18.8	4.1	4.4	3.8	4
18.6 (F)	335	16.5	19.18	18.23	3.91	5.33	3.83	3.15
18.8 (F)	380	18	20.76	24.44	4.4	4.83	4.2	3.74
19 (F)	390	17	22.3	24.62	4.34	4.76	3	2.98
19.3 (M)	360	17	22.53	22.14	6	6.11	5.49	4.55
19.3 (F)	370	17	22.1	22.75	4.7	5	3.2	3.7
19.4 (F)	400	18	20.2	21	5	5.2	3.3	4.3
19.5 (F)	385	18.5	21.7	19.23	3.04	3.89	3.8	4.3

Continued

Table 1. *Continued*

Age (Sex)	Weight (g)	Crown-rump (cm)	RKL(cm)	LKL(cm)	LRRP (mm)	LLRP (mm)	WRRP (mm)	WLRP (mm)
20 (M)	400	18.5	23.42	23.98	5.11	6.05	4.55	4.02
20 (M)	435	19.3	22.76	23.96	3.6	4.83	4.27	4.94
20.4 (F)	455	19.3	23.47	23.31	4.38	4.77	3.77	3.21
20.4 (F)	480	19	17.69	18.29	4.2	4.7	3.35	3.7
21 (M)	545	20	23.12	26.4	5.2	7.2	4.7	5.1
21.4 (M)	580	20.5	22.36	21.29	3.9	3.8	3.6	3.2
23 (M)	780	22.2	26.3	23.56	6.02	6.68	6.87	6.59
25.2 (F)	950	24	25.5	25.9	5.1	5.6	4	4.6

Age given in WPC.

RKL, length of the right kidney; LKL, length of the left kidney; LRRP, length of the right renal pelvis; LLRP, length of the left renal pelvis; WRRP, width of the right renal pelvis; WLRP, width of the left renal pelvis.

Table 2A. Mean and standard deviation of the renal measurements (length, width, and thickness) of the analyzed fetuses in millimeters in the right and left kidney

	Kidney Length (mm)		Kidney Width (mm)		Kidney Thickness (mm)	
	RK	LK	RK	LK	RK	LK
Male fetuses (n = 38)	17.89 ± 3.6	17.87 ± 3.45	9.58 ± 1.97	9.28 ± 2.07	8.08 ± 2.48	8.15 ± 2.27
Female fetuses (n = 32)	18.85 ± 3.57	18.73 ± 3.53	10.32 ± 2.16	9.64 ± 2.01	8.80 ± 2.02	8.86 ± 2.23

RK, right kidney; LK, left kidney.

Table 2B. Mean and standard deviation of the width and length of the renal pelvis in millimeters for the right and left kidney

	Width of The Renal Pelvis (mm)		Length of The Renal Pelvis (mm)	
	RK	LK	RK	LK
Male (n = 38)	3.61 ± 1.1	3.58 ± 1.3	4.28 ± 1.1	4.31 ± 1.0
Female (n = 32)	3.51 ± 0.8	3.43 ± 0.7	4.17 ± 0.95	4.33 ± 0.8

RK, right kidney; LK, left kidney.

the left kidney ranged from 8.28-25.9 cm. The length of the right renal pelvis ranged from 2.3-6.89 mm; the length of the left renal pelvis ranged from 1.9–6.69 mm; the width of the right renal pelvis ranged from 1.32-6.87 mm and the width of the left renal pelvis ranged from 1.7-6.59 mm (Table 1).

The average and standard deviation of the length, width, and thickness of the right and left kidneys, in both sexes, are show in Table 2A. Table 2B shows the average and standard deviation of the width and height of the renal pelvis of the analyzed fetuses.

The correlation between the fetal age and kidney length and the correlation of renal pelvic measurements (width and length) by gestational age are show in Figure 2.

Measurements of the Renal Pelvis and Fetal Kidney

The mean transverse diameter in male fetuses was 3.61 mm on the right side and 3.58 mm on the left side. No statistical difference was observed between the 2 sides ($P < .81$). In female fetuses it was 3.51 mm in the right pelvis and 3.43 mm in the left pelvis. No statistical difference was observed between the 2 sides ($P < .33$) or between sexes ($P < .9$).

The mean longitudinal diameter in male fetuses was 4.28 mm in the right side and 4.31 mm in the left side. No statistical difference were observed between the 2 sides ($P < .82$). In female fetuses, the mean longitudinal diameter was 4.17 mm in the right pelvis and 4.33 mm in the left pelvis. No statistical difference was observed between the 2 sides ($P < .33$) and between sexes ($P < .9$) (Table 2B). The analysis of the fetal kidney measurements (length, width, and thickness) showed no significant statistical difference in any of the analyzed comparisons.

Correlation Between Renal Pelvis Measurements and Fetal Parameters

We performed a simple linear regression analysis between the width and length of the right and left renal pelvis in both sexes, correlating them with the fetal age, fetal weight, and fetal crown-rump length. We subsequently observed a positive linear correlation between the analyzed parameters, where the "r" values for the correlations of the diameters between the renal pelvis compared with fetal age in both sexes were, respectively, 0.21 (right renal pelvis width), 0.23 (left renal pelvis width), 0.15 (right renal pelvis length), and 0.32 (left renal pelvis length).

Correlation Between Pelvis Measurements and Fetal Kidney Parameters

We analyzed a simple linear regression between right and left width and length of the renal pelvis in both sexes,

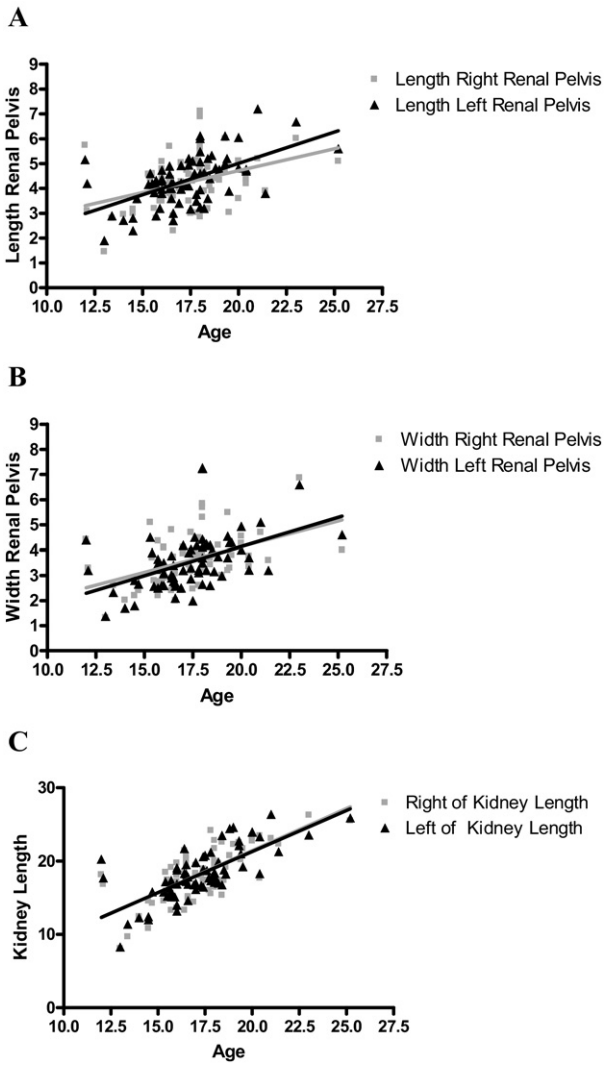


Figure 2. A normative curve of renal length pattern and normative curves of renal pelvis growth pattern during the fetal period studied. (**A**) Correlation of kidney length by gestational age; (**B**) correlation of renal pelvic width by gestational age, and (**C**) correlation of renal pelvic length by gestational age.

correlated with length, width, and thickness of the fetal kidney. A positive linear correlation between all the analyzed parameters was observed, where the "r" values in the correlations between renal pelvis diameters and the length of the fetal kidney in both sexes were, respectively, 0.37 (right renal pelvis length), 0.2 (left renal pelvis length), 0.32 (right renal pelvis width), and 0.43 (left renal pelvis width).

COMMENT

Morphologic alterations of the fetal renal pelvis are frequently detected using prenatal US.[10] Renal pelvis dilation could be a premature sign of hydronephrosis or otherwise may indicate other abnormalities such as vesicoureteral reflux, megaureter, or pyeloureteral syndrome.[5] Hydronephrosis is most commonly assessed by the Society of Fetal Urology grading system or by APDRP.[11,12]

The knowledge of the normal patterns of renal anatomy during the fetal period is important for the follow-up of the fetus during the gestational period as well as for the postnatal follow-up of hydronephrosis or other renal anomalies, avoiding a delay in the diagnosis and facilitating the treatment after the delivery.[21,22] The fetal kidney length can be used to estimate the gestational age.[15,16] Studies evaluating the longitudinal and transversal length of the fetal kidney during the gestational period are well known.[15,16] However, studies that assess renal pelvis development during the human fetal period had not been reported previously in the literature.

The period of the most rapid development of the fetal kidney occurs between the 14th and the 16th WPC.[18] Our sample was composed of fetuses from the second trimester of gestation, a period when the development of the kidney and, consequently, of the renal pelvis, is more intense and their measurements are more difficult to standardized by currently available imaging methods.

The most commonly used method for prenatal hydronephrosis analysis is US, whereas the APDRP is the most common parameter for the follow-up and grading evaluation of hydronephrosis.[7,23,24] Nevertheless, the use of transverse diameter and longitudinal diameter of the renal pelvis by prenatal US in most cases should indicate fetal hydronephrosis when used in conjunction with APDRP.[25]

There are a few alternative methods for the evaluation of the fetal kidney during the gestational age, such as the evaluation of the renal pelvis volume, through three-dimensional US[26] and MRI.[27] MRI is a method that can assist considerably in the analysis of the fetal urinary tract,[13,14] providing important information especially in cases where there are difficulties in the visualization of the fetus using US, as in oligohydramnios and fetal megacystis.[16,27]

In contrast to US, where there is a well defined parameter for the evaluation of the hydronephrosis using APDRP, there are no well defined morphometric parameters to evaluate a fetal renal pelvis by MRI.[14] The measurements of the longitudinal and transverse diameters of fetal renal pelvis and the creation of a normative pattern in renal pelvic development as demonstrated in this paper may be a useful parameter for the evaluation of the fetal renal pelvis by MRI.

The APDRP measurement was not possible in our sample because of the absence of urine in the fetal kidneys. Nevertheless, we were able to easily evaluate the longitudinal and transverse diameters of the renal pelvis in fetuses.

The longitudinal and transverse diameters of the renal pelvis presented a positive correlation with fetal age, weight, and crown-rump length. Also, we found a positive correlation of the renal pelvis parameters with length, width, and thickness of the fetal kidney. Our results show that the linear correlation was not strongly

positive because the work was done with a homogeneous group of fetuses from the second trimester.

The longitudinal diameter of the renal pelvis in our sample of fetuses ranging in age from 12–25 WPC presented an average between 4.17 and 4.33 mm, depending on the side and sex, with no significant statistical differences. The transverse diameter of the renal pelvis presented an average between 3.43 and 3.61, depending on the side and sex, also with no significant statistical differences.

When the value for APDRP was greater than 7 mm in fetuses with more than 18 WPC, this strongly indicated an abnormality in the urinary tract.[24] On the basis of our findings, measurements of the longitudinal diameter of the renal pelvis greater than 6 mm and the transverse diameter greater than 5 mm in fetuses with less than 25 WPC indicated that these individuals should be closely followed up, because it might be a sign of hydronephrosis. These measurements can be useful for the evaluation of the prenatal hydronephrosis, primarily by MRI.

CONCLUSIONS

Fetal renal pelvis development demonstrated a positive correlation with fetal parameters and kidney measurements. The mean longitudinal diameter of the renal pelvis (4.17 mm in right side and 4.33 mm in left side) and the mean transverse diameter of the renal pelvis (3.43 mm in right side and 3.61 mm in left side) obtained from fetuses between 12 and 25 WPC, could be a useful parameter for the analysis of the development of the renal pelvis and hydronephrosis by imaging methods, during the second gestational trimester.

Acknowledgments. Richard Medeiros, Rouen University Hospital Medical Editor, edited the final manuscript.

References

1. Wiesel A, Queisser-Luft A, Clementi M, Bianca S, Stoll C, et al. The EUROSCAN Study Group: prenatal detection of congenital renal malformations by fetal ultrasonographic examination: an analysis of 709,030 births in 12 European countries. *Eur J Med Genet*. 2005;48:131-144.
2. Sthephens FD, Smith ED, Hutson JM. *Normal Embriology of the Upper Urinary Tract and Kidney, Urinary and Genital Tracts*. Chapter V. London: Martin Dunitz, Ltd; 2002.
3. Favorito LA, Cardinot TM, Morais AR, Sampaio FJ. Urogenital anomalies in human male fetuses. *Early Hum Dev*. 2004;79:41-47.
4. Swana HS, Sutherland RS, Baskin L. Prenatal intervention for urinary obstruction and myelomeningocele. *Int Braz J Urol*. 2004; 30:40-48.
5. Braga LH, Liard A, Bachy B, Mitrofanoff P. Ureteropelvic junction obstruction in children: two variants of the same congenital anomaly? *Int Braz J Urol*. 2003;29:528-534.
6. Eckoldt F, Heinick C, Wolke S, Stoven B. Prenatal diagnoses of obstructive uropathies-posite predictive value and effect on postnatal therapy. *Z Geburtshilfe Neonatal*. 2003;207:220-224.
7. Ismaili K, Avni FE, Wissing KM, Hall M. Long-term clinical outcome of infants with mild and moderate fetal pyelectasis: validation of neonatal ultrasound as a screening tool to detect significant nephrouropathies. *J Pediatr*. 2004;144:759-765.
8. Dicke JM, Blanco VM, Yan Y, Coplen DE. The type and frequency of fetal renal disorders and management of renal pelvis dilation. *J Ultrasound Med*. 2006;25:973-977.
9. Ricabona M. Assessment and management of newborn hydronephrosis. *World J Urol*. 2004;22:73-78.
10. Pates JA, Dashe JS. Prenatal diagnoses and management of hydronephrosis. *Early Hum Dev*. 2006;82:3-8.
11. Fernbach SK, Maizels M, Conway JJ. Ultrasound grading of hydronephrosis: introduction to the system used by the Society for Fetal Urology. *Pediatr Radiol*. 1993;23:478-480.
12. Coplen DE, Austin PF, Yan Y, Blanco VM, Dicke JM. The magnitude of fetal renal pelvic dilation can identify obstructive postnatal hydronephrosis, and direct postnatal evaluation and management. *J Urol*. 2006;176:724-727.
13. Poutamo J, Vanninen R, Partanen K, Kirkinen P. Diagnosing fetal urinary tract abnormalities: benefits of MRI compared to ultrasonography. *Acta Obstet Gynecol Scand*. 2000;79:65-71.
14. Witsami L, Brugger PC, Hormann M, Kasparian G, Csapone-Balassy C, Prayer D. Normal renal development investigated with fetal MRI. *Eur J Radiol*. 2006;57:294-302.
15. Sampaio FJ. Theoretical kidney volume versus real kidney volume: comparative evaluation in fetuses. *Surg Radiol Anat*. 1995;17:71-75.
16. Vlajkovic S, Vasovic L, Dakovic-Bjelakovic M, Cukuranovic R. Age related changes of the human fetal kidney size. *Cells Tissues Organs*. 2006;182:192-200.
17. Sampaio FJ, Ambrosio JD. [Length of the kidney and length of the foot. Correlative study during the fetal period]. *J Urol*. 1990;96: 129-131.
18. Hern WM. Correlation of fetal age and measurements between 10 and 26 weeks of gestation. *Obstet Gynecol*. 1984;63:26-32.
19. Mercer BM, Sklar S, Shariatmadar A, et al. Fetal foot length as a predictor of gestational age. *Am J Obstet Gynecol*. 1987;156:350-356.
20. Platt LD, Medearis AL, DeVore GR, et al. Fetal foot length: relationship to menstrual age and fetal measurements in the second trimester. *Obstet Gynecol*. 1988;71:526-531.
21. Lee RS, Cendron M, Kinnamon DD, Nguyen HT. Antenatal hydronephrosis as a predictor of postnatal outcome: a meta-analysis. *Pediatrics*. 2006;118:586-593.
22. Woodward M, Frank D. Post-natal management of antenatal hydronephrosis. *BJU Int*. 2002;89:149-156.
23. Anderson N, Clautice-Engle T, Allan R, Abbott G, Wells JE. Detection of obstructive uropathy in the fetus: predictive value of sonographic measurements of renal pelvic diameter at various gestational ages. *AJR Am J Roentgenol*. 1995;164:719-723.
24. Scott JE, Renwick M. Antenatal renal pelvic measurements: what do they mean? *BJU Int*. 2001;87:376-380.
25. Gotoh H, Masuzaki H, Fukuda H, Yoshimura S, Ishimaru T. Detection and assessment of pyelectasis in the fetus: relationship to postnatal renal function. *Obstet Gynecol*. 1998;92:226-231.
26. Duin LK, Willekes C, Vossen M, Beckers M, Offermans J, Nijhuis JG. Reproducibility of fetal renal pelvis volume measurement using three-dimensional ultrasound. *Ultrasound Obstet Gynecol*. 2008;31: 657-661.
27. Cassart M, Massez A, Metens T, Rypens F, Lambot MA, Hall M, et al. Complementary role of MRI after sonography in assessing bilateral urinary tract anomalies in the fetus. *AJR Am J Roentgenol*. 2004;182:689-695.