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# Ultrasonographic Assessment of Kidney Dimensions in First Six Months of Life

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**A B S T R A C T**

*The kidney growth in children is not linear. The aim of this study was to define normal dimensions of kidneys in healthy infants during the first six months of life. A prospective ultrasonographic screening of 1870 kidneys in 935 healthy full-termed infants (476 males, 459 females) was done throughout a 5-year period. Measured kidneys were divided into six age groups according to gender and side. In the first three months of life males had both kidneys longer than same-age females ($p<0.05$). In the next three-month-period the difference between sexes was not significant ($p>0.05$). Left kidneys were longer than right kidneys in both sexes in the first six months of life ($p<0.01$). Four nomograms with normal values of kidney lengths, according to age, sex and side were done in newborns and infants in the first 6-months of life.*

***Key words:*** *children, growth, kidney, ultrasonography*

## Introduction

Ultrasonography is a reliable and safe method, which can be utilized for the assessment of kidney size in children. In order to distinguish pathological variations in the appearance of kidney from normal variations, it is necessary to establish precise normal values of kidney sizes in healthy children. There are several studies on ultrasonographic measurements of kidney length in children which also include data correlating the kidney dimensions or calculated kidney volume with age, height, body weight, body surface areas, and side of the body[1–7]. Some authors extended those relations to the length of the trunk, upper and lower limbs, breadth of thorax and pelvis, head circumference, maximal cranial length, maximum cranial breadth and skin fold thickness[5,8]. Three different studies showed significant difference between the length of left and right kidneys. In all of them left kidneys were significantly longer[4,5,9]. Some authors compared the data of kidney lengths among the races, and found the differences between Caucasian and Afro American race, while the study made on the Australian and Hong Kong population did not show the described differences[10,11]. Most of the studies did not show the significant difference of the kidney lengths regarding to gender[4,9,11]. Scott et al. (1990) showed that neonatal male kidneys were significantly larger than female ones, while Vujic et al. (2007) showed the same in the groups of children aged 0–3 months, 6–9 months, and 9–12 months[6,12]. In Croatia, the ultrasonographic study of kidney lengths has been carried out only in adults[13].

Nephrogenesis is usually completed in the period between 32$^{nd}$ and 36$^{th}$ gestational weeks. After that period the kidney enlargement is achieved only through processes of cellular hyperplasia and cellular hypertrophy, hence the differences in size between the neonatal and adult kidneys despite of equal number of nephrons[14]. The old rule stating that »kidney length in millimeters correlates with gestational age in weeks during pregnancy« is not exactly correct[15]. The neonatal kidney length increases 17% in the first week of life, in the first four months of life kidney length increases a further 37%, while the relative kidney growth decreases by the end of the first year of life[16]. From the end of the first year of life to the end of the ninth year of life, kidney

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length increases approximately 2–3 mm *per* year. After the tenth year of life, the kidney growth continues but gets even slower[14]. The majority of the above mentioned studies included samples of a relatively wide age range.

The aim of this study is to assess the normal values of kidney length in a large group of termed healthy infants of both sexes in the first six months of life only. The second goal of this study is to provide the first Croatian ultrasonographic study of the kidney lengths in children.

## Subjects and Methods

This study was conducted in a period of 4 years between 1998 and 2002 and included healthy termed infants of both genders. Exclusion criteria were: urinary tract anomalies, cysts and cystic diseases of kidneys, kidney tumours, urinary tract infections, and other diseases affecting urinary tract either directly or indirectly. Infants with vesico-ureteral reflux, which was diagnosed subsequently, were also excluded from the study. The total number of 935 (1870 kidneys) healthy termed infants (476 male, 459 female), aged from 0.5 to 6 months, were examined by a single examiner (K.D.) using ultrasound machine Sonoline Prima Siemens with semi convex probe of 5.0 MHz, and with linear probe of 7.5 MHz, if necessary.

The mean age at examination was 2 months and 18 days. Out of 953 examined infants, 642 (68.7%) were examined within the first 3 months of life, while 293 (31.3%) were examined at the age between 3 and 6 months.

After each kidney was measured six times in longitudinal axis (three times in prone position and three times in supine position), the longest figure was recorded. Data was grouped according to gender, side and age. Age groups include a period of 30 days. In all six age groups, statistical analysis was performed. The mean value, minimal and maximal values, as well as standard deviations were determined by statistic program SPSS 10.0 for Windows, SPSS Inc. Variables were compared by t-test with threshold of significance of $p<0.05$.

## Results

A significant relation between the increase of kidney length (right and left) and the increase of age in studied groups of infants ($p<0.05$) in both sexes was found. That connection was shown by four different nomograms, followed by regression equations (Figures 1–4). We also found that in the first three months of life, male infants had both kidneys that were significantly longer than in female infants ($p<0.05$), while in the next period of three months that difference was not significant anymore ($p>0.05$, Table 1). Regarding possible differences in length between the left and right kidneys, we made statistical analysis of all right and all left kidneys in male infants, and found that left kidneys were longer than right kidneys ($p<0.01$) in first six months of life. The same left-right size ratio was observed in the group of female infants (Table 2). In 63.3% of examined children, the left

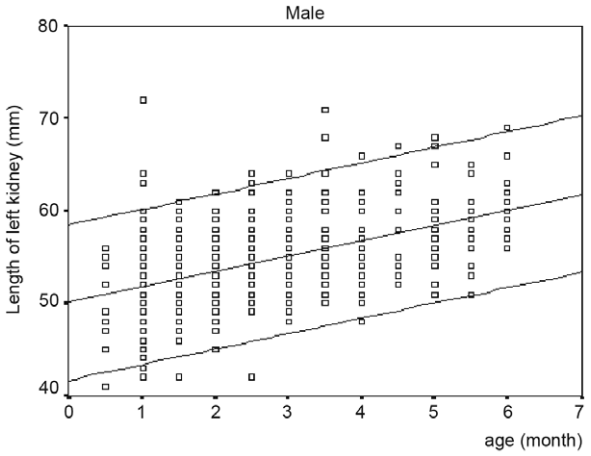


*Fig. 1. The separate nomogram of the left kidney lengths in the male infants during the first six months of life with regression equation (length=5.6×10$^{-2}$×age (days)+50.06 (p<0.01)).*

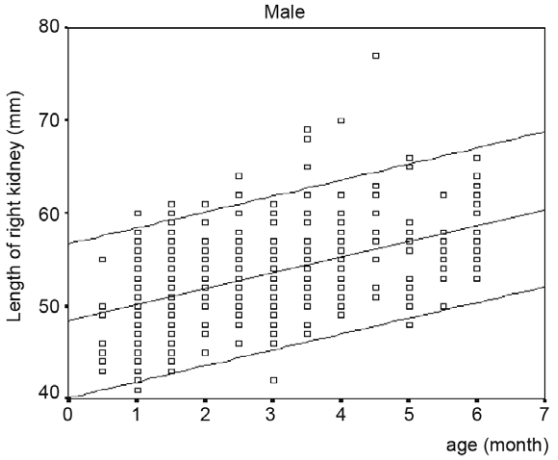


*Fig. 2. The separate nomogram of the right kidney lengths in the male infants during the first six months of life with regression equation (length=5.7×10$^{-2}$×age (days)+48.2 (p<0.01)).*

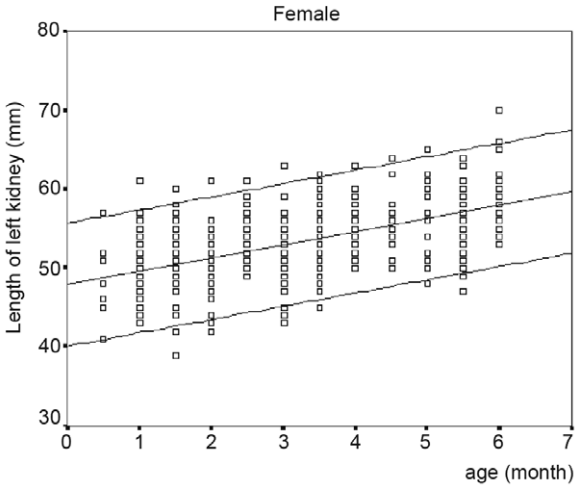


*Fig. 3. The separate nomogram of the left kidney lengths in the female infants during the first six months of life with regression equation (length=5.7×10$^{-2}$×age (days)+47.8 (p<0.01)).*

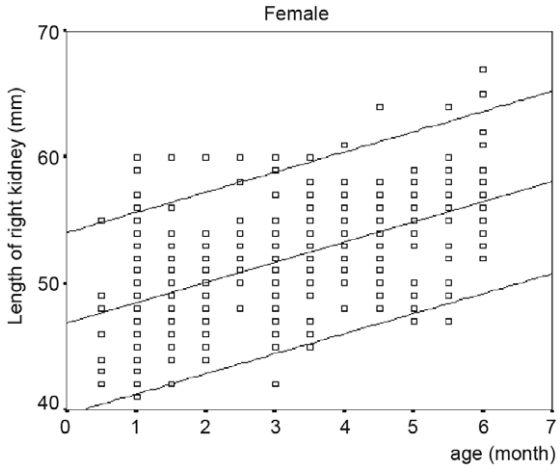


*Fig. 4. The separate nomogram of the right kidney lengths in the female infants during the first six months of life with regression equation (length=5.4×10$^{-2}$×age(days)+46.8 (p<0.01)).*

**TABLE 1**
LENGTHS OF MALE AND FEMALE KIDNEYS

| Month | Length of left kidney | | Length of right kidney | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| 1. | 51.7±4.6 | 49.5±3.6* | 50.4±3.9 | 48.9±4.0* |
| 2. | 53.3±3.7 | 50.6±4.1* | 52.3±3.8 | 49.1±3.3* |
| 3. | 54.7±3.9 | 52.6±4.2* | 52.9±4.3 | 51.3±3.8* |
| 4. | 56.2±4.5 | 55.2±3.0 | 54.5±4.5 | 53.4±3.1 |
| 5. | 58.4±5.1 | 56.6±4.5 | 57.0±5.5 | 54.7±3.7 |
| 6. | 60.5±3.6 | 58.7±4.6 | 58.9±4.0 | 57.6±4.6 |

* Statistically significant (p<0.05)

**TABLE 2**
RIGHT AND LEFT KIDNEY LENGHT

| | |
|---|---|
| Male (476) | Left: 54.3±5.0 |
| | Right: 52.7±5.0 |
| | t=4.9 p=0.000 |
| Female (459) | Left: 52.4±4.8 |
| | Right: 51.1±4.4 |
| | t=4.2, p=0.000 |

kidney was longer than the right kidney. In 21.5% children both kidneys were equal in length, while remaining 15.2% of infants their right kidney was longer than the left kidney.

## Discussion

The neonatal nephrons are significantly smaller and more immature than those in older children and in adults[17]. Despite their smaller size, in order to retain the metabolic steady state, neonatal kidneys must quickly take over the whole function of a mature kidney while this function is being regulated by the placenta during the fetal period[14,18]. Increased demands of the growing organism are the main reason for the accelerated growth of kidneys in first weeks of extrauterine life, due to cellular hyperplasia and hypertrophy. The strong correlation between age and kidney length was found in our study. Other authors found the correlation between body length and kidney length and volume in the first year of life[5,6]. That relative acceleration of kidney growth decreases with advancing age like in other organs such as brain, liver, heart, and adrenals[19–22]. The assessment of kidney length and rate of kidney growth is important for the assessment of urinary system development. There are numerous standards for the ultrasonographic, three-dimensional ultrasonographic, urographic, magnetic resonance and scintigraphic measurements of kidney size. Most of them are based on maximum kidney length or on calculated kidney volume, according to body length, body weight or body surface area[1–6,8–11,13–16,18,23–32]. However, variations in measuring kidney lengths might be significantly different, even if they have been performed by the same person[26,27,32].

Ultrasonography seems to be the most appropriate imaging method because it is harmless, accurate, and available. Unilateral or bilateral reduction in kidney length or its abnormal enlargement might be very important signs of kidney diseases (acute or chronic urinary tract infections, kidney malformations, glomerulopathies, especially in unilateral inherited kidney diseases like Beckwith-Wiedemann syndrome and hemihypertrophy syndrome)[33,34]. In those situations, it is necessary to perform the ultrasonographic follow-up of kidney size at least every four months[34]. Therefore, it is important to be familiar with the normal range of kidney dimensions in healthy infants. When compared to the available literature, our study, based on measurement of 1870 kidneys, represents the largest series of kidney length measurements in newborn children up to six months of life[1–4,8–11,13–16,18,23–26]. The study of Han and Babcock (1985) was carried out on 122 children from newborn to 17 years of life[1]. Dinkel at al. (1985) examined 325 children, aged between 3 days and 16 years and made nomograms for kidney lengths related to body height and nomograms for both left and right kidney volume related to body weight[2]. Dremsek at al. (1987) extended those relations to the length of the trunk, upper and lower limbs, breadth of thorax and pelvis, head circumference, maximal cranial length and maximum cranial breadth in the group consisting of 196 children, aged between 4 weeks and 16 years[8]. Christophe et al. (1986) measured kidney length, thickness, width, volume, largest sagittal and transversal areas against the children's height and body surface in 170 children, aged between 0–15 years[3]. Based on our results, the kidney lengths of males and females in the first three months of life were significantly different. Our result showed that in that period male kidneys were significantly longer than female kidneys. There is contradictory data in other studies regarding male and

female kidney sizes. Schmidt et al. showed that boys had larger kidney volumes than girls[28]. In many studies, the difference between male and female kidneys was not observed except in one study that was recently performed[1,2,6,9,10,14]. Scott et al. (1990) found the kidney length to be significantly longer in male newborns than in female newborns[12]. This finding can be explained by the fact that male neonates are usually heavier and longer than female neonates and by the possibility of hormonal influence of sex steroids and a growth hormone on fetal and infant kidney growth[5,35]. Our study showed also that left kidneys were significantly longer than right kidneys, regardless of the sex in the first six months of life, which agrees with results from some previous studies in children and in adults[7,10,15,16]. This might explain the extensive enlargement of the liver during the period of kidney ascent[36]. This fact might be an important limiting factor in both the right kidney ascent and its elongation. Han and Babcock's study did not find such left to right kidney difference, possibly because they examined small number of children[1]. Study conducted by Vujic et al. also did not find that difference, possibly due to the examination of children in the supine position only[6]. Our study also showed that a group of infants in the first six months of life was not a homogenous group regarding kidney size, side, patient's sex and age. Therefore, we made four nomograms, which could help understand the process of kidney growth in that period. We found that kidney growth especially accelerated during the first six months of life, as also shown in some other studies[16].

In conclusion, male and female infants represent significantly different groups regarding the kidney lengths in the first three months of life. Based on the results of this study we can also conclude that left kidneys significantly differ from right kidneys, regardless of gender in the first six months of life.

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## ULTRAZVUČNA PROCJENA DULJINA BUBREGA U PRVIH ŠEST MJESECI ŽIVOTA


### S A Ž E T A K

Rast bubrega u djece nije linearan. Ova studija imala je cilj odrediti uredne dimenzije bubrega zdrave dojenčadi u prvih 6 mjeseci života. Prospektivni ultrazvučni probir 1870 bubrega od 935 zdrave, donošene dojenčadi (476 muške, 459 ženske) učinjen je tijekom 5-godišnjeg perioda. Izmjereni bubrezi bili su podijeljeni temeljem spola i strane u šest dobnih skupina. U prva tri mjeseca života dječaci su imali dulje bubrege nego djevojčice iste dobi ($p<0,05$). U slijedeća tri mjeseca života ta razlika među spolovima više nije značajna ($p>0,05$). Lijevi bubrezi su bili dulji od desnih u oba spola u prvih šest mjeseci života ($p<0,01$). Napravljena su četiri nomograma s normalnim vrijednostima bubrežnih duljina u odnosu na dob, spol i stranu u novorođenčadi i dojenčadi u prvih šest mjeseci života.