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Sonographic determination of renal volumes in normal neonates

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Abstract. Renal diseases that affect renal size without altering renal architecture require a quantitative means of detection. A prospective study was undertaken to establish normal values for renal volumes in healthy neonates using sonography. Volumes were determined by two methods; (1) the serial area-volume method using parallel transverse images; and (2) the prolate ellipsoid model of the kidney using orthogonal diameters taken from ultrasound images. Renal volumes for both the right and left kidneys in both sexes were found to be approximately 10 ml. There was no significant difference between the results obtained by either method, nor were there significant differences between the volumes of the right and left kidneys within either sex. No difference in renal volume was noted between sexes. The mean greatest renal length was also computed for right and left kidneys in both sexes. Knowledge of normal renal volumes may aid in the diagnosis of urinary system disorders in neonates.

Key words: Renal volume – Neonate – Ultrasonography – Nephromegaly

Questions concerning the presence of pathology within the abdominal cavity frequently arise within hours of birth. This is particularly true for the kidneys which, because of their paried nature, may have unilateral pathology hidden by normal function of the contralateral kidney. Therefore, a high index of suspicion is warranted when there is a question of renal pathology in the newborn. Because of its lack of ionizing radiation as well as its non-invasive nature, the renal ultrasound study has an important role in the work-up of suspected renal disease in the neonate [1, 2]. This is particularly true with infiltrative renal diseases which remain difficult to diagnose because they do not disturb renal architecture and may be overlooked by visual inspection of ultrasound images.

One useful parameter for renal assessment is renal size [3, 4, 5]. Renal volume determinations should be more sensitive to detect many such conditions but there are no reported normal values for renal volumes in neonates obtained from ultrasonographic images. Therefore, we have performed a prospective study of healthy neonates in which the volumes of both kidneys are measured from sonographic images.

Methods

Subjects for this study consisted of infants born at the University of South Alabama Medical Center. An informed consent statement approved by the Human Research Committee was signed by parents of all children who were participants in the study. For this project, a neonate was defined to be a term infant in the first 7 days of life. Only infants who had a normal physical examination were considered for inclusion in the study.

All sonographic images were obtained using a 5 MHz transducer on an articulated-arm instrument. Images were obtained with the neonates in one of two position, prone or lateral decubitus. With the subject in the prone position, we obtained both longitudinal and transverse sections in a serial, parallel manner. Only longitudinal images were recorded while the subject was in the lateral decubitus position, therefore yielding coronal images.

Renal volumes were computed for each kidney by two methods, the serial area-volume method and the prolate ellipsoid model for the kidney.

The serial area-volume method of volume determination has been described previously [6]. This method works theoretically for parallel slices taken in any plane, and initially we tried to obtain volumes from both transverse and longitudinal sections; however, lateral motion by the infants distorted the longitudinal series and we were forced to discard these data.

The second method used to determine the renal volume assumes the kidney to be a prolate ellipsoid. Measuring the greatest diameter of the kidney in three mutually orthogonal planes permits one to calculate the renal volume from the formula: volume $= (A\ B\ C) \times \pi/6$ where A, B, and C are the diameters along the major and minor axes. This method is accurate only if the kidney approaches the assumed shape of a symmetrical ellipsoid.

After volumes were computed for each kidney by both of the methods described, a mean volume was computed for the right and left kidney in each sex utilizing both methods. These means

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Table 1. Renal volume in milliliters

	Males						Females					
Kidney	left			right			left			right		
Method	volume ±	SD	(N)	volume ±	SD	(N)	Volume ±	SD	(N)	Volume ±	SD	(N)
Serial area-volume	11.3	3.8	(36)	9.9	2.8	(36)	9.8	2.7	(26)	9.2	2.3	(25)
Prolate ellipsoid	10.6	3.2	(36)	10.4	2.6	(35)	9.1	2.1	(26)	8.4	2.6	(26)

Table 2. Renal length in centimeters

Kidney	left			right		
Method	length ±	SD	(N)	length ±	SD	(N)
Males	4.27	0.48	(36)	4.12	0.44	(36)
Females	4.27	0.37	(24)	4.18	0.32	(24)

were then compared for statistical differences between the two methods, for differences between the right and left kidneys of subjects of the same sex, and for differences in the renal volumes of male and female subjects.

Additional information obtained from this study was greatest renal length, measured from longitudinal sections. These data were recorded and the mean length of the right and left kidney in each sex was calculated.

We attempted to find simple relationships between calculated renal volumes and other body parameters such as birth weight, body weight at the time of the scan, body height, and body surface area.

Computations were performed with a Numonics Graphic Calculator and hand calculators. All comparisons of means utilized the two-tailed Student t-test.

Results

The average values of renal volumes as determined by the two methods (Table 1) did not differ in a statistically significant manner for any of the four subsets examined ($p > 0.05$). For example, the right kidneys of the male subjects which had mean volumes of 11.3 and 10.6 milliliters by the serial area-volume and prolate ellipsoid methods, respectively, were not significantly different ($t = 0.83$, $n = 36$).

Although the computed mean volume of the left kidney by both methods exceeded that of the right kidney in males and females, the difference was not significant at the 0.05 level of significance in any situation. Comparison of the results obtained for the two sexes showed female kidneys to have slightly smaller volumes but here, also, the differences were not significant at the 0.05 level of significance.

The mean greatest renal length of each kidney for both the male and female subjects were computed (Table 2). In both sexes, the left kidney had the same average length of 4.27 centimeters while the right kidney averaged 4.12 centimeters in males and 4.18 centimeters in females. The values for the right kidneys were not significantly different ($t = 0.57$, 58 df).

Attempts to relate measured renal volumes and lengths to more easily measured variables of the newborn such as weight, height, or surface area were unsuccessful. Both linear and quadratic models were examined but none of these gave a smooth fit to the data.

Discussion

Renal volume determinations in adults by ultrasound scanning have previously been used in normal subjects and in renal transplant patients [5, 7]. Sonographic studies of renal size in children have dealt with parameters such as renal length and thickness [3]. Renal volumes have been calculated in children [8] but renal volumes have not been utilized in newborns. The results of this study indicate that renal volumes in neonates may be obtained from sonographic images by either the prolate ellipsoid or stepped section methods. Contrary to the findings in volume studies of other structures, such as the gravid uterus [6] no significant differences were noted between the results obtained by the methods when studying the neonatal kidney.

The average value for renal volume for both kidneys of both sexes using the prolate ellipsoid method is 9.6 ml with a standard deviation of 2.6 ml. These values result in a coefficient of variation of 27%. This degree of variation in neonatal renal size may also be noted at pathology. According to the standards of Schultz et al., the mean combined normal renal weight is 29 g with a 7-g standard deviation [9]. The results of Schultz yield a coefficient of variation of 24%, very similar to our 27% coefficient.

Diseases that alter renal architecture may be detected by visual inspection of ultrasound images. Diseases that result in nephromegaly without gross changes in renal architecture require a quantitative means of detection. Even with the variability that exists in neonatal renal size, several such conditions emerge that may be detected by neonatal renal volume determinations within 95% confidence limits. Renal size in infants of diabetic mothers is over 100% greater than in controls [10] but the images would result in kidneys that appear normal to visual inspection. Renal vein thrombosis results in kidneys that are 2–3 times normal size [11] with an echo pattern that may reflect only minimal decrease in echogenicity due to edema.

We have encountered Beckwith-Wiedeman Syndrome in young children resulting in nephromegaly but no gross changes in parenchymal patterns. Beckwith-Wiedeman Syndrome has been reported in the newborn resulting in kidneys 2–3 times normal size with only slight increase in cortical echogenicity [12].

The prolate ellipsoid method to compute neonatal renal volume is favored over the serial area-volume method for at least two reasons, both having to do with the actual scanning process. With the serial area-volume method, once the initial plane of sections for the kidney has been obtained, it is imperative that the subject does not move. Movement would change the distance between the other sections necessary for the computation. By contrast, when using the prolate ellipsoid method, one is required only to obtain two images of the kidney; a transverse section through the widest portion of the kidney and, at right angles to this, a longitudinal section containing the greatest length of the kidney. The second reason for favoring the prolate ellipsoid method is concerned with time, for the prolate ellipsoid method is much faster than the serial method. Additionally, the neonate may be examined in an isolette by real-time equipment.

Our findings indicating no difference in renal length or volume between the two sexes are in agreement with the results of several previous studies [13–15]. However, earlier studies by both roentgenographic and ultrasonographic methods in children and adults disagree as to whether the left and right kidneys differ in size. Haugstvedt and Lundberg, using sonography, found the left kidney to be longer than the right in 46 children. Significantly, only nine of their 46 children studied were less than 1 year old [3]. Working with both healthy adults and cadavers, Rasmussen and colleagues found no difference between volumes of the right and left kidneys [7]. In a study comprising 822 normal children of whom 133 were less than half a year old, Bacopoulos et al. observed no difference between right and left kidneys on intravenous urograms [13]. Furthermore, our value for the length of neonatal kidneys, about 4.2 cm, concurs with the findings of Stolpe et al. who found newborns to have renal lengths ranging from 4 to 6 cm [15].

Finally, in this study we were unable to find any good correlation between either renal volume or renal length and other body parameters. By contrast, Haugstvedt and Lundberg and Hodson, Drewe, Karn and King demonstrated strong correlations between mean renal length and age, body height and also, body surface area [3, 4]. Other studies, however, have not corroborated these findings [14, 15]. We feel the inability to demonstrate linear relationships between renal volume and length and other body parameters results from two factors; (1) the actual variability in renal size between neonates of approximately the same age, weight, and height; and (2) the small sampling interval that exists in normal newborns.

Conclusions

Sonographic renal volumes provide a simple way to measure newborn renal size. They may be computed from a simple prolate ellipsoid estimate; a measurement of renal length, width and thickness may be performed in an isolette. Renal volumes should provide a more sensitive means to detect disease that alter renal size and do not alter renal architecture.

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