INTRODUCTION

Renal size is an important parameter used for clinical evaluation of renal growth and renal abnormalities (1). The documentation of symmetric small kidneys supports the diagnosis of progressive chronic renal disease with an irreversible component of scarring. Normal kidney size suggests the possibility of an acute rather than chronic process (2). Accordingly, accurate measurement of renal size can be of importance in the diagnosis and treatment of renal diseases. As the kidneys are not parallel with the craniocaudal direction in the body, in the case of 3D CT or MR imaging techniques, the reconstruction of oblique images that match the long axis of the left or right kidney is necessary for radiologists for accurate measurement of renal length (3).
On the contrary, in case of ultrasonography, it is relatively easy to measure the length in the long axis. Despite ultrasonography is the modality of choice for measuring renal sizes (4, 5), several studies have shown that the measured maximum renal longitudinal length varies with the used images as well as with the patient’s position (6, 7). To the best of our knowledge, until date, there exists no study, which has reported comparison of ultrasonographic renal length with true renal length depending on positional changes. The purpose of this study was to determine a position in which the measured value on ultrasound is close to the true renal length, obtained through a multiplanar reconstructed MR image.

**MATERIALS AND METHODS**

**Study Plan**

We recruited volunteers a total of 34 volunteers, comprising of 16 males and 18 females without any known underlying diseases within a period of two weeks, from March 2, 2015, to March 15, 2015. All the volunteers underwent blood tests within 6 months, and demonstrated normal levels of serum GFR (more than 90 mL/min/1.73 m²) and creatine (0.6–1.2 mg/dL). One male subject was excluded because of a suspected hepatosplenomegaly upon ultrasonography. A total of 33 individuals, henceforth, 33 pairs of kidneys were included in this prospective and cross-sectional study. The average age of subjects was...
Comparative Analysis of Renal Longitudinal Length on Ultrasound with Multiplanar Reconstructed MRI

35.6 years within the group comprising of individuals aged between 26–54 years. The present study with ultrasound was conducted from March 16, 2015 to March 31, 2015. After a month, MR imaging was conducted from April 16, 2015 to April 30, 2015. The Institutional Review Board of our hospital approved this prospective study. Before ultrasonography, all the subjects were interviewed and informed on the characteristics and objective of the study and written informed consent was obtained according to the World Medical Association Declaration of Helsinki, revised in 2000, Edinburgh. Each patient received a report of their first ultrasonographic examination during their second appointment.

Image Acquisition

Ultrasonography was performed using an IU22 ultrasound unit (Philips Ultrasound, Bothell, WA, USA) with a 1–5 MHz convex transducer. The procedure was conducted by a radiologist with four years of experience in ultrasound under supervision of another genitourinary radiologist with 12 years of experience. Renal length was measured as the longest axis at the level of the renal hilum in three positions–supine, lateral decubitus, and prone, respectively (Fig. 1). The maximum longitudinal length of the kidney was measured in the supine and lateral decubitus position through flank measurement with the transducer positioned in the ipsilateral mid-axillary line, and in the prone position through posterior transducer approach. Subsequently, the averages of twice measurement-a-week-intervals were obtained in supine, lateral decubitus, and prone, respectively. With a 3.0 T MR scanner (Philips Achieva, Best, the Netherlands), 3D eTHRIVE sequence (repetition time/echo time 3.0 ms/1.4 ms, 70 slices, slice thickness 3.0, 1.5 spaces, FOV 350 × 350) was acquired (Fig. 2). Next, the maximum longitudinal length of both the kidneys was measured through multiplanar reconstructed MR images using the 3D software (INFINITI Xelis BN4, 1.0 version, Seoul, Korea) by another radiologist with 12 years of experience, who was blind-folded to the results of previous ultrasonography.

Statistical Analysis

Paired t-test was employed to perform comparative analysis between the renal length obtained from ultrasonic measurement of the left and right kidneys depending on the position (supine, lateral decubitus, and prone position, respectively) and the renal length obtained through multiplanar reconstructed MR images. We also applied paired t-test to compare the longest renal length obtained from ultrasonic measurement in three positions and the length obtained through multiplanar reconstructed MR images. Statistical analyses were performed using SPSS version 18.0 software (SPSS Inc., Chicago, IL, USA). Results were considered as statistically significant if the p-value was < 0.05 for all data analyses.

RESULTS

Our study demonstrated significant difference between ultrasonographic-measured renal length in all the three positions and the lengths obtained through multiplanar reconstructed MR images.

Table 1. Comparison between Ultrasonographic Maximum Renal Length and MR Length, a Total of 33 Individuals by Paired t-Test

|                | Mean    | Std. Deviation | Std. Error Mean | 95% CI Lower | 95% CI Upper | t     | p-Value | Correlation Coefficient |
|----------------|---------|----------------|-----------------|--------------|--------------|-------|---------|-------------------------|
| Right          |         |                |                 |              |              |       |         |                         |
| Supine-MRI     | -0.43333| 0.59564        | 0.10369         | -0.64454     | -0.22213     | -4.179| < 0.001 | 0.742                   |
| Lateral-MRI    | -0.42121| 0.43212        | 0.7522          | -0.57443     | -0.26799     | -5.6  | < 0.001 | 0.887                   |
| Prone-MRI      | -0.56061| 0.62397        | 0.10862         | -0.78186     | -0.33936     | -5.161| < 0.001 | 0.753                   |
| Longest-MRI    | -0.06364| 0.4022         | 0.07001         | -0.20625     | 0.70898      | -0.909| 0.37    | 0.893                   |
| Left           |         |                |                 |              |              |       |         |                         |
| Supine-MRI     | -0.63939| 0.43799        | 0.07624         | -0.7947      | -0.48409     | -8.386| < 0.001 | 0.835                   |
| Lateral-MRI    | -0.49394| 0.51596        | 0.08982         | -0.67689     | -0.31099     | -5.499| < 0.001 | 0.849                   |
| Prone-MRI      | -0.53939| 0.63538        | 0.11061         | -0.76469     | -0.31411     | -4.877| < 0.001 | 0.714                   |
| Longest-MRI    | -0.2697 | 0.44755        | 0.07791         | -0.42839     | -0.111       | -3.462| 0.002   | 0.866                   |

Supine (lateral, prone)-MRI: average length of ultrasonographic maximum renal length in supine (lateral, prone) position versus MR reconstructed maximum renal length, Longest-MRI: ultrasonographic longest renal length among the three positions versus MR reconstructed maximum renal length. Std. = standard, t = test statistic value, 95% CI = 95% confidence interval of the difference.
renal length obtained through MRI ($p < 0.001$). However, there was no statistically significant difference between the longest longitudinal length of right kidney among the measured three values by ultrasound and the renal length measured by reconstructed MR image. On the other hand, statistically significant difference was observed between the longest renal longitudinal length of the left kidney and the true renal length obtained through MR image (Table 1).

We also found much stronger correlations between the ultrasonographic-measured renal length and renal length measured through reconstructed MR image in the following order: the longest value amongst the measured three lengths, the length obtained at lateral decubitus, prone and supine position in right kidney, and the longest value among the measured three lengths, the length obtained at lateral decubitus, supine and prone position in left kidney, respectively (Table 1).

The same number of right kidney were measured for a longer time in each of the three positions ($n = 10$ for each position). Meanwhile, large number of left kidney were measured for a longer time in prone position ($n = 14$).

Range and distribution of ultrasonographic renal lengths and the true renal length through MR reconstruction are provided in Tables 1 and 2, respectively. The ultrasonographic renal length of right kidney on lateral decubitus measured all but one renal length within 1 cm of the true renal length.

**DISCUSSION**

Renal length measurement can be considered as an important parameter or indicator of subsequent changes in the diagnosis and treatment of renal diseases. Numerous researches have demonstrated that in various disease conditions, the kidney size changes, probably due to inflammation caused by infections or because of water and mineral concentration. Diabetes can also increase the size of kidneys, and chronic diseases can decrease the size of kidneys (2). Renal ischemia also leads to a decrease in renal size (8). Previous studies have demonstrated correlation between renal size and development of residual renal function in patients undergoing chronic hemodialysis (9).

Considering that there is a difference between the left and right renal rotation axis during developmental ascent (10), in the case of 3D CT or MR imaging techniques, the reconstruction of oblique images that match the long axis of the left or right kidney is necessary for measuring maximum renal longitudinal length, respectively. On the other hand, it is relatively easy to simultaneously measure the length in the long axis through ultrasonography.

Ultrasonography is a safe and simple method for a disadvantage-free diagnosis of renal diseases, such as from radiation exposure and side effect from contrast. Moreover, regardless of renal function, it is relatively easy to examine both the kidneys through ultrasonography and hence, ultrasonography is the modality of choice for measuring renal size (1, 4, 5, 11). However, several studies have shown that the measured maximum renal longitudinal length varies with the patient’s position and it has been recommended that renal length measurements should only be compared with the data collected from the patient at same position during follow-up examinations (6, 7). However, to the best of our knowledge, there exists no study with respect to determination of a position in which the measured value on ultrasound examination is close to the true renal length.

In this study, we attempted to compare ultrasonographic-measured renal length with true renal length through multiplanar reconstructed MR image. There are few published reports on comparison of ultrasonographic measurements with CT or MR imaging for measurement of renal length (12, 13). Bhutani et al. (13) demonstrated strong correlation between ultrasonographic-measured length and MR measured length. We presumed the renal length obtained through multiplanar reconstructed MR imaging as true renal length. Actually, there are no reports
Comparative Analysis of Renal Longitudinal Length on Ultrasound with Multiplanar Reconstructed MRI

concerning comparison between true renal measurements and 3D MR measured parameters. However, renal length or volume measurement by 3D MR imaging technique is considered as an appropriate method for measurement (13). Our study demonstrated significant difference between sonographic renal length in three positions and renal length measured through MRI \((p < 0.001)\). Among them, the lateral decubitus position showed strongest correlation with renal length measured from MRI, which is possibly due to the fact that the lower pole of each kidney is pushed slightly more anterior than the upper pole (14). Presumably, it is also possible that handling probe in a more posterior and wide position in lateral decubitus rather than in supine position during ultrasonography examination led to strong correlation of the position with renal length measured from MRI. It is apparent that the ultrasonographic probe in the lateral decubitus position is most similar to the true renal long axis.

There was no statistically significant difference between the longest longitudinal length of the right kidney among the measured three values by ultrasound and the renal length measured by reconstructed MR image. Accordingly, when measurement of the exact length of right kidney is demanded, ultrasonography should be performed in three positions. Whereas, statistically significant difference was noted between the left kidney and the renal length measured by reconstructed MR image \((p < 0.05)\). The measured length of the left kidney had discrepancy both on ultrasound examination and on the MR image. It is possible that liver could have been used as an acoustic window during ultrasound, which also permits definite renal border at the time of measuring the right kidney. On the other hand, the left kidney lies just below the spleen, surrounded by ribs and is more cephalad and hence the reported results are heterogeneous with poor sonic window because of the overlying bowel gas and ribs (15). However, in left kidney, the strongest correlation with renal length through MR was also observed at the longest longitudinal length among the measured three values by ultrasonography, similar to right kidney.

Our present study is associated with certain limitations. First, a single senior resident carried out the measurements from ultrasonography and reproducibility of ultrasonographic length measurements depends on the examiner (6). Therefore, future prospective studies evaluating interobserver agreements are necessary to substantiate present data. Second limitation is that our study was performed on a small number of subjects without an underlying renal disease. Therefore, further studies on a larger population and a comparative analysis between healthy individuals and individuals with underlying renal disease are mandatory. Third, better results can be achieved if the anterolateral diameter is also measured and not just the length of the long axis. There is a possibility that we might have presumed the renal length through multiplanar reconstructed MR imaging as true renal length. The last limitation is the involved time interval between ultrasonographic measurement and MRI performance.

In conclusion, we recommend measurement of the maximum renal longitudinal length in all possible positions on ultrasonography. But, in practice, such processes are problematic because of lack of enough examination time or absence of cooperation from the patient. In case if measurement of renal length in three positions during ultrasonography is not achieved, the next best measurement is on the lateral decubitus, which shows strongest correlation coefficient with the true renal length.

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초음파상 자세 변화에 따라 측정한 콩팥 최대장경의 다면재구성 자기공명영상과의 비교분석

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목적: 본 연구는 초음파상 자세 변화에 따라 측정한 콩팥의 길이 가운데 자기공명영상의 다면재구성을 통해 얻은 실제 콩팥 길이와 가장 가까운 값을 알아보고자 한다.

대상과 방법: 기저질환이 없는 총 33명(남: 15명, 여: 18명)이 본 연구에 참여하였으며, 콩팥 길이는 양과위, 측과위, 복과위 각각에서 신장문이 보이는 평면의 가장 긴 축으로 측정하였다. 자기공명장치 3.0 T에서 3D eTHRIVE를 얻었으며, 다면재구성을 통해 양쪽 콩팥의 실제 값과 가까운 최대 장경을 측정하였다. 자세 변화에 따라 초음파에서 측정한 콩팥 길이와 다면재구성 자기공명영상으로 얻은 콩팥 길이를 대응표본 \( t \) 검증을 이용하여 분석하였다.

결과: 본 연구 결과 초음파에서 각각의 자세별로 측정한 콩팥 길이는 자기공명영상 다면재구성을 통해 얻은 값과 유의한 차이가 있었다 \( p < 0.001 \). 하지만 자세와 상관없이 초음파상 측정값 중 가장 긴 값을 자기공명영상 재구성을 통해 얻은 실제 값과 비교하였을 때, 오른쪽 콩팥에서 통계적으로 유의한 차이가 없었다 \( p = 0.37 \). 초음파에서 측정한 길이와 자기공명영상 재구성을 통해 얻은 실제 콩팥 길이의 상관관계를 비교한 결과, 우측 콩팥에서 측과위, 복과위, 양과위 순으로, 좌측 콩팥에서는 측과위, 양과위, 복과위 순으로 높은 상관관계를 보였으며, 특히 측과위에서 측정한 길이는 실제 콩팥 길이와 높은 상관관계를 보였다.(오른쪽: 0.887; 왼쪽: 0.849).

결론: 초음파상 콩팥의 길이 측정 시 가능하다면 여러 자세에서 최대 길이를 측정하는 것이 정확하겠으나, 여건이 허락되지 않는다면, 측과위에서 측정한 값이 실제 콩팥 길이와 가장 높은 상관관계를 보였다.

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