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Korean ureter length: A computed tomography–based study

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Purpose: We measured ureter length in healthy Koreans using reformatted computed tomography (UL_{CT}) and found ways to indirectly estimate ureter length by measuring LL_{CT}, the length between the ureteropelvic junction and the ureterovesical junction, and standing and sitting height.

Materials and Methods: A total of 508 ureters of 254 healthy patients (median age, 55.0 years; 148 males and 106 females) were included in this retrospective study. UL_{CT}, LL_{CT}, and sitting and standing body height were measured.

Results: The mean left and right UL_{CT} were 25.2±2.2 and 25.0±2.2 cm, respectively. The mean left and right LL_{CT} were 21.1±1.8 and 20.3±1.9 cm, respectively. Standing and sitting body height were 164.1±8.9 and 88.3±4.3 cm, respectively. Height was significantly correlated with UL_{CT}, but this relation was not linear (r^2=0.064 standing height, 0.062 sitting height). However, LL_{CT} showed a significant linear correlation with UL_{CT} (r^2=0.485). UL_{CT} can be estimated indirectly by the following equation: $UL_{CT}=0.823\times LL_{CT}+8.093$.

Conclusions: We could measure the ureteral length of healthy Koreans by UL_{CT}. UL_{CT} could be estimated indirectly by LL_{CT} and standing and sitting height. Of these variables, LL_{CT} provided the most accurate estimate of ureteral length.

Keywords: Korea; Tomography, x-ray computed; Ureter

INTRODUCTION

Ureteral stenting is commonly performed in various urologic procedures for the treatment of ureteral calculi, ureteral stricture, ureteral injury, and retroperitoneal fibrosis [1-3]. Improper placement of a stent can lead to stent-related morbidity: too long a stent often causes frequent or urgent urination, incontinence, hematuria, and flank pain. Too short a stent increases the risk of migration, resulting in complications that require retraction and replacement [1,4-8]. Therefore, decisions about the correct ureteric stent made on the basis of ureter length are of great importance for reducing the incidence of complications.

Direct ureteral measurement using a guidewire or catheter is the most accurate method for measuring ureteral length but may be impractical and of poor reliability [9-11]. Clinically, most urologists use the patient's height to choose the ideal ureteric stent length. However, the methods for choosing an appropriate stent length according to body height are derived mostly from data for whites, who are

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relatively taller than Asians [12]. Whether these data are applicable to Asians is unclear. Asians are not as tall and have a relatively longer trunk than do whites [13]. There are few studies about Asian ureter length, especially in Koreans. Thus, we performed a study of Korean ureter length by measuring the actual length of the ureteric tract from the ureteropelvic junction (UPJ) to the ureterovesical junction (UVJ) by use of intravenous pyelography (IVP) [9]. In that study, mean Korean ureter length was 23.4±1.9 cm (right) and 24.4±2.0 cm (left). However, that study had many limitations because of the use of patient IVP data and manual measurement.

Recently, multidetector computed tomography (MDCT) has been widely used as a noninvasive tool in evaluating the urinary tract, including the ureters; it can acquire thinly collimated data that can create good three-dimensional images [14-16]. As a result, this method is more useful for tracking curved organs such as vessels and ureters. In particular, multiplanar reformatted images in the standard or curved planes are readily generated with no additional time or radiation. By this technique, ureteral length can also be measured correctly compared with IVP. In the Picture Archiving Communications System (PACS), the length between the UPJ and the UVJ can be measured easily. Therefore, we performed the present study to measure ureter length in healthy Koreans using reformatted CT (UL_{CT}) and the linear distance between the UPJ and the UVJ (LL_{CT}) to determine Korean ureter length. We evaluated the correlations between UL_{CT}, LL_{CT}, and standing and sitting height and found ways to indirectly estimate ureter length.

MATERIALS AND METHODS

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was a retrospective imaging review; thus, informed consent from our subjects was waived. This was approved by the Konkuk University Medical Center Institutional Review Board (approval number: KUH1140084).

Electronic medical records from our institution were searched to identify patients visiting our hospital for the first time with a complaint of microscopic hematuria or flank pain and subsequent multiphase enhanced CT examination from August 2013 to December 2016. Among the 1,023 consecutive patents from our research, 769 were excluded on the basis of the following criteria: previous history of urinary tract diseases (n=48); presence of renal abnormality such as renal solid mass, inflammatory lesion, or renal cyst more than 2 cm in size on CT (n=110); hydronephrosis or congenital abnormality in the urinary tract (n=47); urolithiasis (n=71); ureteral or bladder mass on CT (n=36); or improper opacification of contrast agent in the ureter, which was defined as opacification of the ureter by contrast agent to less than 50% in the entire ureteral length (n=457).

Ultimately, 254 patients aged 17 to 84 years (median age, 55.0 years; 148 males and 106 females) were included in this study. None of the patients had urologic diseases that had been confirmed pathologically.

1. CT imaging

CT scans were obtained on an MDCT scanner (Somatom definition64; Siemens, Erlangen, Germany; LightSpeed VCT XT; GE Healthcare, Milwaukee, WI, USA; or GE optima 660; GE Healthcare, WI, USA). The Siemens scanner was set to the following parameters: detector collimation, 24×1.2 mm; helical pitch, 1.0; section thickness/interval, 3 mm/3 mm; 120 kVp/250 mAs. The GE scanners were set to the following parameters: detector collimation, 64×0.625 mm; helical pitch, 0.984:1; section thickness/interval, 3.75 mm/3.75 mm; 120 kVp/100 to 380 mA. Intravenous contrast was injected at a rate of 3 mL/s with a total volume of 130 mL through the antecubital vein using a mechanical injector. Bolus tracking was not applied, and scanning started 5 minutes after the start of contrast injection. No oral contrast agent was applied. Scanning regularly covered the region from the dome of the liver to the lower urethra. Reformatted images were also created from the source CT dataset using coronal multiplanar reformation (MPR) and maximum intensity projection (MIP). For MPR and MIP images, the slice thickness/interval were 3 mm/3 mm and 10 mm/5 mm, respectively; window width/level was 400/40 and 800/300, respectively.

Standing and sitting height were measured in millimeters with a wall-mounted Harpenden stadiometer before the CT scan.

2. Measurement of ureteral length

We measured the ureteral length using three-dimensional curved MPR on coronal CT images (Fig. 1) [17]. We basically used a CT reformatted technique in which the highest attenuation voxel was selected along lines projected through the volumetric CT dataset with a curved MPR technique where the plane of the cut is parallel to the ureter, thus showing the anatomical details of the ureteral course. The images reconstructed in the axial plane were stacked to create a volume of imaging data from which a plane could be

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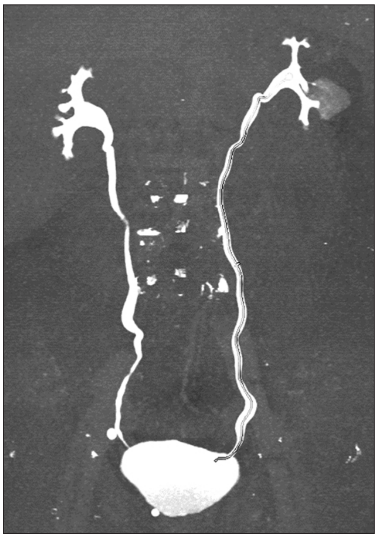

Fig. 1. Ureteral length in healthy Koreans using reformatted computed tomography (UL_{CT}) measured by tracing the ureter from the ureteropelvic junction to the ureterovesical junction with the trackball or mouse using an multiplanar reformation technique on coronal CT reformatted images.

selected to display the course of the ureter [18]. The images displayed in a coronal plane were further manipulated by using planar tilt, which was done by rotating the reference images in various directions. The ureteral length (UL_{CT}) was measured by tracing the ureter from the UPJ to the UVJ using the trackball or mouse. The UPJ was defined as the point where the caliber of the renal pelvis narrowed to match the caliber of the proximal ureter, and the UVJ was defined as the point where the distal ureter could be seen entering the bladder wall [19]. The linear length of the ureter (LL_{CT}) was measured by the linear length between the UPJ and the UVJ.

3. Statistical analysis

Clinical and demographic data were reported using descriptive statistics. Means with standard deviations (SDs) were used to summarize continuous variables; frequencies and percentages were used for categorical variables. The numerical variables were analyzed using a Student's t-test. Categorical variables were compared using a chi-square test or Fisher's exact test. The Pearson correlations were used to assess statistical dependence between variables. A $p<0.05$ was considered to indicate statistical significance. All statistical analyses were done by using SPSS Statistics 17.0 (SPSS Inc., Chicago, IL, USA).

Table 1. Patient characteristics

Variable	Value
Age (y)	52.4±14.7
Sex	
Male	148
Female	106
UL_{CT} (cm)	
Left	25.2±2.2
Right	25.0±2.2
LL_{CT} (cm)	
Left	21.1±1.8
Right	20.3±1.9
Standing height (cm)	164.1±8.9
Sitting height (cm)	88.3±4.3

Values are presented as mean±standard deviation or number only.
UL_{CT}, ureter length in healthy Koreans using reformatted computed tomography; LL_{CT}, linear distance between the ureteropelvic junction and the ureterovesical junction.

Table 2. Pearson correlation coefficients, r^2 between UL_{CT} and other measurements, and equations

	UL_{CT}
LL_{CT}	
Pearson coefficient	0.696
r^2	0.485
Equation	UL_{CT}=0.823×LL_{CT}+8.093
Standing height	
Pearson coefficient	0.253
r^2	0.064
Equation	UL_{CT}=0.0633×standing height+14.807
Sitting height	
Pearson coefficient	0.249
r^2	0.062
Equation	UL_{CT}=0.127×sitting height+13.896

UL_{CT}, ureter length in healthy Koreans using reformatted computed tomography; LL_{CT}, linear distance between the ureteropelvic junction and the ureterovesical junction.

RESULTS

A total of 508 ureters of 254 patients (148 males and 106 females) were included in the study. The patients' mean age was 52.4±14.7 years. The mean standing and sitting body heights were 164.1±8.9 and 88.3±4.3 cm, respectively. The mean left and right UL_{CT} were 25.2±2.2 and 25.0±2.2 cm, respectively. The UL_{CT} did not significantly differ between sides (p=0.236). The mean left and right LL_{CT} were 21.1±1.8 and 20.3±1.9 cm, respectively. These data are summarized in Table 1.

UL_{CT} correlated most strongly with LL_{CT} rather than with standing or sitting height (Pearson coefficients=0.696, 0.253, and 0.249; r^2=0.485, 0.064, and 0.062) (Table 2). Fig. 2

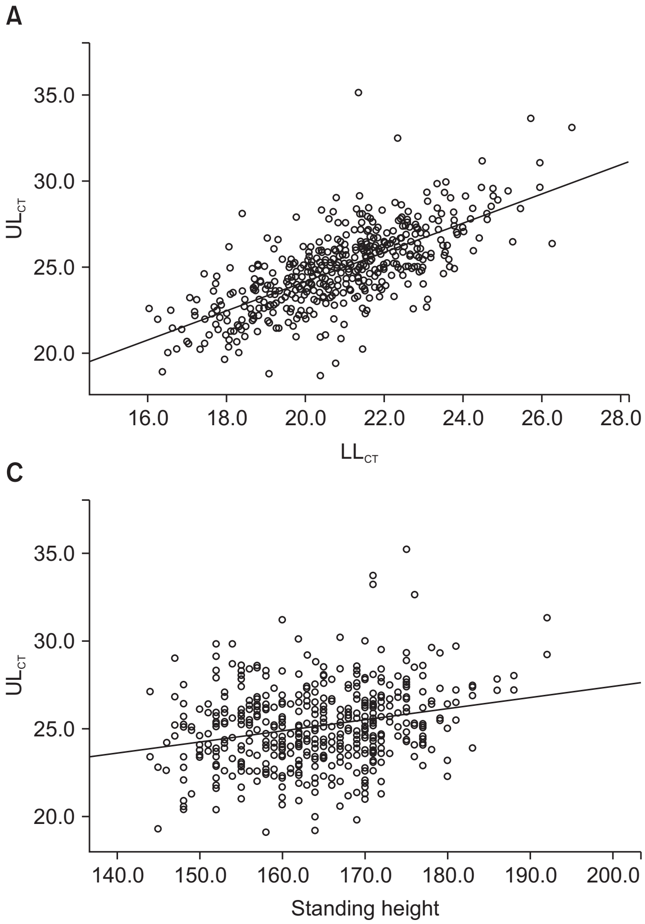

Fig. 2. Linear regression graph. (A) UL_{CT} and LL_{CT}. (B) UL_{CT} and sitting height. (C) UL_{CT} and standing height. UL_{CT}, ureter length in healthy Koreans using reformatted computed tomography; LL_{CT}, linear distance between the ureteropelvic junction and the ureterovesical junction.

shows the UL_{CT} linear regression results with LL_{CT}, standing height, and sitting height.

UL_{CT} can be estimated indirectly by the following equations by the linear regression model:

$UL_{CT}=0.823\times LL_{CT}+8.093$,

$UL_{CT}=0.0633\times$standing height$+14.807$, and

$UL_{CT}=0.127\times$sitting height$+13.896$.

Table 3. Comparison of two Korean ureteral-length studies

	IVP-based study (previous study)	CT-based study (present study)
Ureter length (cm)		
Left	24.4±2.0	25.2±2.2
Right	23.4±1.9	25.0±2.2
Standing height (cm)	164.3±8.3	164.1±8.9

IVP, intravenous pyelography; CT, computed tomography.

DISCUSSION

Although it is important to know the exact length of the ureter, research on ureter length in Asians, especially in Koreans, is rare. Therefore, in this study, we reported Korean ureter length as estimated by CT and the relation with LL_{CT} and standing and sitting height. We did a similar study using IVP in 2005. In that previous study, ureter length was measured by using the IVP of the patient, but the study had many limitations. In the first study attempt, a diverse group of patients was included, with ureters ranging from normal to severe hydroureters. The second attempt had a measurement error because the curved ureter length of the IVP was measured by hand. In the present study, we included only the group with normal ureters and measured ureter length by use of reformatted CT to overcome these limitations and to obtain a more accurate estimate of Korean ureter length. Compared with the previous, IVP-based study, ureter length estimated by CT was longer. We do not know why. Smaller measurements may have been made because of the use of reduced-scale IVP film (Table 3).

In this study, we estimated ureteral length using an MPR technique on coronal CT reformatted images. Although measurement with a ureteral catheter under cystoscopy is considered the gold standard for finding true ureteral length, this is rarely done in practice because it is bothersome for the patient and requires additional instrumenta-

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tion [10,12]. Several authors found that CT measurements of ureteral length showed a high correlation with actual ureteral length, and most of those studies performed the measurement using axial or coronal CT images by counting the number of cuts or the straight LL_{CT} [8,19,20]. However, those measurements might also be problematic, because they are time-consuming or may underestimate the length of a highly curved ureter. In our study, we considered the measurement of ureteral length using the MPR technique on coronal CT images to be a more accurate and easier alternative to the previously reported measurements on CT. This technique had the advantage of measuring the length of a convoluted ureter by tracing it on three-dimensional multiplanes. Thus, this technique is used for the analysis of measurements such as the contour and minimal and maximal diameters of the aorta, cerebral artery, or peripheral artery in CT angiography. In addition, the technique can also be used to evaluate the luminal abnormality of the bronchus, esophagus, small bowel, and colon.

We acknowledge the following limitations in our study. First, our results did not include the ureteral stent-related symptoms or actual stent position in the clinical setting. In our previous Korean-based study, we found that a 22-cm ureteric stent was an appropriate length in Korean patients smaller than 175 cm [21]. However, in this study, mean left and right UL_{CT} were 25.2 and 25.0 cm, respectively, and mean height was 164.1 cm. If we apply this result to the clinic, we should use longer ureteral stents. Thus, the results of the present study are not yet useful for direct clinical application. Second, selection bias may have occurred, because we assessed only patients who underwent CT. To overcome these limitations, we plan to do a prospective study that applies the ureter length resulting from this study in actual clinical practice.

CONCLUSIONS

We could measure the ureteral length of healthy Koreans using CT. UL_{CT} could be estimated indirectly by use of LL_{CT} and standing and sitting height. Of these variables, LL_{CT} provided the most accurate estimate of ureteral length.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

AUTHORS' CONTRIBUTIONS

Research conception and design: Sung Il Jung. Data acquisition: Hee Sun Park, Mi Hye Yu, Young Jun Kim, Hyunjin Lee, Woo Suk Choi, and Hyong Keun Park. Statistical analysis, data analysis and interpretation: Sung Il Jung and Sung Hyun Paick. Drafting of the manuscript: Sung Il Jung and Sung Hyun Paick. Critical revision of the manuscript: Sung Hyun Paick. Obtaining funding: Sung Il Jung. Administrative, technical, or material support: Sung Il Jung and Sung Hyun Paick. Supervision: Hyeong Gon Kim. Approval of the final manuscript: Sung Il Jung and Sung Hyun Paick.

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