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# Retrospective morphometric analysis of patients with horseshoe kidney variation in computed tomography imaging

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***ABSTRACT***

**Objectives:** We aimed to evaluate the morphometric properties of horseshoe kidneys (HSKs) detected in computed tomography.

**Materials and methods:** Between April 2017 and September 2020, A total of 48 patients (30 males, 18 females; mean age: 48.1±19.1 years; range 4 to 92 years) with HSK variation and 20 healthy individuals (9 males, 11 females; mean age: 38.3±23.3 years; range, 4 to 73 years) were included in the study. The thickness, length, location, midline shift of the isthmus and its distance to the diaphragm; the fusion tilt angle, and its orientation were evaluated. The renal pelvis angles (RPA) and the midline orientations; the pole-to-pole angle (PPA), degrees of hydronephrosis, and the presence of stones were assessed.

**Results:** Anteromedial orientation was the most common orientation, and the isthmus was mostly located at L3-L4 (31%) level. Isthmus thickness was 15.7±4.9 mm, width was 37.8±11.9 mm. The mean total calculus volume was 3.14 $mm^3$ and the total calculus density was 543.87 HU. No correlation was found between RPA and calculus ($p>0.05$). The right PPA was 27.2±6.4 degrees, left PPA was 22.6±7.6 degrees. There was a statistically significant difference between between right and left renal pelvis midline angles, right and left renal pelvis horizontal angles, right pole-pole midline angle, and bilateral renal pelvis diameters ($p<0.0001$).

**Conclusion:** Horseshoe kidneys are usually asymptomatic. However, other pathologies such as calculus and hydronephrosis may accompany it. In this study, although there were significant differences in morphological parameters in the HSK group compared to the control group, no statistically significant correlation was found between calculus volume and RPA.

***Keywords:*** Calculi, computed tomography, fused kidney, orientation.

The most prevalent renal fusion defect, with a reported prevalence of one in every 400 newborns and a male predisposition, is the horseshoe kidney (HSK).[1,2] The lower poles of the kidneys frequently have a bilateral parenchymatous or fibrous isthmic connection that crosses the midline. Rare examples, however, have a kidney that resembles an inverted horseshoe, with an isthmus connecting the higher poles. The inferior component (posterior nephrogenic cells) of the metanephric blastema fuses during the fourth and sixth weeks of gestation, prior to the ascent and rotation of the kidneys. Due to this fusion, the kidneys cannot rotate, the calyxes are oriented backward, and the axis of each renal pelvis is located vertically or obliquely in the lateral plan. The inferior mesenteric artery is compressed by the isthmus of the fused tissue, which stops the kidneys from migrating further.[1,3,4]

Although there are a number of imaging modalities that can be used to identify HSK, including computed tomography (CT), magnetic resonance imaging, ultrasonography, micturition cystourethrograms, and others, CT seems to be the most reliable.[5]

In this study, we aimed to investigate the morphometric characteristics of HSK and the correlation between the volume of calculi shown on a CT scan and the angles of the renal pelvis.

## PATIENTS AND METHODS

### Study design and study population

This retrospective case-control study was conducted at Tekirdağ Namık Kemal University, Faculty of Medicine, Department of Radiology between April 2017 and September 2020, 14,674 cases with abdominal CT were scanned

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retrospectively from the picture archiving and communication system (PACS) of the institution's hospital. A total of 48 patients (30 males, 18 females; mean age: 48.1±19.1 years; range 4 to 92 years) with HSK variation and 20 healthy individuals (9 males, 11 females; mean age: 38.3±23.3 years; range, 4 to 73 years) were included in the study. Exclusion criteria for HSK groups were as follows: renal tumor; an expanded cyst at the isthmus level; and insufficient imaging.

### Computed tomography scanning

A 128-row multi-detector CT device (Aquilion Prime; Toshiba Medical Systems Corp., Otawara, Japan) was used in data acquisition. The CT scanning parameters for each protocol were as follows: 100-250 mAs modulated by personal body mass index dose; 100-140 kV tube voltage, 0.5 mm × 80 collimation, 0.35 second gantry rotation time, 0.813 pitch factor, slice thickness 1 mm, slice interval 0.8 mm and 5×5 mm reconstruction interval.

### Data analysis

In the HSK group, the location of the isthmus and its distance to the diaphragm, isthmus length (CC diameter), and thickness (anteroposterior [AP] diameter), isthmus midline shift, fusion angle (FA) and orientation, fusion tilt angle (FTA) and side, the angle and orientation of both renal pelvis with the midline in axial images, both the line drawn from the upper pole to the lower pole and the midline angle in the kidney was evaluated in terms of hydronephrosis (renal pelvic AP diameters and degrees) and the presence of calculi. Stone volume calculation was performed on the Vitrea2® workstation (Canon Medical Systems Vital Images, Minnesota, USA).

### Statistical analysis

Due to the normal distribution of the data after the normality tests, the statistical evaluation was performed using the independent sample t-test and the Pearson test for correlation analysis. The statistical significance level was set as $p<0.05$.

## RESULTS

### Study population

The age distributions between the HSK and control groups were similar (p=0.075). In the HSK group, the distribution of sex was found to be similar (p=0.184).

### Kidney orientations

In both kidneys, the most common orientation was found to be anteromedial (right kidney: 54.2%, n=26; left kidney: 50%, n=24), followed by anterior (right kidney: 31.3%, n=15; left kidney: 33.3%, n=16) and anterolateral orientation (right kidney: 14.6%, n=7; left kidney: 16.7%, n=8) (Figure 1).

### Kidney stone

Calculus was detected in 41.7% (n=20) of the patients. Eight of the patients had calculus in the right kidney, six patients in the left kidney, and six patients had calculus in bilateral kidneys. The mean total calculus volume was 3.14 $mm^3$ (right kidney> left kidney) and the total calculus density was calculated as 543.87 HU (Figure 2).

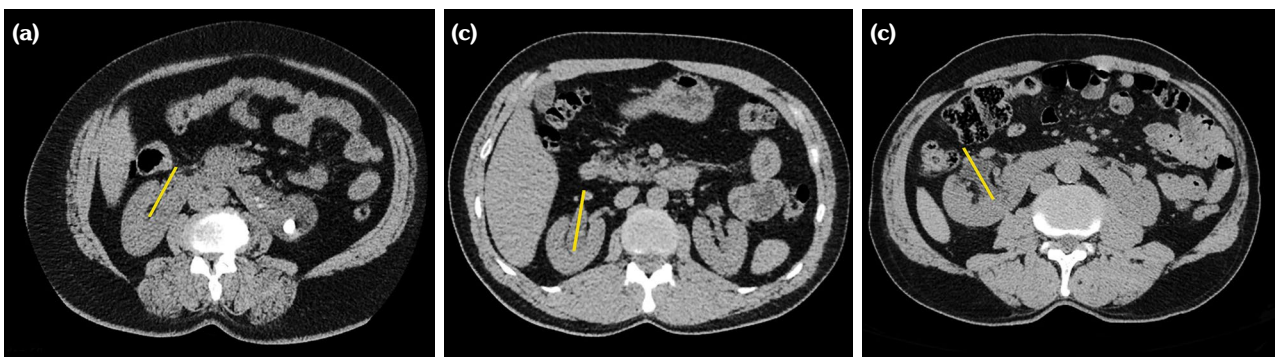


**Figure 1.** Orientations of the horseshoe kidney. **(a)** anteromedial **(b)** anterior **(c)** anterolateral.

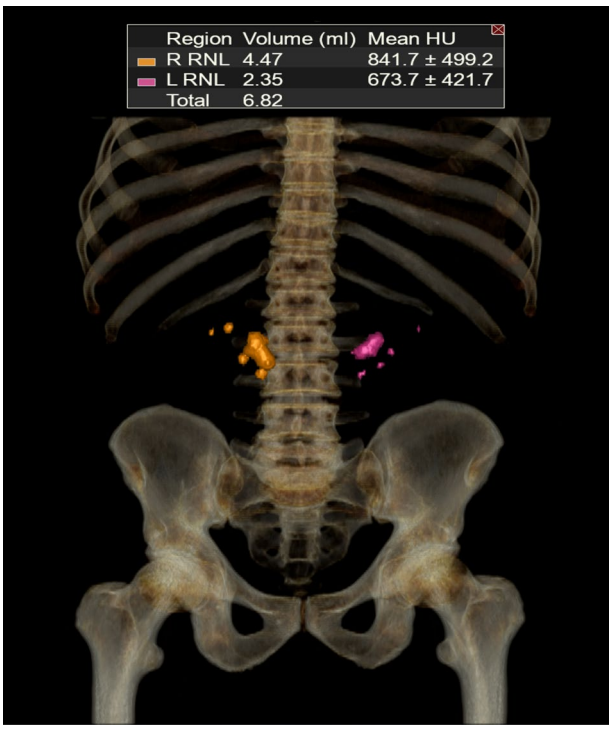


**Figure 2.** Measurement of calculus volume and density.

### Hydronephrosis

Hydronephrosis was detected in 56.3% (n=27) of the patients. In the right kidney in 12 patients (Grade 1 hydronephrosis in eight patients, Grade 2 in two patients, Grade 3 in one patient, Grade 4 in one patient); in the left kidney, it was detected in 15 of the patients (Grade 1 hydronephrosis in eight patients, Grade 2 in four patients and Grade 3 hydronephrosis in three patients).

### Fusion angle orientation

Ten (20.8%) patients had an anterior and 38 (79.2%) posterior FA orientation (Figure 3).

### Fusion tilt angle side

Fusion tilt angle was detected on the right side of 20 (41.7%) and the left side of 28 (58.3%) (Figure 3).

### Isthmus midline shift side

Right side shift was found in nine (18.8%) patients and left side in 39 (81.2%) patients. Atrophy was detected in one (2.1%) patient. Measurements of HSK are given in Table 1 (Figure 3).

### Renal angles

A statistically significant difference was found between the horseshoe kidney group and the control group between right and left renal pelvis midline angles, right and left renal pelvis horizontal angles, right pole-pole midline angle, and bilateral (right and left) renal pelvis diameters ($p<0.0001$) (Table 2) (Figure 4).

### HSK vertebral levels

L3-L4 (30.9%, n=21) were to be found at the most common level, followed by L3 (14.7%, n=10), L4 (10.3%, n=7), L4-L5 (4.4%, n=3), L5 (4.4%, n=3), L2-L3 (2.9%, n=2), L4 inferior end-plate (1.5%, n=1), and L3-L5 (1.5%, n=1). The average distance from the isthmus to the

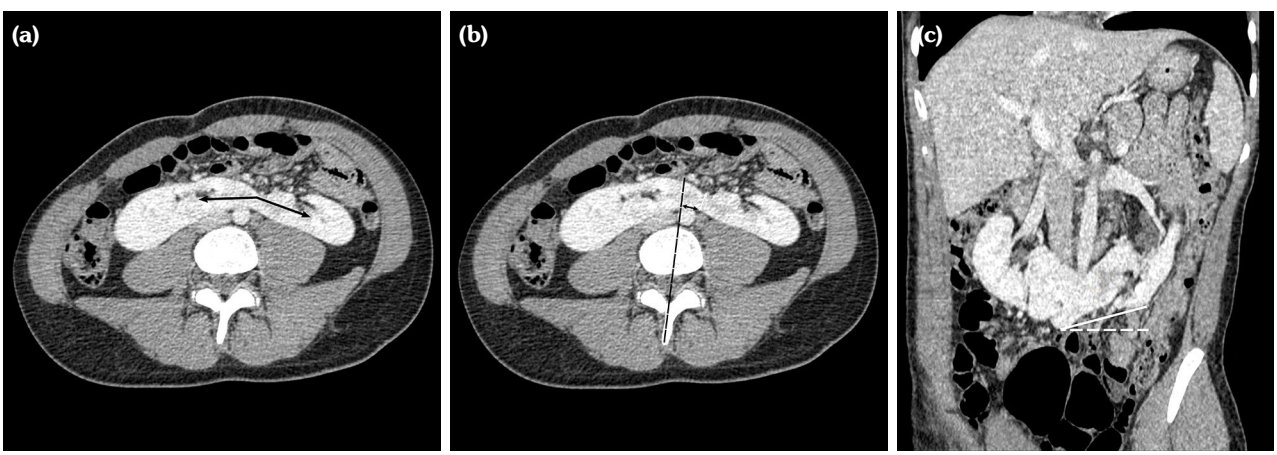


**Figure 3.** **(a)** Fusion angle, **(b)** isthmus width (white arrow) and midline shift (black arrow), and **(c)** fusion tilt angle.

**Table 1.** Measurements of horseshoe kidney (n=48)

| | Mean±SD | Min-Max |
|---|---|---|
| Isthmus thickness-AP | 15.7±4.9 | 5.00-25.80 |
| Isthmus width-CC | 37.8±11.9 | 14.80-64.80 |
| Midline shift | 13.5±9.6 | 1.00-54.00 |
| Fusion angle | 128.9±23.5 | 74.20-176.00 |
| Fusion tilt angle | 10.7±8.2 | 0.30-32.70 |
| Diaphragm distance | 150.6±24.4 | 76.80-197.00 |

SD: Standard deviation; AP: Anteroposterior; CC: Craniocaudal.

diaphragm in the HSK was determined to be 150.6±24.4 mm (Figure 5).

## DISCUSSION

The most common results in the HSK group in the current study were predominately male sex, anteromedial orientation, calculi in the right kidney, and L3-L4 level localized isthmus.

In the study conducted by Kawada et al.[6] in 106 HSK (36 with urolithiasis and 70 without

**Table 2.** Diameters of renal pelvis; angles between the renal pelvis and pol-pole with midline and horizontal lines

| | HSK patients (n=48) | Controls (n=20) | |
|---|---|---|---|
| | Mean±SD | Mean±SD | *p* |
| Right RP midline vertical angle | 24.0±11.4 | 51.0±15.3 | <0.0001 |
| Left RP midline angle | 22.4±12.6 | 50.9±14.1 | <0.0001 |
| Right pole-pole midline angle | 27.2±6.4 | 26.3±10.6 | 0.63 |
| Left pole-pole midline angle | 22.6±7.6 | 17.5±8.1 | <0.0001 |
| Right RP horizontal angle | 60.6±17.9 | 40.5±12.4 | <0.0001 |
| Left RP horizontal angle | 59.0±19.9 | 40.0±11.5 | <0.0001 |
| Right pole-pole horizontal angle | 55.0±16.3 | 62.5±10.6 | <0.0001 |
| Left pole-pole horizontal angle | 56.9±17.4 | 72.9±10.0 | <0.0001 |
| Right RP AP diameter | 8.5±6.3 | 4.3±1.9 | <0.0001 |
| Left RP AP diameter | 9.0±6.3 | 4.6±2.0 | <0.0001 |

SD: Standard deviation; RP: Renal pelvis; AP: Anteroposterior.

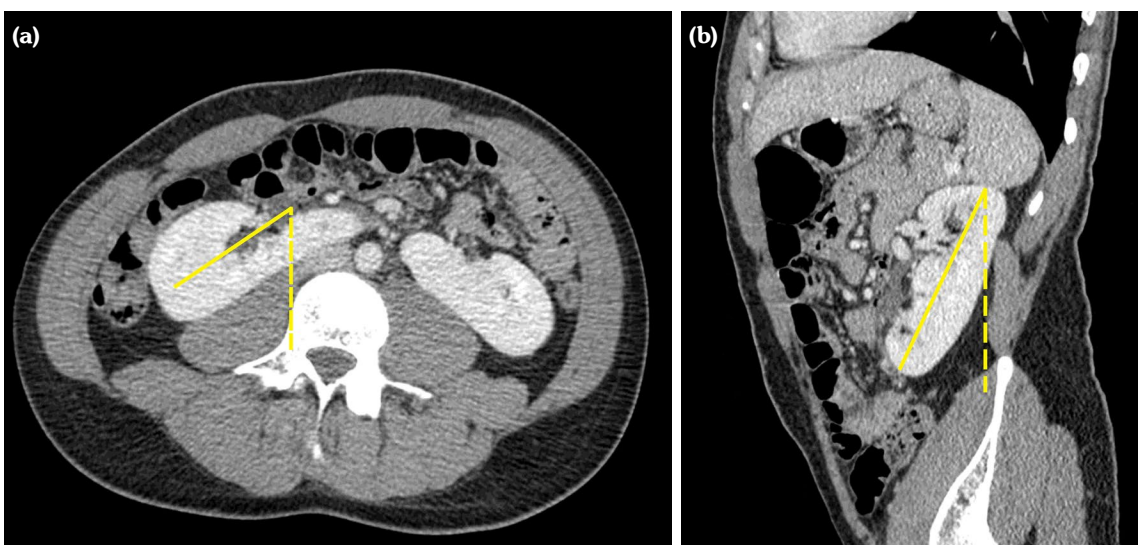


**Figure 4.** **(a)** Renal pelvis-midline angle, **(b)** pole-pole angle.

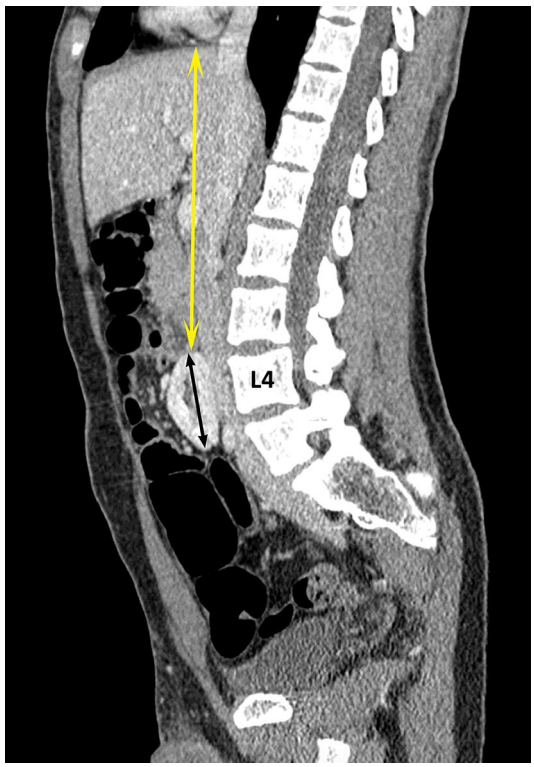


**Figure 5.** The location and length (black arrow) of the isthmus and its distance to the diaphragm (yellow arrow).

urolithiasis), the midline shift was mostly in the left kidney (n=71); it was found to be 59.1% (n=42) in the patients with urolithiasis and 32.3% (n=23) in the patients without urolithiasis. The minimum isthmus width was 11±5.6 mm in the patients with urolithiasis and 9.5±5.1 mm in the patients without urolithiasis. Similarly, in our study, the midline shift was mostly found in the left kidney, 46.2% (n=18, 14.0±7.8 mm) in the patients with calculi and 53.8% (n=21, 13.2±11 mm) in the patients without calculi. The minimum isthmus width was 5±4.3 mm (mean 16.6 mm) in the patients with calculus, and 5.3±5.3 mm (mean 15 mm) in the patients without calculus.

In studies conducted on HSK patients, the stone size varies between 8 mm and 2 cm,[7] and extracorporeal shock wave lithotripsy and ureteroscopy are applied to stones less than 2 cm.[8] In the literature to the best of our knowledge, there is no study in this regard studying the stone volume in HSK patients. In our study, the mean total calculus volume was found mainly in the right kidney as 3.14 $mm^3$ and the total density was 543.87 HU. However, there was no correlation between RPAs and calculus volume.

Glodny et al.[5] found the renal pelvis diameters to be 13.3 mm on the right and 12.2 mm on the left. The angles between the renal pelvis and the midline vertical axis in the axial plane were found to be 28.6 degrees on the right and 22.5 degrees on the left. The angles between the pole-pole and the vertical midline were 31.8 degrees on the right and 28.4 degrees on the left. In the current study, the renal pelvis diameters were 8.5±6.3 mm on the right side and 9.0±6.3 mm on the left side. Renal pelvis-midline vertical angles were 27.0±12.7 degrees on the right, and 23.3±12.1 degrees on the left; the angles between pole-pole and vertical midline were found to be 27.2±6.4 degrees on the right and 24.7±6.4 degrees on the left.

Similar to the current study, Al Otay et al.[9] conducted a retrospective evaluation of 144 patients with HSK during a 12-year period. Renal stones were detected in 28 patients (19.4%), The clinical presentation, prior stone management history, and preoperative stone size identified by radiologic modalities (ultrasound, intravenous pyelography, and CT) were all reviewed for all selected patients. As a guide for the intervention technique, the stone's maximum dimension was chosen. When there were numerous stones, the largest two stones' combined maximum dimensions were measured. When there were numerous stones, the largest two stones' combined maximum dimensions were measured. There were 25 patients with HSK (29 renal units), 16 men (64%), and nine women (36%), with a mean age of 37 years (2-78 years). Fourteen patients (56%) had stones in the left compartment, whereas seven patients (28%) had them in the right compartment, and four patients (16%) had bilateral renal stones. In our study, most of the stones were detected predominantly in the right kidney (n=8), followed by the left kidney and bilaterally (n=6). In addition, male patients (n=30) were more affected compared to female patients.

Nonetheless, the current study has several limitations. First, malignancies can be seen in

HSK patients. Due to the retrospective nature of the study, patients with HSK developing malignancy could not be followed up. Second, if the type of stone was identified, stratification and typing could be done.

In conclusion, horseshoe kidneys are usually asymptomatic, but gastrointestinal symptoms (such as abdominal pain, nausea, or vomiting) may be observed in these patients. Also, other pathologies such as renal calculi and hydronephrosis may accompany them. In this study, although there were significant differences in morphological parameters in the HSK group compared to the control group, no statistically significant correlation was found between calculus volume and RPAs.

**Ethics Committee Approval:** Approval of the Chief Physician of Tekirdağ Namık Kemal University Hospital has been obtained (date: 31.12.2020). The study was conducted in accordance with the principles of the Declaration of Helsinki.

**Patient Consent for Publication:** A written informed consent was obtained from each patient.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** Conceptualization, data curation, methodology, formal analysis, writing-original draft, writing-review & editing: H.S.; Formal analysis, critical review & editing: M.Ö., N.E.

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