

Evaluation of renal anomalies, inferior vena cava variations, and left renal vein variations by lumbar magnetic resonance imaging in 3000 patients

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Background/aim: The variations and anomalies of the kidneys besides the variations of the inferior vena cava (IVC) and left renal vein (LRV) are mostly asymptomatic, but they carry potential risks particularly during retroperitoneal surgery and radiological interventions. Our aim was to find the frequencies, types, and sex distribution of renal anomalies and variations of the IVC and LRV utilizing magnetic resonance imaging (MRI).

Materials and methods: Between November 2010 and April 2011, a retrospective study was conducted including lumbar spinal MRI of 3000 consecutive patients (1869 females and 1131 males) with a median age of 54 years (range: 9–78 years).

Results: The percentages of renal anomalies and variations of the IVC and LRV were 0.9%, 0.07%, and 2.6%, respectively. Sex did not affect the distribution of renal anomalies ($P = 0.2$), IVC variations ($P = 0.72$), or LRV variations ($P = 0.26$).

Conclusion: Lumbar spinal MRI is useful in detecting renal anomalies and variations of the IVC and LRV.

Key words: Magnetic resonance imaging, anatomy, cross-sectional, kidney, vena cava, inferior, renal veins

1. Introduction

Magnetic resonance imaging (MRI) can provide multiplanar images with high soft-tissue resolution without giving ionizing radiation to the patient. Hence, MRI is currently used for lumbar spinal imaging with the aim of evaluating spinal pathologies and low back pain (1,2). Routine use of MRI for low back pain and spinal pathologies has increased the frequency of identifying extraspinal findings (3).

While facilitating correct diagnosis in daily radiology practice, anatomical knowledge of anomalies and variations could help reduce complications of abdominal surgery and invasive radiological procedures. There are many variations and anomalies of the kidneys and the inferior vena cava (IVC) that are mostly asymptomatic but pose potential hazards to the surgeon, especially

during retroperitoneal surgery, aortic operations, and interventional radiology applications (4). Variations of the IVC and the left renal vein (LRV) are of clinical significance in the surgical planning before nephrectomy. More information about renal venous anatomy is required during laparoscopic donor nephrectomy, as the inspected area during laparoscopy is more limited than the area inspected during open nephrectomy. It is important for any pelvic surgeon performing abdominal lymphadenectomy to be familiar with the anomalies of the retroperitoneal vascular system (5,6). Recognizing IVC variations is crucial in preparing for invasive procedures, including liver transplantation (7). The purpose of this study was to figure out the frequencies and types of renal anomalies, IVC variations, and LRV variations by means of lumbar spinal MRI. The relationship of sex with these anomalies and variations was also evaluated.

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2. Materials and methods

2.1. Study design

We conducted a retrospective study including 3000 consecutive patients who were examined by routine lumbar spinal MRI for discopathy between November 2010 and April 2011. The study was performed in accordance with World Medical Association's Declaration of Helsinki (revised in 2000, Edinburgh). Written informed consent was obtained from each patient and parental consent was obtained for patients under 18 years of age. The study group consisted of 1869 female patients (62.3%) and 1131 male patients (37.7%) with a median age of 54 years (range: 9-78 years). Before collecting the data, all the researchers reached a consensus on how to recall the variations. Extraplural findings were classified as either congenital anomalies of the kidney or anatomical variations of the IVC or LRV. A renal anomaly was defined as an abnormal physical condition of one or both kidneys resulting from defective genes or developmental deficiencies. An IVC variation was defined as a marked difference or deviation of the IVC from the normal or recognized number, form, or location. A single preaortic LRV joining the IVC was described as a normal LRV. Left renal veins with preaortic and retroaortic courses and forming a collar around the abdominal aorta before joining the IVC at different levels were accepted as circumaortic left renal veins (CLRVs). A single renal vein crossing posteriorly to the abdominal aorta before joining the IVC was accepted as a retroaortic left renal vein (RLRV).

2.2. Imaging protocols

All MRI examinations were performed with a 1.5-T system (Philips Achieva, Philips Medical Systems, Eindhoven, the Netherlands) with the spine coil in a supine position. We obtained axial images starting from the L1 to L2 level and continued caudally (L2-L3, L3-L4, L4-L5, L5-S1). Routine T1-weighted and T2-weighted axial and sagittal images for intervertebral discs were evaluated and additional images were obtained only after detection of the mentioned congenital anomalies and anatomical variations, for verification. Lumbar spinal MRI consisted of sagittal T1W, sagittal T2W, and axial T2W images. In the present study, the parameters for lumbar spinal MRI were as follows: sagittal T1W (TR/TE, 400/9 ms; thickness/gap, 4/0.4 mm; NEX, 3; matrix, 225 × 524), sagittal T2W (TR/TE, 3000/120 ms; thickness/gap, 4/0.4 mm; NEX, 3; matrix, 225 × 524), and axial T2W (TR/TE, 3000/110 ms; thickness/gap, 4/0.4 mm; NEX, 3; matrix, 148 × 520).

2.3. Statistical analysis

Descriptive statistics were calculated for all IVC and LRV variations and for all renal anomalies. The relationships of sex with renal anomalies, IVC variations, and LRV variations were evaluated with the chi-square test and Fisher's exact test. $P < 0.05$ was considered statistically

significant. All analyses were performed with SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

3. Results

The number of cases with the correspondent percentage of renal anomalies was 27/3000 (0.9%), including unilateral renal agenesis ($n = 8/3000$, 0.3%), malrotation ($n = 6/3000$, 0.2%) (Figure 1), ectopia ($n = 7/3000$, 0.2%) (Figure 2), and horseshoe kidney ($n = 6/3000$, 0.2%) (Figure 3), respectively. The numbers of cases with the correspondent percentages of renal anomalies for females and males were 20/1869 (1.1%) and 7/1131 (0.6%), respectively ($P = 0.2$). The frequencies and distribution of renal anomalies by sex are given in Table 1. The detected IVC variations were left IVC variation ($n = 1$) (Figure 4) and double IVC variation ($n = 1$) (Figure 5). The number of cases with the correspondent percentage of detected IVC variations was 2/3000 (0.07%). Sex did not affect the distribution of IVC variations ($P = 0.72$). Variations of the LRV consisted of CLRV and RLRV. The number of cases with the correspondent percentages of the total LRV variations, CLRV, and RLRV (Figure 6) was 79/3000 (2.6%), 15/3000 (0.5%), and 64/3000 (2.1%), respectively. The numbers of female and male patients with all of the LRV variations and their correspondent percentages were 54/3000 (1.8%) and 25/3000 (0.8%), respectively. The percentage of total LRV variations in the female patient group was 2.9% and in the male patient group it was 2.2% ($P = 0.26$). Sex had no effect on either LRV variation ($P = 0.56$ and $P = 0.15$, respectively). Frequencies and distribution of LRV variations are given in Table 2.

4. Discussion

Embryologically, the kidneys arise in the pelvic region, but they ascend to the lumbar region over time (8). If any disruption occurs in the developmental process,

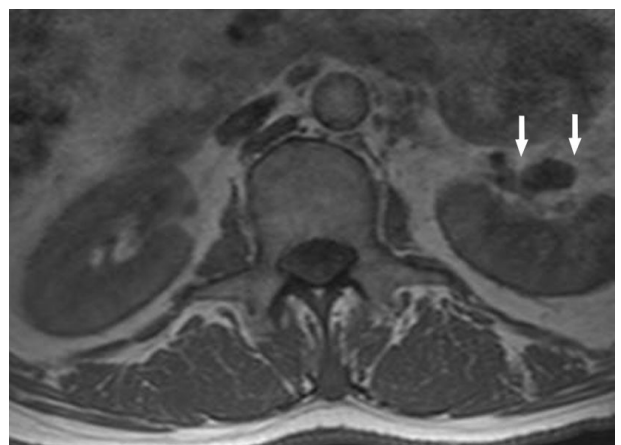


Figure 1. Axial T2-weighted image shows malrotation of the kidney on the left side (arrows).

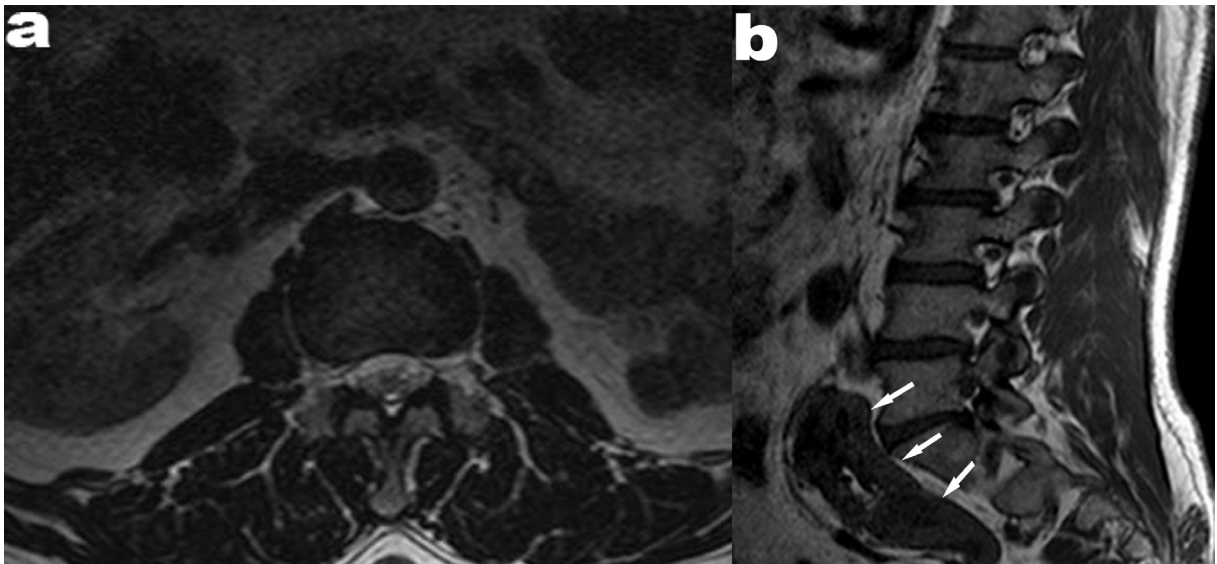


Figure 2. Axial T2-weighted image reveals a missing kidney on the left side (a). Sagittal T2-weighted image shows a renal ectopia anterior to the vertebral bodies on the left side of the pelvic region (arrows) (b).

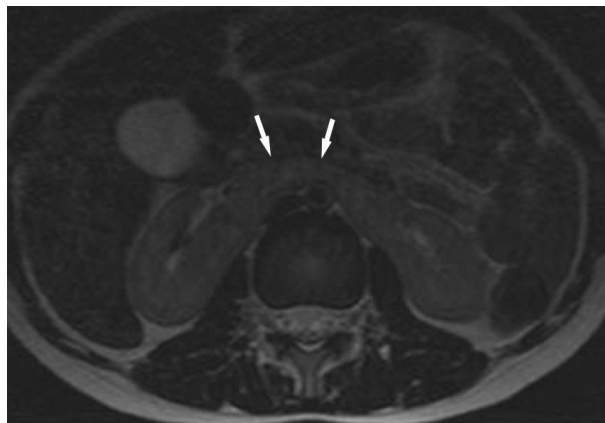


Figure 3. Axial T2-weighted image shows horseshoe kidney (arrows: connecting bridge of renal parenchyma anterior to the abdominal aorta).

Table 1. Frequency and distribution of renal anomalies based on sex.

Renal anomalies	Females (n = 1869), n of patients (%)	Males (n = 1131), n of patients (%)	Total (n = 3000), n of patients (%)
Unilateral renal agenesis	7 (0.4%)	1 (0.1%)	8 (0.3%)
Renal ectopia	6 (0.3%)	1 (0.1%)	7 (0.2%)
Horseshoe kidney	3 (0.2%)	3 (0.3%)	6 (0.2%)
Renal malrotation	4 (0.2%)	2 (0.2%)	6 (0.2%)
Total	20 (1.1%)	7 (0.6%)	27 (0.9%)

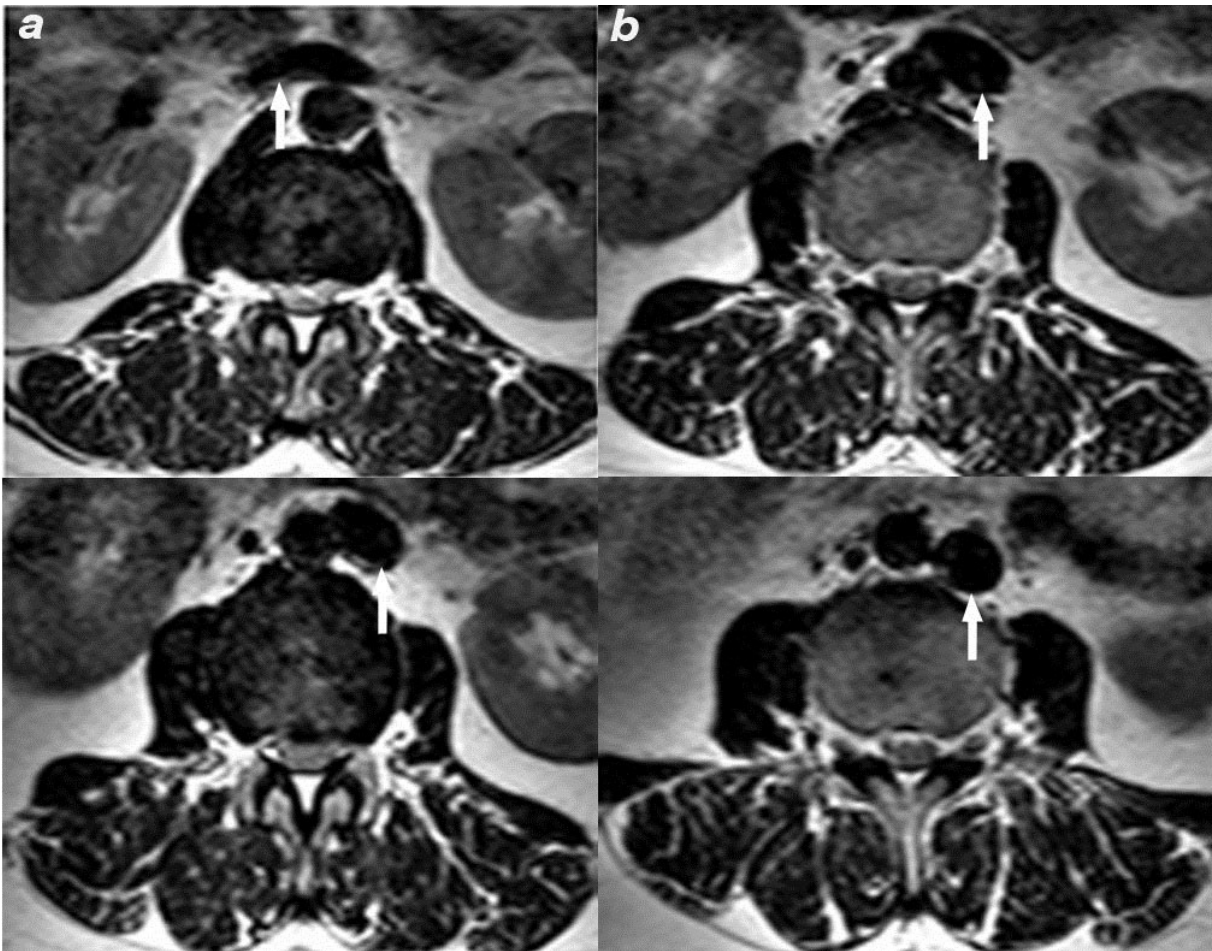


Figure 4. Axial T2-weighted images demonstrate the course of the left inferior vena cava (arrows) on the left side of the abdominal aorta.

the following anomalies are observed: bilateral renal agenesis (0.0025%–0.025%), unilateral renal agenesis (0.1%–0.025%), malrotation, and renal ectopia (0.07%–1%) (9). In a previous study, postmortem examination of cadavers revealed that renal agenesis occurred mostly in males. The sex difference could be explained by the higher number of male cadavers that underwent autopsy (10). However, in our study, it was interesting to see that the majority of renal agenesis was observed in female patients ($n = 7/8$). The exact prevalence of renal malrotation is unknown due to limited literature. Case studies of renal anomalies have emphasized that the renal hilum is usually displaced laterally, which is especially important for donor nephroureterectomies (11,12). In our study, we found renal malrotation in both the right and left kidneys of six patients ($n = 6/3000$, 0.2%). The kidneys, sometimes outside the normal anatomic position (ectopic kidneys), can be located in the pelvic, abdominal, or thoracic regions, or on the contralateral side (13–15), and are more

frequently found on the left side than on the right side (16). Ectopic kidneys have a reported frequency of 0.2% to 0.9%. Most commonly, one kidney is normal and the other is located in the pelvic region (0.03%), while ectopic thoracic kidney (0.008%) is the least common (9). In our study, it was interesting to notice that besides six female patients with ectopic kidneys, only one male patient had an ectopic kidney. Horseshoe kidney is a relatively common renal fusion anomaly found in 0.25% of the general population and observed twice as frequently in males as in females (17). In our study, we observed horseshoe kidney in three female patients and three male patients, with no statistically significant difference between the sexes.

The duplication of the IVC results from persistence of both supracardinal veins (18,19). The percentages for duplication of the IVC and left IVC were reported as 0.2%–3% and 0.2%–0.5%, respectively (18,20). In a computed tomography (CT) study of 1120 patients, the rate of left IVC variation was found to be 0.1% (19). In our study, we

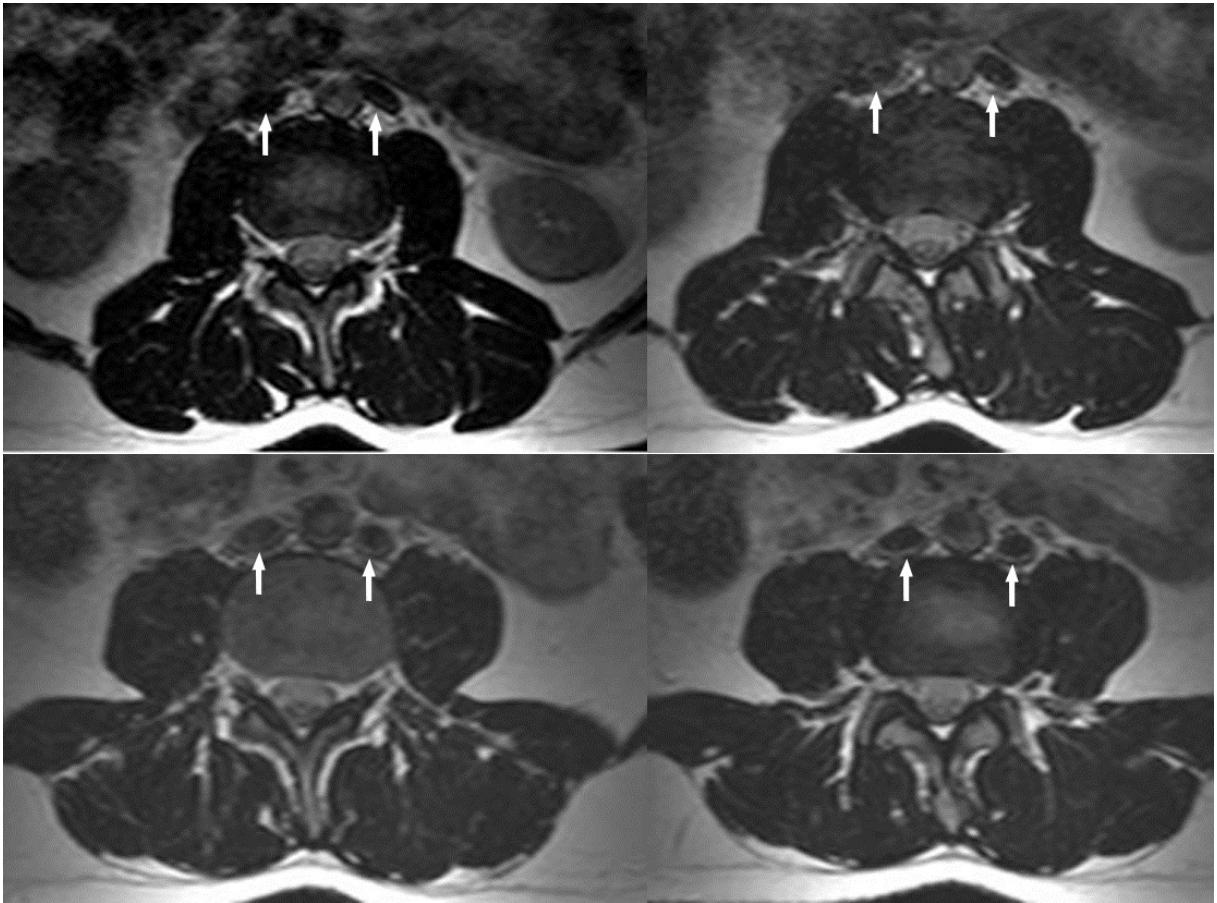


Figure 5. Axial T2-weighted images show the course of the double inferior vena cava (arrows) on both sides of the abdominal aorta.

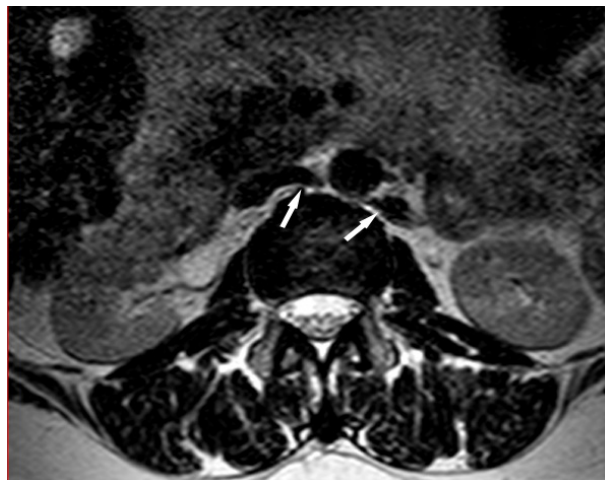


Figure 6. Axial T2-weighted image demonstrates the retroaortic left renal vein (arrows).

Table 2. Frequency and distribution of left renal vein variations based on gender.

Left renal vein variations	Females (n = 1869), n of patients (%)	Males (n = 1131), n of patients (%)	Total (n = 3000), n of patients (%)
Retroaortic left renal vein variations	42 (2.25%)	22 (1.9%)	64 (2.1%)
Circumaortic left renal vein variations	12 (0.6%)	3 (0.2%)	15 (0.5%)
Total	54 (2.9%)	25 (2.2%)	79 (2.6%)

found left IVC in one patient (0.03%) and double IVC in one patient (0.03%).

Circumaortic left renal vein duplication results from persistence of the dorsal limb of the embryonic LRV and the dorsal arch of the intersupracardinal anastomosis (21). There are two LRVs in a CLRV variation. The superior renal vein connects with the left adrenal vein and crosses anteriorly to the aorta. The inferior renal vein connects with the left gonadal vein and crosses posteriorly to the aorta. The prevalence of CLRV duplication may be as high as 8.7% (18,22). Retroaortic left renal vein results from persistence of the dorsal arch of the intersupracardinal anastomosis. The intersubcardinal anastomosis (ventral arch) regresses; therefore, a single renal vein passes posteriorly to the abdominal aorta (21). Some studies reported the prevalence of RLRV as 2.1% (18,22). Another study conducted by Yeşildağ et al. (23) revealed the incidences of RLRV and CLRV as 2.3% and 0.9%, respectively. Yagci et al. (24) also stated the prevalence of RLRV as 2.9%. The frequencies in the present study are within the range of the above-mentioned studies, which helped us compare other imaging modalities with MRI and led us to conclude that MRI can be used in the evaluation of the left renal vein and its variations.

We did our best to recruit patients from both sexes homogeneously. Unfortunately, since nearly 2/3 of our patients who were referred to MRI for lumbar pain were female (mostly due to obesity, osteoporosis, menopause, etc.), and because we had to include our patients consecutively without eliminating any of them so as not to cause any bias, such a patient profile was unavoidable. Though the anatomical resolution and contrast resolution of our MRI images are superior to those of most other imaging modalities, still the main limitation of the present study is our being unable to verify MRI images of left renal vein variations with other imaging modalities. For the demonstration of LRV variations, renal venograms (25), contrast-enhanced CT (23,26,27), color Doppler US (24,28), magnetic resonance angiography (MRA) (29), and [¹⁸F]-2-fluoro-2-deoxy-D-glucose (FDG)-positron emission tomography (PET)/CT (30) have been used. Computed tomography is a preferable imaging modality in the evaluation of abdominal venous vascular structures

since it is relatively less costly, fast, easily applicable, and reliable in terms of patient compliance (31,32). However, CT has long-term risks of ionizing radiation and patients are exposed to a significant amount of iodinated intravenous contrast medium, which has potential side effects (33). Using PACS, the frequency of IVC variations and LRV variations can reliably be studied retrospectively by reevaluating the contrast-enhanced spiral abdominal CT images of the patients who readily underwent CT examination due to various abdominal problems (34). However, because of the above-mentioned risks, optional and additional CT imaging is inappropriate for only the verification of MRI images in such frequency studies. This was the reason why we strictly avoided performing CT to verify our results. Since our patients were not primarily oncology patients but were those who underwent routine lumbar spinal MRI for discopathy, and because of the risks of ionizing radiation as mentioned above, we also could not use FDG-PET/CT for verification. Unlike CT, no ionizing radiation or iodinated contrast medium is used in MRI, and the image quality (anatomical resolution) was comparable to CT, although MRI is rather costly and requires longer imaging time compared to CT. Instead of CT, additional MRI images were obtained when necessary (only after detection of any congenital anomalies and anatomical variations). Color Doppler US is usually unreliable in obese patients because of its insufficiency in this patient group (35). This is the main reason why we did not rely on the records of the patients who underwent color Doppler US in the present study. According to medical records we noticed that not all of our patients underwent gray-scale US, so we could not use US to verify renal anomalies, which can be accepted as another limitation of our study. We also could not use MRA in order to verify our results because our study was basically a retrospective study without routine use of MRA and it was based largely on MRI sequences, which were already being applied during routine lumbar spinal MRI examinations. Additionally, we have to mention that the plane of the axial MR images (T2-weighted) that we obtained in routine lumbar spinal MRI examinations were limited only to intervertebral disc spaces (not continuous), as is the case in most centers. This situation is still accepted as a technical limitation of

our study and might have caused some influence on the frequencies of the variations of the IVC and LRV. Though the sagittal images for the intervertebral discs besides further imaging for verification of a suspected renal anomaly helped increase the utility of lumbar MRI, we also accept noncontinuous axial imaging as a technical limitation for the detection of the whole spectrum of renal anomalies.

In conclusion, routine lumbar spinal MRI is useful in detecting renal anomalies, IVC variations, and LRV variations. MRI provides excellent anatomical detail and it is a relatively safe method, since no iodinated contrast material or ionizing radiation is used. Careful evaluation

of routine lumbar spinal MRI will contribute to the overall clinical evaluation of patients and will reduce the likelihood of development of complications during surgery or radiological interventions.

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References

1. Chou R, Qaseem A, Owens DK, Shekelle P; Clinical Guidelines Committee of the American College of Physicians. Diagnostic imaging for low back pain: advice for high-value health care from the American College of Physicians. *Ann Intern Med* 2011; 154: 181-189.
2. Gundry CR, Fritts HM. Magnetic resonance imaging of the musculoskeletal system. Part 8. The spine, section 1. *Clin Orthop Relat Res* 1997; 338: 275-287.
3. Berlin L. The incidentaloma: a medicolegal dilemma. *Radiol Clin North Am* 2011; 49: 245-255.
4. Bartle EJ, Pearce WH, Sun JH, Rutherford RB. Infrarenal venous anomalies and aortic surgery: avoiding vascular injury. *J Vasc Surg* 1987; 6: 590-593.
5. Matthews R, Smith PA, Fishman EK, Marshall FF. Anomalies of the inferior vena cava and renal veins: embryologic and surgical considerations. *Urology* 1999; 53: 873-880.
6. Costa HC, Moreira RJ, Fukunaga P, Fernandes RC, Boni RC, Matos AC. Anatomic variations in vascular and collecting systems of kidneys from deceased donors. *Transplant Proc* 2011; 43: 61-63.
7. Katsanos KH, Christodoulou D, Kalampokis G, Tsianos EV, Theodorou SJ, Tsampoulas C, Xeropotamos N. Radiological evidence of double inferior vena cava in two patients with liver function abnormalities. *Eur J Intern Med* 2009; 20: e17.
8. Sadler TW. Langman's Medical Embryology. 8th ed. Philadelphia, PA, USA: Lippincott Williams & Wilkins Publishers, 2000.
9. Belsare SM, Chimmalgi M, Vaidya SA, Sant SM. Ectopic kidney and associated anomalies: a case report. *J Anat Soc India* 2002; 51: 236-238.
10. Campbell MF. Congenital absence of one kidney: unilateral renal agenesis. *Ann Surg* 1928; 88: 1039-1044.
11. Atasever A, Çelik HH, Durgun B, Yılmaz E. Unrotated left kidney associated with an accessory renal artery. *J Anat* 1992; 18: 507-508.
12. Ingole IV, Ghosh SK. Laterally rotated kidney—A rare congenital anomaly. *J Anat Soc India* 2005; 54: 19-21.
13. Thompson GJ, Pace JM. Ectopic kidney. A review of 91 cases. *Surg Gynecol Obstet* 1937; 64: 935-943.
14. Sharp RJ. Developmental anomalies of the kidney. In: Ashcraft KW, editor. *Pediatric Urology*. Philadelphia, PA, USA: W.B. Saunders; 1990. pp. 77-116.
15. Perlmutter AD, Retik AB, Bauer SB. Anomalies of the upper urinary tract. In: Walsh PC, Gittes RF, Perlmutter AD, Stamey TA, editors. *Campbell's Urology*. 5th ed. Philadelphia, PA, USA: W.B. Saunders; 1986. pp. 1665-1741.
16. Kara E, Ozturk NC, Ozgur A, Yildiz A, Ozturk H. Ectopic kidney with varied vasculature: demonstrated by CT angiography. *Surg Radiol Anat* 2011; 33: 81-84.
17. Faggioli G, Freyrie A, Pilato A, Ferri M, Curti T, Paragona O, D'Addato M. Renal anomalies in aortic surgery: contemporary results. *Surgery* 2003; 133: 641-646.
18. Phillips E. Embryology, normal anatomy, and anomalies. In: Ferris EJ, Hipona FA, Kahn PC, Phillips E, Shapiro JH, editors. *Venography of the Inferior Vena Cava and Its Branches*. Baltimore, MD, USA: Williams & Wilkins; 1969. pp. 1-32.
19. Koc Z, Ulusan S, Oguzkurt L, Tokmak N. Venous variants and anomalies on routine abdominal multi-detector row CT. *Eur J Radiol* 2007; 61: 267-278.
20. Minniti S, Visentini S, Procacci C. Congenital anomalies of the venae cavae: embryological origin, imaging features and report of three new variants. *Eur Radiol* 2002; 12: 2040-2055.
21. Strauss A, Kuemper C, Mundhenke C, Schaefer F, Jonat W, Hilpert F. Congenital retroperitoneal vascular anomalies: impact on pelvic surgery. *Arch Gynecol Obstet* 2011; 284: 1169-1173.
22. Bass JE, Redwine MD, Kramer LA, Huynh PT, Harris JH Jr. Spectrum of congenital anomalies of the inferior vena cava: cross-sectional imaging findings. *Radiographics* 2000; 20: 639-652.

23. Yeşildağ A, Adanır E, Köroğlu M, Baykal B, Uyar O, Gülsoy UK. Incidence of left renal vein anomalies in routine abdominal CT scans. *Tani Girişim Radyol* 2004; 10: 140-143 (in Turkish with abstract in English).
24. Yagci B, Tavasli B, Karabulut N, Kiroglu Y. Clinical significance and renal haemodynamics of incidentally detected retroaortic left renal vein: assessment with venous Doppler sonography. *Br J Radiol* 2008; 81: 187-191.
25. Satyapal KS, Kalideen JM, Haffejee AA, Singh B, Robbs YV. Left renal vein variations. *Surg Radiol Anat* 1999; 21: 77-81.
26. Karaman B, Koplay M, Ozturk E, Basekim CC, Ogul H, Mutlu H, Kizilkaya E, Kantarci M. Retroaortic left renal vein: multidetector computed tomography angiography findings and its clinical importance. *Acta Radiol* 2007; 48: 355-360.
27. Ayaz ÜY, Dilli A, Tüzün ÖM, Hekimoğlu B. Retroaortic left renal vein: CT images: original image. *Turkiye Klinikleri J Cardiovasc Sci* 2011; 23:161-164.
28. Cheon JE, Kim WS, Kim IO, Kim SH, Yeon KM, Ha IS, Cheong HI, Choi Y. Nutcracker syndrome in children with gross haematuria: Doppler sonographic evaluation of the left renal vein. *Pediatr Radiol* 2006; 36: 682-686.
29. Wang DS, Stolpen AH, Bird VG, Ishigami K, Rayhill SC, Winfield HN. Correlation of preoperative three-dimensional magnetic resonance angiography with intraoperative findings in laparoscopic renal surgery. *J Endourol* 2005; 19: 193-199.
30. Ayaz S, Ayaz ÜY. Detection of retroaortic left renal vein and circumaortic left renal vein by PET/CT images to avoid misdiagnosis and support possible surgical procedures. *Hell J Nucl Med* 2016; 19: 135-139.
31. Rastogi N, Sahani DV, Blake MA, Ko DC, Mueller PR. Evaluation of living renal donors: accuracy of three-dimensional 16-section CT. *Radiology* 2006; 240: 136-144.
32. Raman SS, Pojchamarnwiputh S, Muangsomboon K, Schulam PG, Gritsch HA, Lu DS. Surgically relevant normal and variant renal parenchymal and vascular anatomy in preoperative 16-MDCT evaluation of potential laparoscopic renal donors. *AJR Am J Roentgenol* 2007; 188: 105-114.
33. Piechowiak EI, Peter JF, Kleb B, Klose KJ, Heverhagen JT. Intravenous iodinated contrast agents amplify DNA radiation damage at CT. *Radiology* 2015; 275: 692-697.
34. Dilli A, Ayaz UY, Kaplanoğlu H, Saltas H, Hekimoglu B. Evaluation of the left renal vein variations and inferior vena cava variations by means of helical computed tomography. *Clin Imaging* 2013; 37: 530-535.
35. Karaman B, Koplay M, Ozturk E, Basekim CC, Ogul H, Mutlu H, Kizilkaya E, Kantarci M. Retroaortic left renal vein: multidetector computed tomography angiography findings and its clinical importance. *Acta Radiol* 2007; 48: 355-260.