



Retroaortic left renal vein and its new Variations: Triple retroaortic and circumiliac left renal veins

Ukrit Rompsaithong¹, Pattama Amarttayakong², Jaturat Kanpittaya³, Arada Chaiyamoorn⁴ and Sukrit Sangkhano^{5,*}

¹Department of Surgery, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

²Faculty of Medicine, Mahasarakham University, Maha Sarakham, Thailand

³Department of Radiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

⁴Department of Anatomy, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

⁵School of Public Health, Walailak University, Nakhon Si Thammarat, Thailand

*Corresponding author: sukrit.sa@mail.wu.ac.th

Received 17 July 2021

Revised 13 September 2021

Accepted 31 October 2021

Abstract

Variations of renal veins are important in urology and other areas of medicine. The purpose of this study was to evaluate the prevalence and type of retroaortic left renal vein (RLRV) in patients who underwent multidetector computed tomography (MDCT). Between January 2010 and December 2019, a retrospective study was performed on 4,424 patients examined with abdominal MDCT. The prevalence and type of RLRV were determined. Age, gender, indications for imaging, and symptoms related to the variants of renal venous anatomy were recorded. MDCT images revealed RLRV in 84 of 4,424 patients (1.90% [95% cumulative incidence (CI) 1.52–2.34%]). These included 44 males (52.38%) and 40 females (47.62%). The average age of patients with RLRV was 58.29 ± 12.45 years (range, 19–88 years). RLRV types I, II, III, and IV had a distribution of 34 (0.77%), 1 (0.02%), 45 (1.02%), and 0 (0%), respectively. The extremely rare double RLRV was additionally detected in 2 cases (0.05%). Two new variations, 1 case (0.02%) with the triple RLRV and 1 case (0.02%) with the circumiliac left renal vein, were discovered. None of the patients had symptoms related to renal vein variations. Congenital anomaly of RLRV is clinically important in the investigation and exploration of retroperitoneal procedures. Therefore, preoperative imaging should be carefully considered to avoid fatal problems during surgery. To the best of our knowledge, this is the first study that reports two new variations of the left renal vein, that is, the triple RLRV and the circumiliac left renal vein.

Keywords: Retroaortic left renal vein, Double retroaortic left renal vein, Triple retroaortic left renal vein, Circumiliac left renal vein, Computed tomography

1. Introduction

Left renal veins are usually single and located anterior to the aorta. Because of the highly complicated embryological development of the left renal vein, there are numerous clinically significant variations [1]. Among the numerous variations of the left renal vein, the retroaortic left renal vein (RLRV) is the most common reported variance. According to previous studies, the prevalence of RLRV has been reported to be 0.5–3.7% [1–5]. It is an anomaly characterized by the presence of the left renal vein passing behind the aorta to join the inferior vena cava (IVC).

It is critical to understand the anatomy and congenital defects of the renal vein for retroperitoneal surgery, such as radical nephrectomy, living-related kidney transplantation, and procedure for an abdominal aortic aneurysm [1,6–10]. Inadvertent injury to these venous anomalies can result in severe hemorrhage, nephrectomy, and even death [7,11]. In addition, it may also provide safety guidelines for endovascular procedures, such as renal venography, renal venous renin sampling, adrenal venous sampling, spermatic vein embolization, and IVC

filter placement [12]. Compression of the RLRV between the aorta and the vertebra is termed the posterior nutcracker phenomenon [3,13]. It causes venous hypertension and subsequent urological problems, such as hematuria, varicocele, pelvic congestion syndrome, and ureteropelvic junction obstruction [3,13-17].

Since renal veins are sometimes neglected, cadaveric studies were one of the main sources of information about these developmental variations [1,4,5]. The role of conventional angiographic study has been challenged by recent advances in multidetector computed tomography (MDCT) angiography, which has become a principal imaging technique for assessing renal vasculature. It is a fast and noninvasive method that enables a highly accurate and detailed evaluation of normal renal vascular structure and variations, such as the number, size, and course of the renal arteries and veins [2-4,18,19].

This study aimed to investigate the prevalence and types of RLRV in Thai patients examined in the abdominal region with MDCT.

2. Materials and methods

This study is a ten-year retrospective study of patients examined with abdominal MDCT at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, between January 2010 and December 2019. The protocol was performed from the diaphragm down to the level of the pubic symphysis, and then angiography was rendered on a dual-source CT scanner (Siemens SOMATOM Definition Flash, Malvern, PA, USA). Images of each case were reviewed to identify the RLRV by one radiologist who had experience in interpreting genitourinary system imaging.

The RLRV in this study was categorized following previous studies into four types [2,19]. Type I is the left renal vein passing behind the abdominal aorta and joining the IVC in the orthotopic position. Type II is a single RLRV joining the IVC at the level of L4-L5. Type III is the circumaortic or collar left renal vein, which consists of two left renal veins. The superior vein passes at the usual level in front of the aorta, whereas the inferior vein runs downward and medially behind the aorta and drains into the IVC [20]. Type IV is the lowest RLRV coursing obliquely and caudally behind the aorta before joining the left common iliac vein.

The prevalence and types of RLRV were determined. Age, gender, indications for imaging, and symptoms related to these variants of the renal venous anatomy were anonymously recorded.

3. Results

A total of 4,424 patients with an average age of 57.28 ± 13.71 years (range, 18–94 years) were examined with MDCT. There were 2,391 males (54.05%) and 2,033 females (45.95%). MDCT images revealed the RLRV in 84 of 4,424 patients (1.90% [95% cumulative incidence (CI) 1.52–2.34%]). These included 44 males (52.38%) and 40 females (47.62%). The average age of patients with the RLRV was 58.29 ± 12.45 years (range, 19–88 years). The distribution and prevalence among the types I, II, III, and IV of the RLRV were 34 (0.77%), 1 (0.02%), 45 (1.02%), and 0 (0%), respectively (Table 1) (Figure 1A-C). The extremely rare double RLRV was additionally detected in 2 cases (0.05%) (Figure 1D). Two new variations were also discovered. The triple RLRV was found in 1 female case (0.02%), which had two upper veins joining into the IVC in the orthotopic position and at the level of L4–L5 and one lower vein joining into the left common iliac vein (Figure 1E). The circumiliac left renal vein, together with the normal left renal vein, was discovered in 1 female case (0.02%) (Figure 2). In addition, IVC anomalies were found in 19 (0.43%) cases. Of these, 14 (0.31%) cases had duplicated IVC and 5 (0.11%) cases had left-sided IVC.

Table 1 The distribution and the prevalence among the types of retroaortic left renal vein.

Type	Total	Prevalence (%), <i>N</i> = 4,424	Gender (M : F)	Age (years, mean \pm SD)
Overall RLRV	84	1.90	44:40	58.29 \pm 12.45
- Type I	34	0.77	17:17	58.65 \pm 14.52
- Type III	45	1.02	25:20	59.16 \pm 9.61
- Double RLRV	2	0.05	1:1	43.37 \pm 7.34
- Type II	1	0.02	1:0	75
- Triple RLRV*	1	0.02	0:1	27
- Circumiliac left renal vein*	1	0.02	0:1	49
- Type IV	0	0	0	0

RLRV, retroaortic left renal vein.

*New variations.

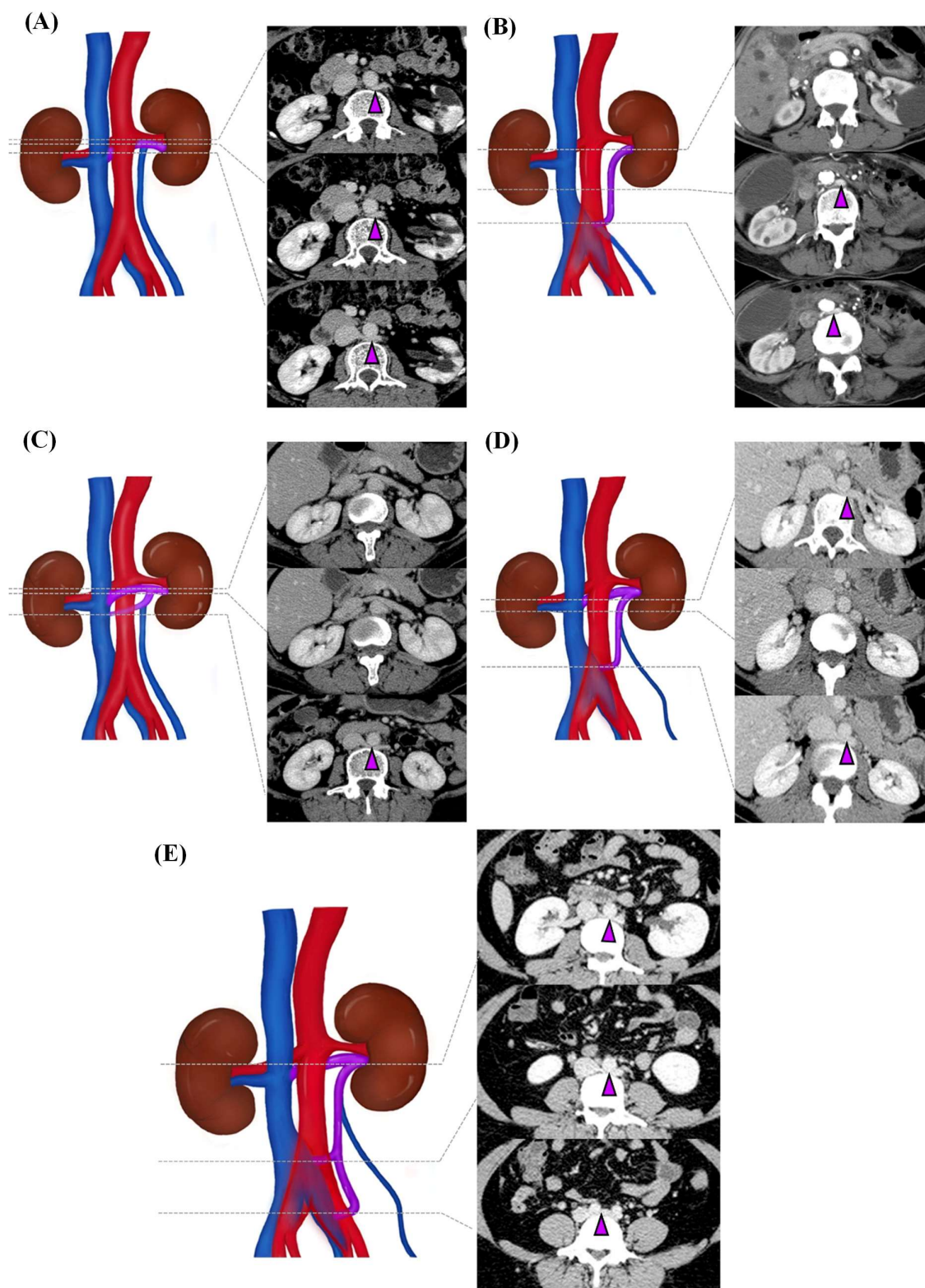


Figure 1 Drawings and relevant computed tomography (CT) images of the retroaortic left renal vein (RLRV). The RLRV was labeled in purple on the drawing and was indicated by a purple arrowhead on the CT image; type I RLRV (A), type II RLRV (B), type III circumaortic vein (C), double RLRV (D), and triple RLRV (E).

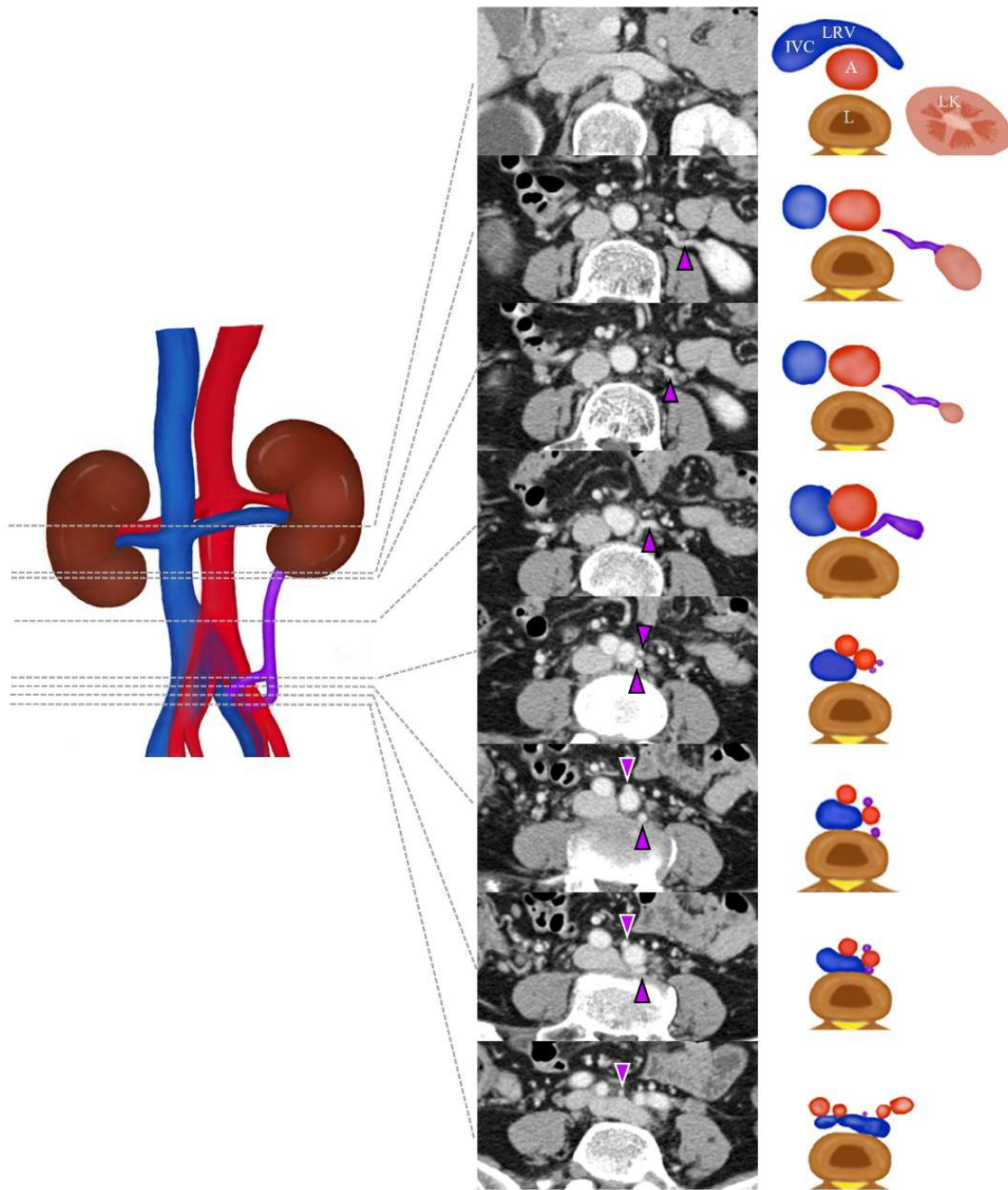


Figure 2 Drawings and relevant computed tomography (CT) images of the circumiliac left renal vein. The circumiliac left renal vein was labeled in purple on the drawing and was indicated by a purple arrowhead on the CT image. A, aorta; IVC, inferior vena cava; LRV, left renal vein; L, lumbar vertebra; LK, left kidney.

The indications for imaging of the 84 patients with the RLRV were hepato-pancreato-biliary diseases of 33 patients (39.29%), gastrointestinal problems of 18 patients (21.43%), gynecology of 11 patients (13.10%), urology of 7 patients (8.33%), and the other indications of 15 patients (17.86%) (Table 2). None of the patients underwent any surgery or intervention involving the renal vein.

The clinical symptoms of the posterior nutcracker phenomenon related to venous hypertension, such as hematuria, varicocele, pelvic congestion syndrome, and ureteropelvic junction obstruction, were not detected.

Table 2 Indications for imaging of the patients with the retroaortic left renal vein.

Indications for imaging	Total (%) <i>n</i> = 84
Hepato-pancreato-biliary diseases	33 (39.29%)
Gastrointestinal problems	18 (21.43%)
Gynecology	11 (13.10%)
Urology	7 (8.33%)
Others	15 (17.86%)

4. Discussion

Our study determined the prevalence and types of RLRV using MDCT in a large population. The prevalence of RLRV in this study was 1.90% (95% CI 1.52–2.34%), consistent with the previous studies of approximately 0.5–3.7% on cadaveric dissections, intraoperative findings, and cross-sectional imaging [1-5].

The most common type was type III or circumaaortic (1.02%), followed by type I (0.77%) and type II (0.02%). We could not detect type IV at all. These results were not similar to those of Karaman's study, in which types I, II, III, and IV were 0.014%, 0.012%, 0.009%, and 0.002%, respectively [2].

The formation of renal veins is part of the complex developmental process of IVC, which begins during the fourth week until the eighth week of fertilization. The posterior cardinal, subcardinal, and supracardinal veins are the three prominent parallel veins forming the IVC portions [21]. During IVC development, the circumaaortic collar is established by subcardinal and supracardinal anastomotic communications (Figure 3A). The collar consists of the ventral or preaaortic limb and the dorsal or retroaortic limb encircling the abdominal aorta. Finally, the retroaortic limb is obliterated, but the preaaortic limb persists to become the normal left renal vein (Figure 3 (B)) [14,19,21,22].

Type I RLRV results from preaaortic limb obliteration and the persistence of the retroaortic limb joining the IVC orthotopically (Figures 1A and 3C) [20,21]. Type III, the circumaaortic left renal vein, develops from the remaining of both preaaortic and retroaortic limbs of the collar (Figures 1C and 3E) [20,23]. In addition to the retroaortic limb of the circumaaortic collar, there are other dorsal anastomoses of the supracardinal veins, such as types II and IV. Type II is the obliteration of the preaaortic limb and remaining dorsal anastomosis at the level of L4–L5 before joining the IVC (Figures 1B and 3D), whereas dorsal anastomosis of type IV joins the left common iliac vein (Figure 3F) [19].

Our study also detected the tremendously rare left renal vein variation giving off double retroaortic branches as the result of type I together with type II (Figures 1D and 3G) [14,24]. Moreover, we found two new variations. The triple RLRV combines the features of types I, II, and IV with the lower branch joining the left common iliac vein (Figures 1 (E) and 3 (H)). The circumiliac left renal vein arises from the renal inferior polar and runs downward and medially to give off two branches surrounding the left common iliac artery before joining the left common iliac vein (Figure 2).

The posterior nutcracker phenomenon is the entrapment of RLRV between the aorta and the vertebral column. When symptoms arise, they are called posterior nutcracker syndromes [3,25]. According to literature reviews, symptoms of elevated renal venous pressure are rarely seen [2,3]. Nishimura et al. reported that left renal vein hypertension was defined by a pressure gradient between the left renal vein and the IVC greater than 3.0 mmHg [26]. Urological symptoms, especially hematuria, were commonly found in types II and IV, assumed by excessive renal vein compression on these types [2]. The low crossing of type II could cause ureteropelvic junction obstruction [19]. Other symptoms have been reported, including pelvic congestion syndrome and varicocele. Two cases of double RLRV were diagnosed with pelvic congestion syndrome presenting with chronic pelvic pain and varicose veins around the pelvic organs [14]. Patients with the RLRV demonstrated the presence of varicocele by scrotal Doppler ultrasound [1]. Our study did not observe the clinical symptoms associated with renal venous hypertension in any patient, probably due to the small number of type II and IV patients.

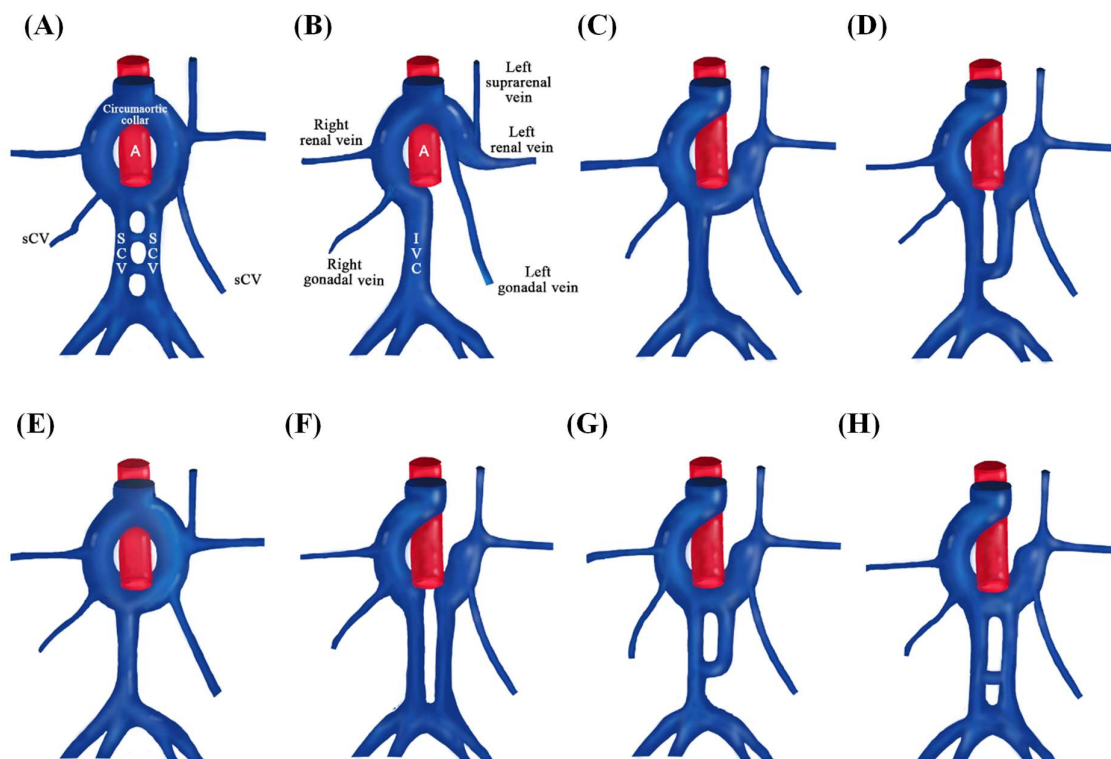


Figure 3 Drawings of renal vein development modified from [24]. Circumaortic collar at week 8 of embryogenesis (A), normal development of the renal veins (B), type I retroaortic left renal vein (RLRV) (C), type II RLRV (D), type III circumaortic vein (E), type IV RLRV (F), double RLRV (G), and triple RLRV (H). A, aorta; sCV, subcardinal vein; SCV, supracardinal vein.

Among the various indications of imaging, we did not find any procedures involving the renal vein. However, our report may contribute to expanding knowledge of retroperitoneal anatomy due to the rarity of each variant. Recognizing the variations in RLRV would be particularly helpful because if not taken into account, it could lead to injury and complications during the procedure, resulting in life-threatening consequences.

Our study had several limitations. First, it was a retrospective review; the data in the medical records may not identify the specific symptoms of the posterior nutcracker, especially those whose symptoms were not obvious. Second, a relatively small proportion of urologic patients may not experience significant urinary tract symptoms or not have enough renal vein procedures. Therefore, further studies should be performed in symptomatic patients to evaluate vascular pathophysiology and determine the relationship between the renocaval pressure gradient and the compression ratio of the venous lumen.

5. Conclusion

Knowing the location of the left renal vein joining the IVC compared with the level of lumbar vertebrae should be significantly considered before abdominal and retroperitoneal procedures. Therefore, a careful reading of preoperative cross-sectional imaging looking for the RLRV is considerably helpful in avoiding fatal complications during the operation. The present study, to the best of our knowledge, is the first to report two new unique variations of the left renal vein, that is, the triple RLRV and the circumiliac left renal vein.

6. Ethical approval

This study was approved by the Khon Kaen University Ethics Committee in Human Research (reference number: HE631154).

7. Acknowledgements

This research was supported by grant WU-IRG-62 040 from Walailak University. Moreover, this research was contributed from the Department of Anatomy and the Department of Radiology, Faculty of Medicine, Khon Kaen University. We would like to express our very great appreciation to Dr. Suwichak Chaisit for illustration drawing. Finally, we also favorably thank Mr. Wichai Wichatracul for maintaining Synaps software.

8. References

- [1] Satyapal KS, Kalideen JM, Haffjee AA, Singh B, Robbs JV. Left renal vein variations. *Surg Radiol Anat.* 1999;21(1):77-81.
- [2] Karaman B, Koplay M, Ozturk E, Basekim CC, Ogul H, Mutlu H, et al. Retroaortic left renal vein: multidetector computed tomography angiography findings and its clinical importance. *Acta Radiol.* 2007;48(3):355-360.
- [3] Shi Y, Yang H, Feng Z, Chen F, Zhang H, Wu Z. Evaluation of posterior nutcracker phenomenon using multisection spiral CT. *Clin Radiol.* 2018;73(12):P1060.E9-P1060.E16.
- [4] Hoeltl W, Hruby W, Aharinejad S. Renal vein anatomy and its implications for retroperitoneal surgery. *J Urol.* 1990;143(6):1108-1114.
- [5] Covantev S, Mazuruc N, Belic O. Renal veins: developmental variations and clinical significance. *Online J Health Allied Scs.* 2017;16(4):12.
- [6] Sabouri S, Hosseini A, Shivaee SS. Retro-aortic inverted left renal vein: a rare anomaly found in a renal donor. *Iran J Radiol.* 2015;12(2):e11374.
- [7] Karkos CD, Bruce IA, Thomson GJ, Lambert ME. Retroaortic left renal vein and its implications in abdominal aortic surgery. *Ann Vasc Surg.* 2001;15(6):703-708.
- [8] Thomas TV. Surgical implications of retroaortic left renal vein. *Arch Surg.* 1970;100(6):738-740.
- [9] Otsuki H, Kuroda K, Kosaka T, Ito K, Hayakawa M, Asano T. A case report of retroaortic left renal vein with tumor thrombus of renal cell carcinoma. *Clin Exp Nephrol.* 2011;15(3):438-441.
- [10] Silva TA, Buonfiglio VB. Triple retroaortic renal vein with tumor thrombus. *Urol.* 2021;154:e17-e18.
- [11] Tatar I. Retroaortic and circumaortic left renal veins with their CT findings and review of the literature. *Int J Clin Exp Anat.* 2008;2:72-76.
- [12] Trigaux JP, Vandroogenbroek S, Wispelaere JF, Lacrosse M, Jamart J. Congenital anomalies of the inferior vena cava and left renal vein: evaluation with spiral CT. *J Vasc Interv Radiol.* 1998;9(2):339-345.
- [13] Lau JL, Lo R, Chan FL, Wong KK. The posterior "nutcracker": hematuria secondary to retroaortic left renal vein. *Urol.* 1986;28(5):437-439.
- [14] Koc Z, Ulsan S, Tokmak N, Oguzkurt L, Yildirim T. Double retroaortic left renal veins as a possible cause of pelvic congestion syndrome: imaging findings in two patients. *Br J Radiol.* 2006;79(946):e152-e155.
- [15] Marone EM, Psacharopulo D, Kahlberg A, Coppi G, Chiesa R. Surgical treatment of posterior nutcracker syndrome. *J Vasc Surg.* 2011;54(3):844-847.
- [16] Gibo M, Onitsuka H. Retroaortic left renal vein with renal vein hypertension causing hematuria. *Clin Imaging.* 1998;22(6):422-424.
- [17] Arslan H, Etlik O, Ceylan K, Temizoz O, Harman M, Kavan M. Incidence of retro-aortic left renal vein and its relationship with varicocele. *Eur Radiol.* 2005;15(8):1717-1720.
- [18] Türkvan A, Ozdemir M, Cumhuri T, Olçer T. Multidetector CT angiography of renal vasculature: normal anatomy and variants. *Eur Radiol.* 2009;19(1):236-244.
- [19] Nam JK, Park SW, Lee SD, Chung MK. The clinical significance of a retroaortic left renal vein. *Korean J Urol.* 2010;51(4):276-280.
- [20] Anson BJ, Caudwell EW. The anatomy of the para-renal system of veins, with comments on the renal arteries. *J Urol.* 1948;60(5):714-737.
- [21] McClure CFW, Butler EG. The development of the vena cava inferior in man. *American J Anat.* 1925;35(3):331-383.
- [22] Mathews R, Smith PA, Fishman EK, Marshall FF. Anomalies of the inferior vena cava and renal veins: embryologic and surgical considerations. *Urol.* 1999;53(5):873-880.
- [23] Huntington GS, McClure CFW. The development of the veins in the domestic cat (*felis domestica*) with especial reference, 1) to the share taken by the supracardinal veins in the development of the postcava and azygos veins and 2) to the interpretation of the variant conditions of the postcava and its tributaries, as found in the adult. *Anat Rec.* 1920;20(1):1-31.
- [24] Kyung D, Lee J, Shin D, Kim D, Choi I. The double retro-aortic left renal vein. *Anat Cell Biol.* 2012;45:282-284.

- [25] Calàbria CH, Gómez QS, Cerqueda SC, Presa BR, Miranda A, Castells AA. Nutcracker or left renal vein compression phenomenon: multidetector computed tomography findings and clinical significance. *Eur Radiol.* 2005;15(8):1745-1751.
- [26] Nishimura Y, Fushiki M, Yoshida M, Nakamura K, Imai M, Ono T, et al. Left renal vein hypertension in patients with left renal bleeding of unknown origin. *Radiology.* 1986;160(3):663-667.