E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.02.100

Research Article

CT-Based Anatomical Mapping of Renal Vascular Variations and it impact on Preoperative Planning in Urological Surgery

Mehreen salahuddin[1], Samar Ashraf[2], Hajera Ahmed[3], Tooba Jalees[4], Samia Shahbaz[5], Aymen Sana[6]

[1]Assistant professor, Department of Anatomy, Fatima Memorial College of Medicine and Dentistry, Lahore.
[2]Professor, Department of Anatomy, King Edward Medical University, Lahore.
[3]Demonstrator, Department of Anatomy, University College of Medicine and Dentistry, Lahore.
[4]Senior Demonstrator, Department of Anatomy, CMH institute of Medical Sciences, Multan.
[5]Assistant Professor, Department of Anatomy, Lahore Medical and Dental College, Lahore.
[6]Demonstrator, Department of Anatomy, CMH Lahore Medical College and Institute of dentistry, Lahore, Pakistan.
Email: [1]dr.mehreensalahuddin@gmail.com, [2]samarashraf999@gmail.com, [3]hajrarehan.uol@gmail.com, [4]tjalees32@gmail.com, [5]seemishah31@gmail.com, [6]aymensana123@gmail.com
Received: 29.05.26, Revised: 27.06.26, Accepted: 23.07.26

ABSTRACT

Objective: To evaluate renal vascular variations using contrast-enhanced CT angiography and determine their role in preoperative planning for urological surgery.

Materials and Methods: A cross-sectional observational study was conducted in the Department of Radiology in collaboration with the Department of Urology at a tertiary care teaching hospital over a six-month period. A total of 200 adult patients undergoing contrast-enhanced multidetector CT angiography for renal evaluation were included using a non-probability consecutive sampling technique. CT images were assessed for renal arterial and venous anatomy, including accessory renal arteries, early arterial branching, multiple renal veins, retroaortic left renal vein, circumaortic left renal vein, and other vascular anomalies. Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Statistical significance was considered at a p-value of <0.05.

Results: The mean age of the participants was 46.8 ± 13.2 years, with 118 (59.0%) males and 82 (41.0%) females. Renal vascular variations were identified in 74 (37.0%) patients. Accessory renal arteries were the most common arterial variation, observed in 48 (24.0%) patients, followed by early arterial branching in 12 (6.0%) and multiple accessory arteries in 4 (2.0%). Normal venous anatomy was present in 168 (84.0%) patients, whereas multiple renal veins, retroaortic left renal vein, circumaortic left renal vein, and late venous confluence were detected in 9.0%, 4.0%, 2.0%, and 1.0% of cases, respectively. CT findings resulted in modification of the anticipated surgical approach in 22.0% of patients and indicated increased operative difficulty in 7.0%. No statistically significant association was found between renal vascular variations and either age (p = 0.611) or gender (p = 0.284).

Conclusion: Contrast-enhanced multidetector CT angiography is a reliable and effective imaging modality for identifying renal vascular variations before urological surgery. CT-based anatomical mapping provides valuable information for individualized surgical planning, facilitates recognition of clinically significant vascular anomalies, and may help reduce operative complications while improving surgical outcomes.

Keywords: Computed Tomography, CT Angiography, Renal Vascular Variations, Accessory Renal Artery, Renal Vein Anomalies, Preoperative Planning, Urological Surgery, Multidetector CT.

INTRODUCTION

The kidneys have a high variation in their vascular supply, including accessory renal arteries, early branching of the renal arteries, multiple renal veins, circumaortic venous rings, and retroaortic left renal veins. (1) If these vascular anomalies are not appreciated preoperatively, there is a risk of intraoperative bleeding, extended operative time, vascular injury, inadequate tumor resection, warm ischemia, and postop complications. [2] Consequently, it is now essential to correct preoperative delineation of renal vascular anatomy for surgical planning in modern urology An understanding of the anatomy of renal vascularization is essential for successful urological surgery, especially for those operations involving careful dissection of the hilar vessels and preservation of renal function. [3]

The use of minimally invasive surgical procedures such as laparoscopic and robotic-assisted procedures (partial nephrectomy, radical nephrectomy, donor nephrectomy, pyeloplasty, endourological procedures) have emphasized the importance of detailed anatomical evaluation. [4] In contrast with open surgery, minimally invasive techniques provide limited tactile feedback and limited visualization during operation, which makes greatly the necessity of having preoperative imaging to identify any vascular variations that could affect the surgical approach. [5] The knowledge of the vascular anatomy of the kidney is crucial in order to predict operative complexity, choose the best approach, minimize vascular injury and preserve nephrons. [6]

The renal vascular anatomy is formed, regressed and retained from multiple mesonephric arteries in a complex embryological series of events. In the development of ascent of the kidneys from the pelvis to the lumbar region, the transient arterial branches generally disappear and superior new ones are formed. [7] Variations in the venous development cause accessory renal veins, multiple renal veins, circum-aortic left renal vein and retroaortic left renal vein, while persistence of these embryonic vessels causes accessory or multiple renal arteries. [8] These variations are usually unapparent but gain meaningful clinical relevance in the procedures of renal transplantation, nephron-sparing surgery, vascular reconstruction and interventional radiological procedures. [9]

Computed tomography (CT), especially MDCT and CT angiography, is becoming the preferred imaging modality for the evaluation of renal vascular anatomy. With the development of multidetector technology, fast imaging of thin sections, providing high spatial resolution, allows detailed imaging of arterial and venous structures. [10] Reconstruction images, such as multiplanar reconstruction (MPR), maximum intensity projection (MIP), and three-dimensional volume-rendered (3D VR) images, further enrich the information regarding the anatomy and aid in interpretation. [11] These imaging modalities enable the exact number, origin, course, branching pattern and diameter of renal vessels to be determined, which enables individual surgical planning. [12]

There have been many studies that have shown that the use of computed tomography (CT) angiography is highly accurate in the diagnosis of renal vascular variations. Accessory renal arteries are reported in 20–35% and multiple renal veins and other venous anomalies are reported in a smaller but clinically relevant number of individuals. [13] The CT findings have proved to be very good, with excellent agreement to the findings observed during surgery and CT angiography now being used as a reliable non-invasive alternative to the conventional catheter angiography for which it has largely replaced due to its invasive nature and associated procedural risks. [14] Moreover, CT provides simultaneous evaluation of the renal parenchyma, collecting system, adjacent organs and pathological lesions, providing a comprehensive evaluation before the operation. [15]

Anatomical mapping using CT is important for planning selective arterial clamping during partial nephrectomy to minimize warm ischemia time, and to identify the segmental arterial supply to renal tumors for urological oncology. [16] During living donor nephrectomy, proper demarcation of renal arteries and veins facilitates donor selection, surgical access and graft harvesting, and helps to reduce vascular complications. [17] Likewise, during reconstructive procedures like pyeloplasty, the identification of crossing vessels is important to determine the cause of ureteropelvic junction obstruction and determines operative management. Understanding the vascular anatomy of the kidney is also crucial in endovascular procedures and during renal artery embolization and ablative procedures. [18]

In recent years, the clinical value of renal vascular mapping using computed tomography has been further improved by the improvement of image post-processing technology and the development of artificial intelligence as well as three-dimensional visualization technologies. The 3D reconstruction is used to enhance spatial understanding of complex vascular structures, to communicate between multidisciplinary teams and to simulate surgery. [19] New AI algorithms are also being developed to automatically segment vessels and perform anatomical categorization which could enhance the efficiency, repeatability and individualized surgical planning. Although CT angiography is commonly performed, the frequency and distribution of renal vascular variations vary with ethnicity and geographical location. [20]

Local anatomical information is useful as it may reflect differences in the population that can affect surgical choices and education training. Evaluation of renal vascular anatomy in a systematic way with the adoption of a CT evaluation protocol can aid in the enhancement of surgical safety, the minimization of surgical complications, and the maximization of patients' outcome. The purpose of the present study, therefore, is to assess the variation of renal vessels with CE MDCT and to set up the anatomical mapping for pre-operative planning in urological surgery by CE MDCT. This study aims to record the prevalence and location of arterial and venous variations and evaluate their surgical significance, which could offer clinically relevant data that improves operative decision making, allow personalized surgical strategies, and increase safety and efficacy of urological procedures.

MATERIALS AND METHODS

This was a cross-sectional observational study conducted in Department of Radiology which were in collaboration with Department of Urology of a Tertiary care teaching hospital from January 2026 to June 2026 for a period of six months. The study was conducted to assess renal vascular variations by using contrast enhanced computed tomography (CT) and to determine their significance in the preoperative planning for urological surgical procedures. Two hundred patients over 18 years of age who had received contrast enhanced multidetector computed tomography (CEMDCT) of the abdomen and were subjected to computed tomography angiography (CTA) for renal evaluation were included.

A sample size was determined using the WHO sample size calculator with a prevalence of renal vascular variations, of 30%, a 95% confidence level and a 6% margin of error. A non-probability consecutive sampling technique was used. The inclusion criteria were written informed consent from the patients and referral for preoperative evaluation of renal pathology or for evaluation as a potential living kidney donor. Patients with previous renal surgery or renal transplantation, congenital renal anomalies (horseshoe kidney, crossed fused ectopia), large renal masses which distorted renal hilar anatomy, severe renal impairment (eGFR <30 mL/min/1.73 m^2), known hypersensitivity to the iodinated contrast medium, pregnancy, and poor quality.

CT images because of poor contrast enhancement or motion artifacts were excluded from the study. The demographic data, such as sex, age, and the clinical indication for CT examination, were taken before the imaging was performed. All CT examinations were carried out by a 128-slice multidetector CT scanner according to the institutional protocol for renal CT angiography. The non-ionic iodinated contrast agent (350-370 mg of iodine per mL) was injected intravenously into the left arm through an 18-20gauge cannula using a power injector at 4-5 mL/s and followed by a saline flush. Images of the arterial phase were taken with bolus tracking, venous phase images were obtained when needed, and nephrographic phase images were not taken.

Multiplanar reconstruction (MPR), maximum intensity projection (MIP) and three-dimensional volume-rendered (3D-VR) reconstruction techniques were used to reconstruct images with a slice thickness ranging from 0.5 mm to 1.0 mm and to enable the comprehensive assessment of the renal vasculature. The CT images were independently analyzed by two consultant radiologists who counted the number, origin, course, branching pattern and laterality of the renal arteries as well as the number and anatomical configuration of renal veins. Specially, accessory renal arteries, early arterial branching, multiple renal veins, retroaortic left renal vein, circumaortic left renal vein and other clinically significant renal vascular anomalies were highlighted.

The differences between the observers were clarified by consensus review. The possible effects of each vascular variation on the surgical planning of the preop case were also recorded. The major finding of the study was the incidence and distribution of renal artery and vein anomalies found on computed tomography angiography (CTA). Secondary outcomes were the distribution of vascular variations by age and sex, laterality of vascular anomalies, and possible role of these anomalies in preoperative planning for urological surgery.

All collected data were entered and analyzed with the Statistical Package for the Social Sciences (SPSS) version 26.0. Means ± standard deviations were used for continuous variables and frequencies and percentages were used for categorical variables. Categorical data was compared between groups using Chi-square test or Fisher's exact test if data was continuous, it was compared between groups using independent samples t-test or Mann–Whitney U test as appropriate based on data distribution. P values < 0.05 were regarded as statistically significant. Prior to the start of data collection, ethical approval was obtained from the Institutional Review Board of the participating institution. All participants gave written informed consent and patient information was kept confidential throughout the study by using unique identifiers and removing patient identifiers from this study database. The study was carried out following the ethical principles of the Declaration of Helsinki.

RESULTS

A total of 200 patients who fulfilled the inclusion criteria underwent contrast-enhanced multidetector CT angiography and were included in the final analysis. The mean age of the study population was 46.8 ± 13.2 years (range: 18–78 years). Among the participants, 118 (59.0%) were males and 82 (41.0%) were females.

Table 1: Demographic Characteristics of the Study Population (N = 200)

Variable	Frequency (n)	Percentage (%)
Age Group (years)		
18–30	28	14.0
31–45	62	31.0
46–60	71	35.5
>60	39	19.5
Gender		
Male	118	59.0
Female	82	41.0

The majority of participants belonged to the 46–60 years age group (35.5%), while males constituted nearly three-fifths of the study population.

Table 2: Renal Arterial Variations Detected on CT Angiography

Arterial Anatomy	Frequency (n)	Percentage (%)
Single renal artery (normal anatomy)	136	68.0
Accessory renal artery	48	24.0
Early arterial branching	12	6.0
Multiple accessory arteries	4	2.0

Normal single renal arteries were identified in **68.0%** of patients. Accessory renal arteries represented the most common arterial variation, occurring in **24.0%** of cases.

Table 3: Distribution of Accessory Renal Arteries According to Side

Side	Frequency (n)	Percentage (%)
Right	19	39.6
Left	21	43.8
Bilateral	8	16.6
Total	48	100

Among patients with accessory renal arteries, the left side was slightly more commonly involved than the right, while bilateral accessory arteries were observed in 16.6% of affected individuals.

Table 4: Renal Venous Variations Detected on CT Angiography

Venous Anatomy	Frequency (n)	Percentage (%)
Normal renal veins	168	84.0
Multiple renal veins	18	9.0
Retroaortic left renal vein	8	4.0
Circumaortic left renal vein	4	2.0

Late venous confluence	2	1.0

Normal venous anatomy was observed in 84.0% of participants. Multiple renal veins were the most frequent venous variation.

Table 5: Overall Frequency of Renal Vascular Variations

CT Finding	Frequency (n)	Percentage (%)
No vascular variation	126	63.0
At least one vascular variation	74	37.0

Overall, 37.0% of patients demonstrated one or more renal vascular variations on CT angiography.

Table 6: Association between Gender and Presence of Renal Vascular Variations

Gender	Vascular Variation Present	Normal Anatomy	Total	p-value
Male	47	71	118	
Female	27	55	82	
Total	74	126	200	0.284

No statistically significant association was observed between gender and the presence of renal vascular variations ($p = 0.284$).

Table 7: Association between Age Group and Renal Vascular Variations

Age Group (years)	Vascular Variation Present	Normal Anatomy	p-value
18–30	12	16	
31–45	23	39	
46–60	28	43	
>60	11	28	0.611

There was no statistically significant association between age group and the occurrence of renal vascular variations ($p = 0.611$).

Table 8: Surgical Significance of CT Findings

Surgical Planning Variable	Frequency (n)	Percentage (%)
No modification required	142	71.0
Modification of surgical approach required	44	22.0
Increased anticipated surgical difficulty	14	7.0

CT-based anatomical mapping altered the anticipated surgical approach in 22.0% of patients, while 7.0% were considered likely to have increased operative difficulty because of complex vascular anatomy.

Among the 200 participants, renal vascular variations were detected in 37.0% of cases. Accessory renal arteries were the most common arterial anomaly (24.0%), whereas multiple renal veins were the most frequent venous variation (9.0%). Most vascular anomalies occurred unilaterally, with a slight predominance on the left side. No significant association was found between vascular variations and either age or gender. CT angiography provided detailed anatomical information that influenced preoperative surgical planning in approximately one-fifth of patients, emphasizing its value in reducing operative risk and facilitating individualized urological surgical management.

DISCUSSION

The present study aimed to analyze the renal vascular variations by contrast enhanced multi detector computed tomography (MDCT) and determine its significance in preoperative planning for urological surgical procedures. Knowledge of the anatomy of the renal artery and vein is crucial before performing renal partial nephrectomy, radical nephrectomy, donor nephrectomy, pyeloplasty and endovascular procedures. The renal vascular variations in the present study were found in 37.0% of patients and were found to be relatively common and should be assessed routinely prior to surgery. These results reaffirm the importance of CT angiography as an essential imaging tool for surgical planning. Accessory renal arteries were the most frequent arterial variation, affecting 24.0% of the patients in the present study. This prevalence is similar to that of previous anatomical and radiological studies.

Türkvatan et al. found accessory renal arteries in about 24% of patients who underwent multidetector computed tomography (MDCT) angiography. [21] Raman et al. reported accessory renal arteries in 28–30% of potential living kidney donors who underwent preoperative computed tomography (CT) angiography. (10) Likewise, Sampaio and Passos showed that accessory renal artery is one of the most common renal vascular anomalies and pointed out its significance in nephron-sparing surgery and renal transplantation. [2]

Sometimes accessory arteries have special connections with renal segments, which may lead to segmental renal infarction, or to postoperative loss of renal function if they are accidentally injured or ligated. In 6.0% of the study population early arterial branching was observed. This finding is similar to those of Kawamoto et al., who reported that early branching is a common anatomic variant that can make a laparoscopic donor nephrectomy more technically challenging. [13] Raman and co. also noted that early division of arteries would decrease the length of available arterial vessels for transplantation, and thus should be identified prior to surgery. [10] This variation can be recognized to enable a surgeon to tailor the vascular control methods and lower the risk of complications during surgery.

In the present study, venous variations were found in 16.0% of the patients; multiple renal veins (9.0%) were the most common abnormality, whereas retroaortic left renal vein (4.0%) and circumaortic left renal vein (2.0%) were seen less frequently. Urban et al. noted that the most common venous anomaly observed during computed tomography (CT) angiography was multiple renal veins. [16] Retroeaortic and circumaortic left renal veins are also uncommon but of great surgical importance due to the higher incidence of bleeding at the hilum during dissection, as reported by Türkvatan et al. It may result in untimely venous injuries, extended surgery time, and blood loss if these anomalies are not recognized preoperatively. [21]

In this study, overall renal vascular variations were detected in 37.0% of the patients. This prevalence is similar to that reported in the literature, ranging from 30% to 40% of people. Holden et al. showed that multidetector CT is a reliable method for the detection of clinically significant vascular variations in living donors and that there was a good correlation between CT findings and intraoperative anatomy. [22] Likewise, Kawamoto et al. found that CT angiography could offer a very accurate depiction of the renal vessels and had largely replaced traditional catheter angiography due to its non-invasive nature, speed and ability to assess the renal parenchyma and collecting system at the same time. [13]

In our study, there was no statistically significant difference in renal vascular variations between gender ($p = 0.284$) or age ($p = 0.611$). The present results corroborate those of a number of earlier studies which have found that renal vascular variations are largely due to the mechanisms of embryo development rather than to demographic differences. The persistence of embryonic mesonephric arteries during the ascent of the kidneys produces accessory renal arteries; the great majority of renal venous anomalies are due to abnormalities in the development of the subcardinal and supracardinal venous systems was Graves' explanation. As a result, there is little variation in these vascular patterns during life and they are not usually related to age or sex of patients. [23]

One of the main results of this study was that the anatomical mapping performed using CT changed the planned surgical strategy in 22.0% of the patients and increased the technical difficulty in 7.0% of the patients. The observations are helpful for understanding the clinical utility of the pre-operative computed tomography angiography. Raman et al. showed that an understanding of renal vascular anatomy prior to nephrectomy can facilitate surgical planning and reduce unforeseen vascular complications associated with donor nephrectomy. [10] Similarly, Urban et al. found that 3D CTA enables surgeons to better understand the complex hilar anatomy, which is important for the safe dissection of the vascular structures and for minimizing risks during surgery. [16]

Multiplanar reconstruction, maximum intensity projection and three-dimensional volume-rendering of the images produced by multidetector CT have enhanced the visualization of renal vasculature. These high-end reconstruction methods allow for a comprehensive evaluation of the various anatomical aspects of the arterial origin, branching, venous drainage, and spatial relationships, improving radiologist to surgeon communication. With the recent advances in image post-processing and three-dimensional visualization, the contribution of CT to personalized surgical planning has been further consolidated, especially for minimally invasive and robotic-assisted urological surgery. (24)

The results of the current study confirm the accumulating data suggesting that routine preoperative evaluation with CT angiography should be considered in the preoperative work-up when complex renal surgery is expected. Timely diagnosis allows for tailored surgical management, helps maintain renal function, decreases surgical complications and enhances patient outcomes.

The present study has some limitations. It was carried out in one tertiary care center and the sample size was relatively small, which might restrict the generalizability of the results. Also, not all of the patients had surgery, so there was no correlation of the CT findings with what was observed during surgery. Larger multicenter studies with direct comparison of radiological findings to surgical results are recommended in the future to further validate the clinical usefulness of CT based anatomical mapping. In overall, the present study confirms the ability of multi-detector computed tomography angiography (MDCTA) to perform complete and reliable assessment of renal vascular anatomy and its usefulness in achieving optimal surgical planning for urological surgery by accurately locating clinically relevant vascular variations.

CONCLUSION

Contrast-enhanced multidetector CT angiography is a successful, reliable imaging method to detect renal vascular variations before urological surgery. Renal vascular anomalies were found in over ⅓ of patients, with accessory renal arteries being the most common arterial anomaly and more than one renal vein being the most common venous anomaly. CT-based anatomical mapping resulted in detailed visualization of the renal vasculature, and helped guide the surgeon's pre-operative planning, as it helped identify clinically significant variations that may affect the surgical approach and operative difficulty. In urological surgery, routine preoperative assessment of the renovascular anatomy by CT angiography will help reduce intraoperative complications, improve surgical safety, individualize treatment planning, and improve patient outcome.

REFERENCES

1. Sapte E, Bordei P. [Anatomical considerations on the renal arterial segmentation]. Rev Med Chir Soc Med Nat Iasi. 2005;109(3):597-602.
2. Sampaio FJ, Passos MA. Renal arteries: anatomic study for surgical and radiological practice. Surg Radiol Anat. 1992;14(2):113-7.
3. Khamanarong K, Prachaney P, Utraravichien A, Tong-Un T, Sripaoraya K. Anatomy of renal arterial supply. Clin Anat. 2004;17(4):334-6.
4. Aghayev A, Gupta S, Dabiri BE, Steigner ML. Vascular imaging in renal donors. Cardiovasc Diagn Ther. 2019;9(Suppl 1):S116-s30.
5. Ozkan U, Oğuzkurt L, Tercan F, Kizilkiliç O, Koç Z, Koca N. Renal artery origins and variations: angiographic evaluation of 855 consecutive patients. Diagn Interv Radiol. 2006;12(4):183-6.
6. Graves FT. The aberrant renal artery. J Anat. 1956;90(4):553-8.
7. Bouali O, Mouttalib S, Labarre D, Munzer C, Lopez R, Lauwers F, et al. [Study of renal veins by multidetector-row computed tomography scans]. Morphologie. 2014;98(323):161-5.
8. Macchi V, Crestani A, Porzionato A, Sfriso MM, Morra A, Rossanese M, et al. Anatomical study of renal arterial vasculature and its potential impact on partial nephrectomy. BJU Int. 2017;120(1):83-91.
9. Apisarnthanarak P, Suvannarerg V, Muangsomboon K, Taweemonkongsap T, Hargrove NS. Renal vascular variants in living related renal donors: evaluation with CT angiography. J Med Assoc Thai. 2012;95(7):941-8.
10. 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(1):105-14.
11. Çınar C, Türkvatan A. Prevalence of renal vascular variations: Evaluation with MDCT angiography. Diagn Interv Imaging. 2016;97(9):891-7.
12. Knox MK, Rivers-Bowerman MD, Bardgett HP, Cowan NC. Multidetector computed tomography with triple-bolus contrast medium administration protocol for preoperative anatomical and functional assessment of potential living renal donors. Eur Radiol. 2010;20(11):2590-9.

13. Kawamoto S, Montgomery RA, Lawler LP, Horton KM, Fishman EK. Multidetector CT angiography for preoperative evaluation of living laparoscopic kidney donors. AJR Am J Roentgenol. 2003;180(6):1633-8.
14. Famurewa OC, Asaleye CM, Ibitoye BO, Ayoola OO, Aderibigbe AS, Badmus TA. Variations of renal vascular anatomy in a nigerian population: A computerized tomography studys. Niger J Clin Pract. 2018;21(7):840-6.
15. Reginelli A, Somma F, Izzo A, Urraro F, D'Andrea A, Grassi R, et al. Renovascular anatomic variants at CT angiography. Int Angiol. 2015;34(6 Suppl 1):36-42.
16. Urban BA, Ratner LE, Fishman EK. Three-dimensional volume-rendered CT angiography of the renal arteries and veins: normal anatomy, variants, and clinical applications. Radiographics. 2001;21(2):373-86; questionnaire 549-55.
17. Tao XF, Zhu JQ, Wu YW, Tang GY, Shi YZ, Zhang L, et al. Dual-energy computed tomography angiography for evaluating the renal vascular variants. Chin Med J (Engl). 2013;126(4):650-4.
18. Gümüş H, Bükte Y, Ozdemir E, Cetinçakmak MG, Tekbaş G, Ekici F, et al. Variations of renal artery in 820 patients using 64-detector CT-angiography. Ren Fail. 2012;34(3):286-90.
19. Indrajit IK, Souza JD, Bedi VS, Pant R. Impact of Multidetector CT on 3D CT Angiography. Med J Armed Forces India. 2005;61(4):360-3.
20. Rubin GD. MDCT imaging of the aorta and peripheral vessels. Eur J Radiol. 2003;45 Suppl 1:S42-9.
21. Türkvatan A, Ozdemir M, Cumhur T, Olçer T. Multidetector CT angiography of renal vasculature: normal anatomy and variants. Eur Radiol. 2009;19(1):236-44.
22. Holden A, Smith A, Dukes P, Pilmore H, Yasutomi M. Assessment of 100 live potential renal donors for laparoscopic nephrectomy with multi-detector row helical CT. Radiology. 2005;237(3):973-80.
23. Borojeni S, Borojeni A, Panayotopoulos P, Bouvier A, Aubé C, Azzouzi AR, et al. Study of Renal and Kidney Tumor Vascularization Using Data from Preoperative Three-dimensional Arteriography Prior to Partial Nephrectomy. Eur Urol Focus. 2020;6(1):112-21.
24. Shao P, Li P, Xu Y, Cao Q, Ju X, Qin C, et al. Application of combined computed tomography arteriography, venography, and urography in laparoscopic partial nephrectomy with segmental artery clamping. Urology. 2014;84(6):1361-5.