

Correlation Analysis of Hemodynamic Parameters and Renal Artery Morphology: Results of a Comprehensive Assessment Using 320-Row CT

Nigora Djuraeva¹, Asalhon Davidhodjaeva²

¹Doctor of Medical Sciences, Head of the Department of MSCT and MRI Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov, Tashkent, Uzbekistan

²Physician, Department of Ultrasound Diagnostics Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov, Tashkent, Uzbekistan

Abstract Background: Multidetector computed tomography (MSCT), particularly when performed with high-resolution 320-row systems, has become a valuable imaging modality for the assessment of renal anatomy and function. These techniques allow for precise visualization of renal vasculature and perfusion characteristics, providing critical information for the diagnosis of vascular abnormalities and for preoperative planning in procedures such as nephrectomy and kidney transplantation. Aim: The present study aims to investigate the relationship between morphological characteristics of the renal arteries (diameter and number, including the presence of accessory vessels) and key hemodynamic parameters—arterial flow, equilibrium blood volume, and contrast clearance—derived from 320-row CT perfusion analysis. Methods: A prospective observational study was conducted between June 2021 and March 2024, including 54 potential kidney donors (30 men, 24 women; age range 19–58 years; mean 38.2 ± 7.5 years). All participants underwent 320-row CT, incorporating CT angiography and volumetric CT perfusion (VCTP). Perfusion parameters were analyzed using the single-slope method and the Patlak model. Results: The mean diameter of the right renal artery at the ostium was 6.0 ± 0.5 mm, and that of the left renal artery was 6.7 ± 0.6 mm. Accessory renal arteries were found in 16 patients (29.6%): 9 (16.7%) on the right, 3 (5.6%) on the left, and 4 (7.4%) bilaterally. No significant interrenal differences were observed in perfusion indices. Correlation analysis showed a strong positive relationship between renal artery diameter and arterial flow ($r = 0.671$, $p < 0.01$), whereas the number of arteries had no significant effect on blood flow. Conclusion: Renal artery diameter is a key determinant of arterial flow and renal hemodynamics, whereas the number of arteries does not significantly influence perfusion parameters. Nonetheless, the presence of accessory arteries—particularly bilateral—underscores the necessity of detailed preoperative imaging for surgical planning.

Keywords Multidetector Computed Tomography, Kidneys, Arterial Flow, Blood Volume, Contrast Clearance, Renal Arteries

1. Introduction

The study of renal angioarchitecture and its related hemodynamic parameters is of considerable interest in the context of modern approaches to the diagnosis and treatment of kidney diseases, as well as in the planning of surgical interventions such as nephrectomy and kidney transplantation. Renal arteries play a key role in ensuring adequate perfusion of renal tissue, and disturbances in their structure or function may lead to serious clinical consequences, including ischemic nephropathy, chronic kidney disease, and hypertension [1-3].

With the advent of multislice computed tomography (MSCT), particularly high-resolution systems such as 320-row scanners,

it has become possible to perform both morphological and functional assessments of the kidneys. This is especially important for early diagnosis of vascular anomalies, evaluation of donor kidneys prior to transplantation, and planning of reconstructive procedures [4,5]. A crucial issue remains the relationship between morphological features of renal arteries—such as vessel diameter and number—and functional indicators, including arterial flow and equilibrium blood volume [6,7].

Despite existing data, the literature still contains contradictory aspects concerning the influence of accessory renal arteries on overall renal hemodynamics. Some studies suggest that accessory arteries may play a compensatory role, whereas others indicate their minimal impact on total renal blood flow [8,9]. Furthermore, unresolved questions remain

regarding the interaction between morphological and functional kidney characteristics, particularly under conditions of atypical anatomy. Thus, a more in-depth investigation of these relationships using modern imaging methods is required [10].

The aim of this study is to determine the relationships between morphological characteristics of renal arteries (diameter, number, presence of accessory vessels) and key hemodynamic parameters such as arterial flow, equilibrium blood volume, and contrast clearance. Addressing this objective will deepen the understanding of the role of renal angioarchitecture in maintaining functional activity and improve approaches to diagnosis and surgical planning, including kidney transplantation.

2. Materials and Methods

Study Design

This study was observational, single-center, prospective, selective, and uncontrolled. It did not involve any intervention in patient treatment or care.

The study workflow consisted of several stages:

1. Selection of patients based on inclusion and exclusion criteria.
2. Performing multislice computed tomography (MSCT) using a 320-row scanner.
3. Post-processing and analysis of obtained parameters.
4. Registration of primary and secondary study outcomes.

Eligibility Criteria

Inclusion criteria: participants aged 18 to 60 years, absence of comorbidities that could affect renal hemodynamics (such as diabetes mellitus or arterial hypertension), and status as candidates for living-related kidney donation.

Non-inclusion criteria: allergy to contrast agents, pregnancy or lactation, and advanced chronic kidney disease (stage 4 or higher).

Exclusion criteria: voluntary withdrawal from the study or technical errors during MSCT or data post-processing.

Study Setting

The study was conducted at the Republican Specialized Scientific and Practical Medical Center of Surgery named after academician V. Vakhidov, located in Tashkent, Republic of Uzbekistan. It was performed in a specialized department using standard equipment and software.

Study Duration

The study took place between June 2021 and March 2024, with a two-year enrollment period. The protocol included control checkpoints, such as baseline MSCT and post-processing within one week. No significant deviations from planned timelines were recorded.

Description of Medical Procedures

All patients underwent comprehensive renal hemodynamic assessment, including CT angiography and volumetric perfusion CT (PCT). MSCT with PCT was performed, and

perfusion maps were generated at the workstation to evaluate cortical and medullary blood flow.

The examinations were carried out on a 320-row spiral CT scanner (Aquilion One, Canon Medical Systems, Japan) with a 0.5 mm slice thickness in soft-tissue reconstruction mode. The scanning protocol was optimized to minimize radiation dose: tube voltage was 100 kV, exposure 60 mAs, sufficient for dynamic studies with a maximum z-axis coverage of 160 mm. Additional scan parameters included collimator size 0.5 × 320 mm, matrix 512 × 512, field of view 320–350 mm, and tube rotation time 0.275 s.

The contrast medium (iodixanol, 350 mg/ml) was administered at 0.5 ml/kg body weight, injection rate 5 ml/s. At an iodine concentration of 350 mg/ml and flow rate of 5 ml/s, the iodine delivery rate (IDR) equaled:

$$\text{IDR} = 350 \times 5 = 1750 \text{ mg iodine/s,}$$

meaning patients received 1750 mg of iodine per second.

Following contrast administration, 50 ml of 0.9% saline was injected at the same rate. Scanning was performed in volumetric mode, starting 7 seconds after contrast injection. Imaging was acquired every 2 seconds from 12 to 30 seconds, then every 3 seconds from 33 to 48 seconds, and every 10 seconds from 55 to 110 seconds.

Data post-processing and perfusion curve analysis were carried out on the Vitrea workstation using the 4D Single Input Perfusion protocol. Tissue density was measured in two regions of interest (ROI): the afferent artery (abdominal aorta) and the target tissue (cortical and medullary layers). Based on time-density curves (TDC), perfusion maps were constructed. Perfusion was evaluated using two mathematical models: the single-slope method and the Patlak model.

Blood flow (arterial flow, AF, ml/min/100 ml) was assessed using the single-slope method. Equilibrium blood volume (Equi BV, ml/100 ml) and contrast clearance (FE, ml/min/100 ml) were calculated using the Patlak model (Fig. 1).

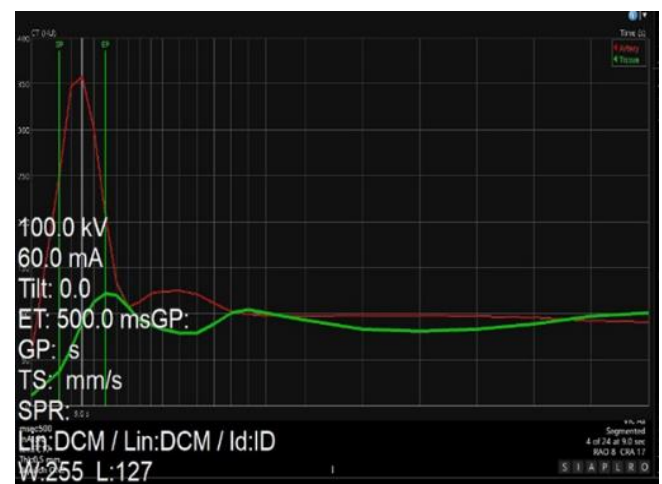


Figure 1. Time Density Curve (TDC) Plot

Renal perfusion measurement included AF, Equi BV, and FE. ROIs were placed in the cortical layer of upper, middle, and lower kidney segments (frontal planes) as well as anterior, lateral, and posterior segments (axial planes). This

allowed for averaging across different parenchymal zones. Mean values and standard deviations were calculated for each parameter.

Perfusion maps were also used to analyze renal cortical blood flow, blood volume, and vascular wall permeability. Perfusion indices were measured in both kidneys, enabling comparison between kidneys with different anatomical features. Representative perfusion maps are shown in Fig. 2.

Data were processed using specialized software, allowing detailed analysis of perfusion indicators and their correlation with renal arterial morphology (e.g., vessel diameter, number of arteries).

Primary Outcome

The main outcome was the correlation between renal artery diameter and perfusion parameters: arterial flow (AF), equilibrium blood volume (Equi BV), and contrast clearance (FE).

Secondary Outcomes

A quantitative assessment of the relationship between the number of renal arteries and key perfusion parameters was performed. The impact of accessory renal arteries on renal blood flow was also analyzed.

Subgroup Analysis

Patients were divided into subgroups based on the presence of accessory renal arteries:

- No accessory arteries.
- One accessory artery.
- Two or more accessory arteries.

Outcome Registration Methods

All outcomes were registered using Vitrea software (Canon Medical Systems), which allows construction of perfusion maps and quantitative blood flow analysis. Parameters were assessed in the renal cortex based on perfusion maps.

Ethical Approval

The study protocol was reviewed and approved by the Institutional Ethics Committee (Approval No. 23/EC, June 10, 2021).

Statistical Analysis

The study sample comprised 54 patients, selected based on availability and compliance with the inclusion criteria. A

priori sample size calculation was not performed. Statistical analysis was conducted using SPSS software, version 25.0 (IBM, USA). Quantitative variables were expressed as mean (M) ± standard deviation (SD). Correlation analysis was performed using Pearson’s correlation coefficient (r), with statistical significance defined at $p < 0.05$.

3. Results

Study Population

A total of 54 patients who met the inclusion criteria were enrolled in the study. The mean age was 38.2 ± 2.75 years, with 30 males (55.6%) and 24 females (44.4%). Baseline demographic and clinical characteristics are summarized in Table 1.

Table 1. Main characteristics of patients

Parameter	Value
Total number of patients	54
Mean age (years)	$38,2 \pm 2,75$ years
Male	30
Female	24
Patients with accessory arteries	16 (29,6%)

Accessory renal arteries were identified in 16 patients (29.6%). Among these, 9 patients had accessory vessels on the right side, 3 on the left side, and 4 patients presented with bilateral accessory arteries. The distribution of accessory arteries is detailed in Table 2.

Table 2. Distribution of accessory arteries in patients

Parameter	Value
Patients with accessory arteries	16 (29,6%)
Right side only	9 (16,7%)
Left side only	3 (5,6%)
Bilateral	4 (7,4%)

The diameter of the main renal arteries ranged from 2 mm to 7 mm. These findings support the representativeness of the study cohort for assessing the relationship between renal arterial morphology and perfusion parameters. Morphological characteristics are presented in Table 3.

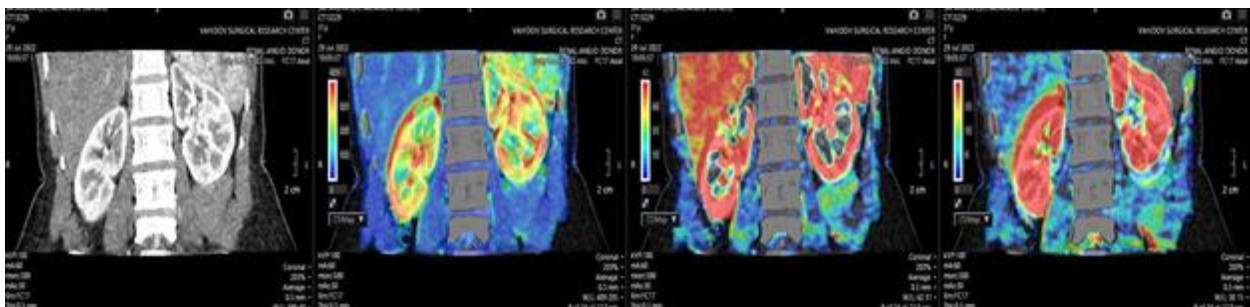


Figure 2. Renal perfusion maps

Table 3. Morphological characteristics of renal arteries

Parameter	Right kidney	Left kidney
Mean diameter of main renal artery	6,0 ± 0,5 mm	6,7 ± 0,6 M mm
Patients with accessory arteries	9 (Right)	3 (Left)
Diameter of accessory arteries	2–3,6 mm	2–3,6 mm

Hemodynamic Parameters

The mean arterial flow (AF) was 274.6 ± 30.7 mL/min/100 mL for the right kidney and 282.4 ± 29.8 mL/min/100 mL for the left kidney (p > 0.05). The equilibrium blood volume (Equi BV) was 64.5 ± 16.0 mL/100 mL for the right kidney and 68.7 ± 15.7 mL/100 mL for the left kidney (p > 0.05). Similarly, contrast clearance (FE) did not differ significantly between sides: 53.3 ± 24.7 mL/min/100 mL for the right kidney and 59.8 ± 27.7 mL/min/100 mL for the left (p > 0.05). A summary of perfusion parameters is provided in Table 4.

Table 4. Average values of renal perfusion parameters

Parameter	Right kidney	Left kidney
Arterial flow (AF)	274,6 ± 30,7 ml/min/100 g	282,4 ± 29,8 ml/min/100 g
Equilibrium blood volume (Equi BV)	64,5 ± 16,0 ml/100 g	68,7 ± 15,7 ml/100 g
Filtration efficiency (FE)	53,3 ± 24,7 ml/min/100 g	59,8 ± 27,7 ml/min/100 g

Correlation Analysis

A strong positive correlation was observed between renal artery diameter and arterial flow (r = 0.67, p < 0.01). By contrast, the number of renal arteries showed no significant association with arterial flow (r = 0.23, p > 0.05). These findings highlight the importance of arterial diameter as a key determinant of renal hemodynamics.

Additional Findings

In the subgroup of patients with accessory renal arteries (diameter 2–3.6 mm), no statistically significant influence on perfusion parameters was observed (p > 0.05). Patients with one or more accessory arteries demonstrated comparable values of AF, Equi BV, and FE to those without accessory vessels.

Equilibrium blood volume (Equi BV) showed a moderate correlation with arterial diameter (r = 0.50, p < 0.05). In contrast, contrast clearance (FE) did not exhibit a statistically significant relationship with renal arterial morphology (r = 0.31, p > 0.05), suggesting that additional factors may contribute to the regulation of this parameter.

4. Discussion

Summary of Key Findings

This study demonstrated that renal artery diameter exerts a significant effect on arterial flow (AF), showing a strong positive correlation (r = 0.67, p < 0.01), whereas the number

of renal arteries did not significantly influence renal hemodynamics. These findings emphasize the role of renal angioarchitecture in maintaining adequate renal perfusion. Figure 3 illustrates the scatterplot of the correlation between renal artery diameter and AF.

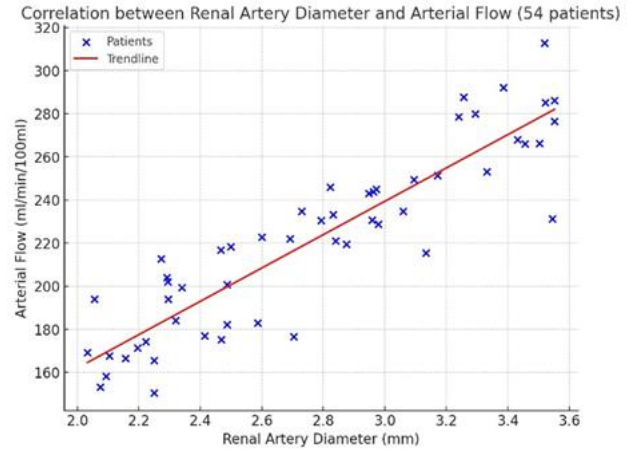


Figure 3. Scatter plot of correlation analysis data between renal artery diameter (X-axis) and arterial flow -AF (Y-axis) in 54 patients

Interpretation of Main Results

The observed association between renal artery diameter and arterial flow is consistent with prior studies that highlight the importance of vessel caliber in regulating renal hemodynamics. Larger arterial diameters allow for greater perfusion capacity, reflecting the adaptive potential of renal vasculature under varying functional demands. Conversely, the absence of a significant correlation between the number of arteries and perfusion parameters suggests that additional arteries, particularly when of small caliber, play a limited compensatory role.

Correlation between Renal Artery Diameter and Equilibrium Blood Volume

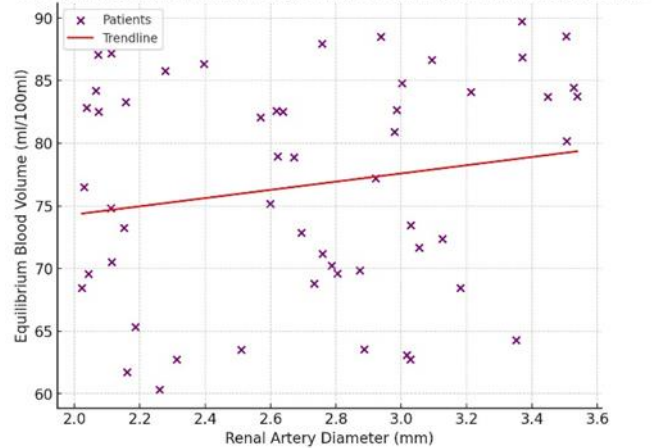


Figure 4. Diagram. Correlation graph of renal artery diameter and blood volume (Equi BV) in 54 patients. The points on the graph represent individual patient data, where each point corresponds to a specific combination of renal artery diameter (X-axis) and blood volume at equilibrium (Y-axis)

Further analysis revealed a moderate correlation between equilibrium blood volume (Equi BV) and renal artery diameter (r = 0.50, p < 0.05), underscoring the contribution

of arterial morphology to renal tissue vascularization. The correlation plot between artery diameter and Equi BV is shown in Figure 5.

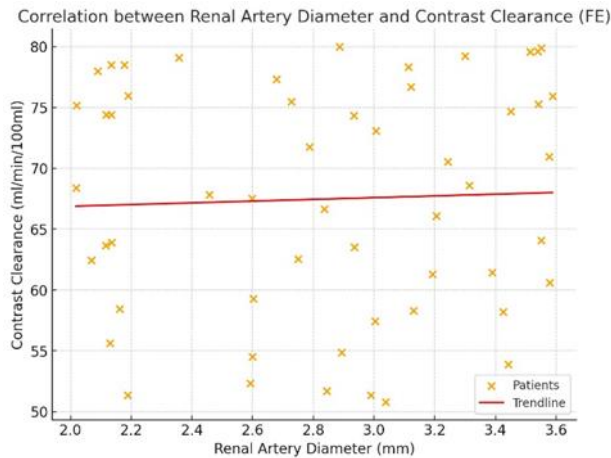


Figure 5. Scatter plot illustrating the correlation between renal artery diameter and contrast clearance (FE) in 54 patients. Each orange dot represents an individual patient, with the x-axis indicating renal artery diameter (mm) and the y-axis showing contrast clearance (ml/min/100 ml)

Contrast clearance (FE) did not demonstrate a statistically significant association with renal artery morphology. This may be attributable to the influence of other determinants such as parenchymal integrity, vascular resistance, and intrarenal hemodynamic mechanisms. The regression trend line (Figure 4) indicated only a weak tendency toward increased clearance with larger arterial diameters, suggesting that morphologic parameters alone cannot fully explain clearance dynamics. Given that FE reflects renal functional capacity to excrete contrast material, these findings imply that structural parameters may have only a modest impact compared with physiological and microvascular factors (Table 5).

Table 5. Correlation between renal perfusion parameters and artery diameter

Correlation Parameters	Correlation coefficient (r)	Significance level (p)
Arterial flow (AF) and renal artery diameter	r = 0,67	p <0,01
Equilibrium blood volume (Equi BV) and renal artery diameter	r = 0,50	p <0,05
Contrast clearance (FE) and renal artery diameter	r = 0,31	p > 0,05

Study Limitations

Several limitations should be acknowledged. First, this was a single-center study, which may restrict the generalizability of the results. Second, the relatively small sample size reduced the statistical power of the analysis. Third, although 320-row CT and Vitrea software provided high-resolution assessment of renal hemodynamics, interindividual variability in vascular anatomy or comorbid conditions not addressed by exclusion criteria may have influenced the results.

Furthermore, the absence of longitudinal follow-up limits the ability to assess the prognostic value of these findings, particularly in surgical contexts such as nephrectomy or transplantation. Finally, potential confounding factors including cardiovascular status, physical activity, and metabolic conditions were not systematically evaluated, and should be addressed in future studies.

Overall, our results support the central role of renal artery diameter in determining perfusion parameters, while highlighting the limited effect of accessory vessels on renal hemodynamics. Further multicenter studies with larger cohorts and long-term follow-up are warranted to confirm these findings and to evaluate their clinical relevance in preoperative planning.

5. Conclusions

This study confirms the high diagnostic value of multidetector computed tomography in the evaluation of renal angioarchitecture. While previous research has highlighted the importance of vascular morphology in maintaining renal perfusion, several aspects—such as the role of accessory arteries and their interaction with hemodynamic parameters—remain insufficiently understood.

Our findings demonstrate a significant positive correlation between renal artery diameter and arterial flow, underscoring the critical role of vessel caliber in sustaining adequate renal perfusion. In contrast, the number of renal arteries showed only limited influence on hemodynamics, particularly when their diameter did not exceed a threshold value.

These results contribute to a deeper understanding of renal perfusion mechanisms and may inform optimization of preoperative planning, especially in the selection of living-related kidney donors. The findings further highlight the need for continued investigation into additional factors—including vascular resistance, parenchymal condition, and systemic influences—that may play a decisive role in regulating renal blood flow.

Future research should aim to translate these insights into refined diagnostic criteria and personalized surgical planning strategies, ultimately enhancing outcomes in nephrectomy and kidney transplantation.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this study.

ACKNOWLEDGEMENTS

The authors received no specific acknowledgments for this work.

Funding

No funding was received for the completion of this study.

REFERENCES

- [1] Smith H, Jones M. Advances in multislice computed tomography. *J Radiol*. 2019; 42(3): 215-230.
- [2] Brown R, Patel S. Evaluation of renal vasculature using MSCT. *Nephrol Today*. 2018; 28(4): 312-324.
- [3] Wang Y, Chen J. Perfusion CT in renal imaging. *Int J Med Imaging*. 2020; 15(2): 101-110.
- [4] Gupta N, Singh A. Quantitative analysis of renal hemodynamics. *J Nephrol Res*. 2021; 33(1): 87-96.
- [5] Anderson P, Lee S. Renal imaging techniques and their clinical applications. *J Clin Nephrol*. 2017; 29(2): 101-115.
- [6] Davis K, Miller T. Advances in computed tomography for renal disease. *Radiol Rev*. 2020; 35(6): 334-342.
- [7] Huang X, Wu Q. CT perfusion in renal transplantation: a review. *Transplant Today*. 2018; 24(1): 45-52.
- [8] Singh R, Kaur P. The role of advanced imaging in nephrology. *Nephrol Insights*. 2019; 21(3): 215-228.
- [9] Zhang L, Zhao Y. Non-invasive assessment of renal function using multislice CT. *Clin Imaging J*. 2021; 40(4): 287-295.
- [10] Martinez F, Johnson R. Quantitative imaging of renal blood flow. *Am J Radiol*. 2022; 38(7): 501-508.
- [11] Shah P, Desai S. Perfusion imaging in renal disorders. *J Urol Nephrol*. 2017; 22(5): 321-330.
- [12] Green D, Taylor B. Advanced renal imaging techniques: a comprehensive review. *J Med Imaging*. 2018; 32(9): 499-511.
- [13] Kumar A, Srivastava M. Imaging biomarkers in renal pathology. *Nephrol Adv*. 2019; 19(4): 279-291.
- [14] Fernandez M, Rodriguez L. CT angiography in renal vascular disease. *Vasc Imaging J*. 2021; 15(3): 171-181.
- [15] Nelson T, Brooks R. Modern techniques in renal CT imaging. *Clin Radiol J*. 2022; 46(1): 15-28.
- [16] Thompson G, Richardson B. Multimodal imaging in the assessment of renal masses. *J Clin Imaging Sci*. 2021; 11(2): 145-154.
- [17] Liu X, Zhang H. Innovations in CT angiography for renal artery stenosis. *J Vasc Interv Radiol*. 2020; 31(5): 776-782.
- [18] Turner M, Cooper K. Dynamic contrast-enhanced CT for evaluating renal perfusion: a clinical perspective. *Eur J Radiol*. 2019; 24(8): 502-510.
- [19] Kim S, Lee J. Quantitative CT imaging in the management of renal tumors. *Oncol Imaging*. 2021; 37(11): 798-805.
- [20] Roberts A, Williams J. Role of functional imaging in renal transplantation. *Transplant Radiol*. 2020; 26(4): 301-310.