International Journal of Anatomy and Research,
Int J Anat Res 2022, Vol 10(1):8275-8282. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2021.204

Original Research Article

A Contrast-Enhanced MDCT Study on the Morphology of Renal Vessels, Their Variations and Clinical Implications

Manu Gupta [*1], Nisha V Kaul [2], Ashish Kumar Shukla [3].

[*1] Ph.D. Scholar, Department of Anatomy, Santosh Medical College and Hospital, Ghaziabad, Uttar Pradesh, India.

[2] Professor & HOD, Department of Anatomy, Santosh Medical College and Hospital, Ghaziabad, Uttar Pradesh, India.

[3] Professor & HOD, Department of Radiodiagnosis, Santosh Medical College and Hospital, Ghaziabad, Uttar Pradesh, India.

ABSTRACT

Introduction: The kidneys—the main organs of the excretory system, are supplied by a paired renal artery, originating from the Abdominal Aorta at the level of a disc between L1 and L2 and drained by a paired renal vein exiting from the hilum of the kidney to the Inferior vena cava.

Aim: To evaluate the morphology of renal vessels, their variations & clinical implications during renal surgeries in the subjects of the North India population by contrast-enhanced MDCT.

Materials and Method: The present study was conceptualized & carried out in the Department of Anatomy, in collaboration with the Department of Radiodiagnosis, Santosh Medical College & Hospital, Ghaziabad and from Dr. O.P Gupta Imaging Centre, Meerut. This study was performed on the 108 patients who were referred for abdominal CECT examination with suspected abdominal pathologies. Contrast-enhanced MDCT scan images of the Abdomen were reviewed for normal anatomy of renal vessels and their variants.

Result: Out of 108 patients, anatomical variations of the renal vessel were found in 72 (66.66%) patients. Variations of the renal artery were found in 56 patients (51.85%). Out of these 56 patients, 47 had supplementary renal artery, 17 had early branching of the renal artery and 8 patients had both supplementary and early branching of the renal artery. Supplementary renal arteries were seen in 15 patients on the right side, 16 patients on the left side & 16 patients bilaterally. Earlier branching of the renal artery was found in 9 patients on the right side, 10 patients on the left side and in 2 patients bilaterally. Variations of the renal vein were more commonly found on the right side, late renal vein confluence was seen in 28 (25.92%) patients and supplementary renal veins in 9 (8.3%) patients. On the left side, 2 (1.85%) patients had late renal vein confluence and 2 (1.85%) patients had retroaortic vein.

Conclusion: Variations of the renal artery are found frequently. Morphological evaluation of renal vessels is useful for planning and performing the endovascular, laparoscopic and urological procedure.

KEY WORDS: Renal artery (RA), Renal vein (RV), Supplementary Renal artery (SRA), Early branching (EB), Supplementary renal vein (SRV), Contrast-enhanced Multidetector Computerized Tomography (MDCT).

Corresponding Author: Mrs. Manu Gupta, (Ph.D. Scholar), Batch-2108, C/O Dr. Nisha V Kaul, Professor & HOD, Department of Anatomy, Santosh Medical College and Hospital, Ghaziabad, Uttar Pradesh, India- 201009. E-Mail: manug0409@gmail.com

Access this Article online	Journal Information
Quick Response code	International Journal of Anatomy and Research ISSN (E) 2321-4287 | ISSN (P) 2321-8967 https://www.ijmhr.org/ijar.htm DOI-Prefix: https://dx.doi.org/10.16965/ijar
DOI: 10.16965/ijar.2021.204	Article Information
	Received: 13 Dec 2021 Accepted: 15 Jan 2022 Peer Review: 14 Dec 2021 Published (O): 05 Mar 2022 Revised: 06 Jan 2022 Published (P): 05 Mar 2022

INTRODUCTION

Renal vessels are known for having a broad spectrum of variations. Comprehensive knowledge of the renal vessel variants holds major clinical implications at the time of renal surgeries, interventional procedures and proper interpretation of radiological images. Conventionally, there are two kidneys in a human being, each kidney is supplied by a single renal artery, emerging as the lateral branch from the Abdominal Aorta at the level of a disc between L1 and L2 below the origin of the Superior Mesenteric Artery (SMA). The venous blood of each kidney is drained by a single renal vein into the Inferior Vena Cava (IVC) [1].

Most often encountered morphological variations of the renal artery are (1) Early division of renal artery: when the first branch from the main renal artery takes off before reaching the hilum within under 1.5 cm from the beginning of the renal artery [2]. (2) Variable number of renal arteries: They are known as additional, extra, accessory, aberrant, supplementary and multiple [3].

Bordei et al (2004) [4] classify the renal artery variations as follows:

a) Main hilar renal artery is the biggest orthogonal diameter artery arising from the Abdominal Aorta and enters through the hilum of the kidney to supply it.
b) Hilar supplementary artery as the smaller one run along the main renal artery to reach the hilum of the kidney to supply it.
c) Superior/Inferior polar arteries supply to the respective poles of the kidney.
Morphological variations of renal vein include its variable number knowns as (multiple, supplementary, supernumerary) renal veins, formation (late renal vein confluence) and its unusual course such as (retroaortic and circumaortic) renal veins [5,6].

The veins emerging from the hilum of the kidney and draining into IVC, other than the main hilar renal vein is known as supplementary renal vein [7]. Left renal vein draining into the Inferior Vena Cava by passing posterior to the Abdominal Aorta known as retroaortic left renal vein. When the left renal vein divides into ventral and dorsal limbs that encircle the Abdominal Aorta bypassing from the front and back surface of the Abdominal Aorta and going into IVC referred to as circumaortic left renal vein [8]. Late renal venous confluence is considered when venous branches meet inside 1.5cm from the left lateral wall of the Abdominal Aorta on the left and when venous branches merge inside 1.5cm of the confluence with the IVC on the right side [9]. Knowledge of anatomical variants of renal vessels in each population is essential as morphological variations of renal vessels vary with ethnicity [10].

Aim: Our study aims to evaluate the morphology of renal vessels, their variations & clinical implications during routine diagnostic procedure in the subjects of the North India population by contrast-enhanced MDCT.

MATERIALS AND METHODS

The study was performed on the patients referred to the Department of Radiodiagnosis, Santosh Medical College & Hospital, Ghaziabad and Dr. O.P Gupta Imaging Centre, Meerut for contrast-enhanced MDCT examination abdomen. Prior written consent was obtained from all the patients who were included in the study. Contrast-enhanced MDCT scans of the Abdomen were performed on a 32-slice (Siemens Healthineers) and 128-slice (Di GE Optima 660) MDCT Scanner. Contrast-enhanced MDCT scan images were reviewed for normal anatomy of renal vessels and their variants from April 2019 to October 2021. A proper ethical clearance was obtained from the Ethical committee of the Institute. We followed Bordei et al (2004) [4] classification for renal artery variants in the current study.

RESULTS

In the present study, 108 patients were assessed. Anatomical variations of renal vessels were found in 72 (66.66%) patients. Variations of the renal artery were observed in 56 (77.77%) patients, renal vein in 38 (52.77%) patients and 22 (30.55%) patients showed variations in both the renal artery and vein. Among 72 patients, variations of the renal artery were the commonest as compared to that of the renal vein.

Table 1: Distribution of renal artery variations on the right and left sides or bilaterally.

S. N	Variations of Renal artery	Number of patients showing variations (n=108)	Number of patients with variations on Right side (n=108)	Number of patients with variations on Left side (n=108)	Number of patients showing variations bilaterally (n=108)
1	Supplementary renal artery	**47 (43.5%)**	**31 (28.70%)**	**32 (29.62%)**	**16 (14.81%)**
2	Early bifurcation of renal artery	**17 (15.74%)**	**9 (8.33%)**	**10 (9.25%)**	**2 (1.85%)**

Table 2: Distribution of supplementary renal arteries on the right and left side, according to its type.

S. N	Type of Supplementary renal arteries	Number of patients with variations in right kidneys (n=31)	Number of patients with variations in left kidneys (n=32)
1	One Hilar supplementary artery	**19 (61.29%)**	**17 (53.12%)**
2	Two Hilar supplementary arteries	**1 (3.25%)**	**2 (6.25%)**
3	Three hilar supplementary arteries	**0**	**1 (3.12%)**
4	One superior polar	**3 (9.67%)**	**5 (15.62%)**
5	One inferior polar	**4 (12.90%)**	**4 (12.5%)**
6	One hilar supplementary and one superior polar	**3 (9.67%)**	**2 (6.25%)**
7	Two superior polar	**1 (3.22%)**	**0**
8	Two superior polar and one hilar supplementary	**0**	**1(3.12%)**

Table 3: Distribution of renal vein and its variations.

S. N	Variations of renal vein	Number of patients with variations on Right side (n=108)	Number of patients with variations on Left side (n=108)
1	Single Main hilar renal vein	**99 (91.66%)**	**108 (100%)**
2	Supplementary RV	**9 (8.3%)**	**0**
3	Retroaortic RV	**0**	**2 (1.85%)**
4	Late renal vein confluence	**28 (25.92%)**	**2 (1.85%)**

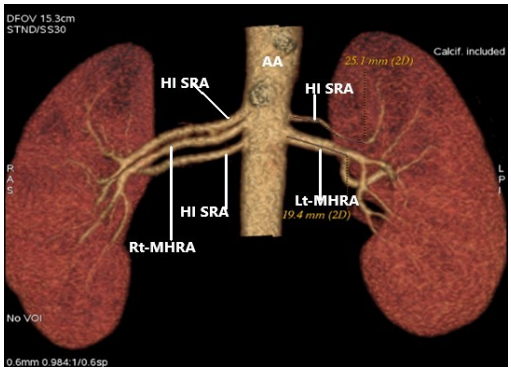

Fig. 1: Contrast-enhanced MDCT image showingtwo Hilar Supplementary renal arteries (HI SRA) on the right side and one Hilar Supplementary renal artery (HI SRA) on the left side.

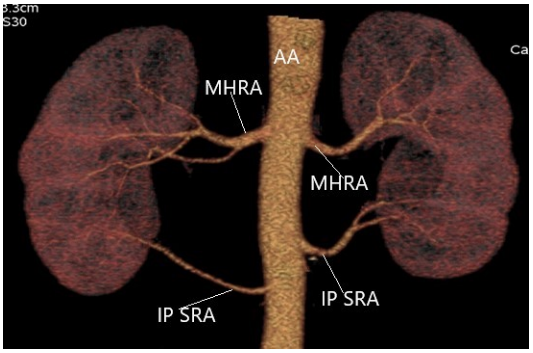

Fig. 3: Contrast-enhanced MDCT image showing one Inferior Polar Supplementary renal artery (IP SRA) arising from the AA on both the sides.

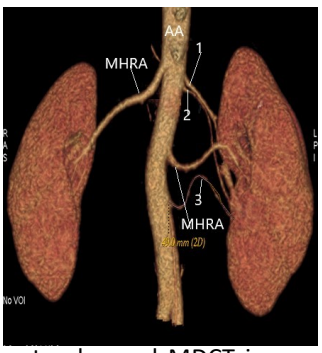

Fig. 2: Contrast-enhanced MDCT image showingthree Hilar Supplementary renal arteries on the left side. (1,2,3 denotes HI SRA on left side).

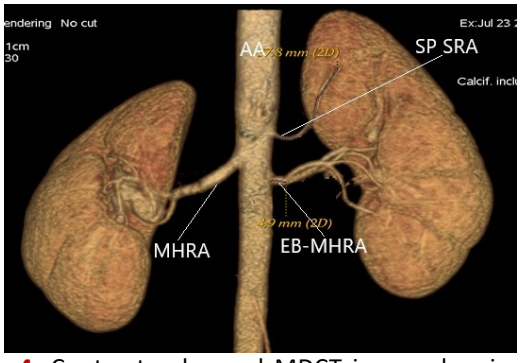

Fig. 4: Contrast-enhanced MDCT image showing one Superior Polar supplementary renal artery (SP SRA) and Early branching of the main hilar renal artery (EB- MHRA) on the left side.

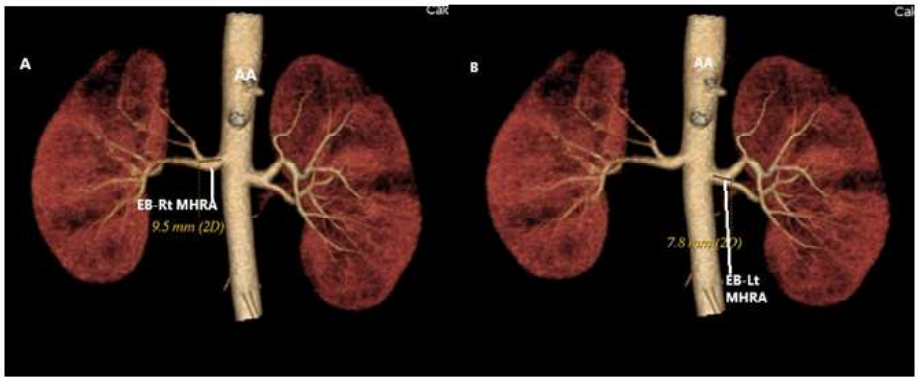

Fig. 5: Contrast-enhanced MDCT image showing Early branching of MHRA (EB-Rt MHRA and EB-Lt MHRA) in both the sides.

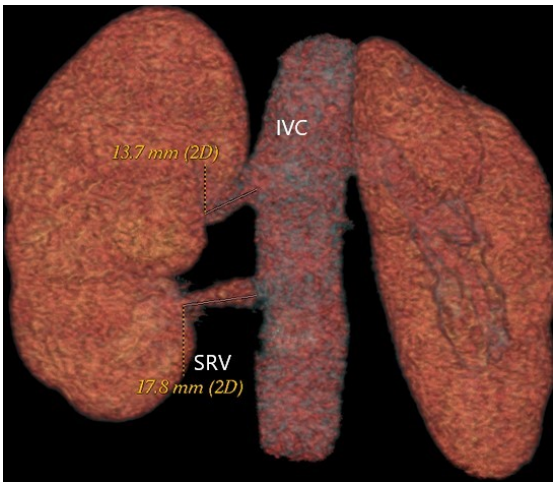

Fig. 6: Contrast-enhanced MDCT image showing one Supplementary renal vein (SRV) on the right side.

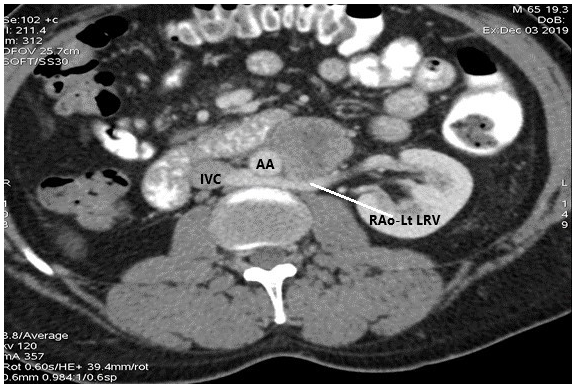

Fig. 7: Contrast-enhanced MDCT image showing Left Retroaortic renal vein (RAo Lt RV).

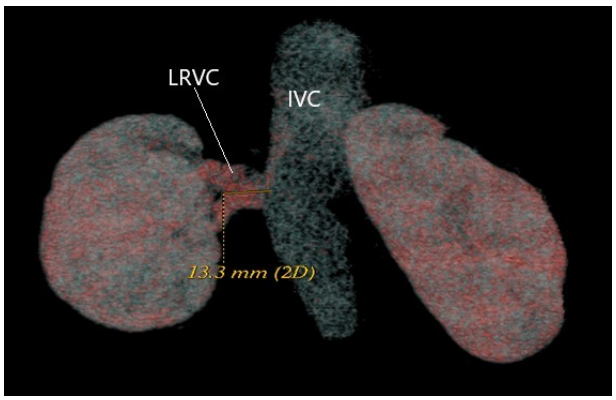

Fig. 8: Contrast-enhanced MDCT image showing Late Renal Vein Confluence (LRVC) on the right side.

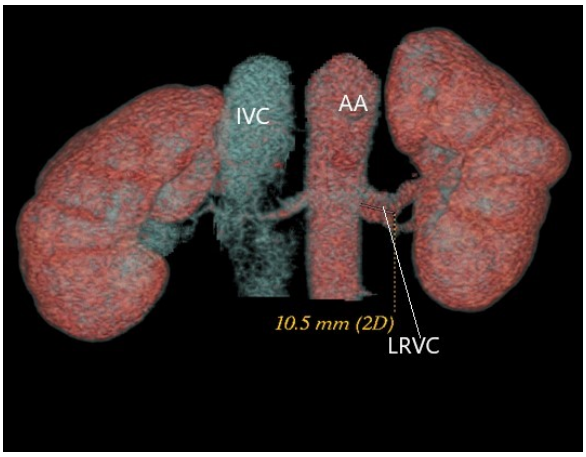

Fig. 9: Contrast-enhanced MDCT image showing Late renal vein confluence (LRVC) on the left side.

DISCUSSION

Renal vessels are renowned for their variations. Awareness and knowledge of the possible variations and anomalies of the renal vessels, their clinical implications and embryological basis are very essential. The current study reports great variability in the blood supply of kidneys with a detailed description of their clinical implications and embryological basis.

Clinical implications of supplementary renal arteries:

1. In the Laparoscopic living donor nephrectomy (LDN), bleeding due to injury of these arteries may culminate into Open laparotomy.

2. Missed case may cause an infarct in a transplanted kidney and associated hypertension in the recipients [11].

3. They may increase the operative time and complexity in both donor and recipient surgeries with resultant risk of arterial thrombosis and also influence the decision of kidney to be donated [12].

4. Supplementary renal arteries may also influence the course of the post-transplantation period.

5. Inferior polar renal artery runs anterior to the ureter at the pyelo-ureteral junction, may obstruct the ureter which can lead to hydronephrosis [13].

6. Inferior polar arteries provide blood supply to the upper of the ureter, if it gets cut or thrombosed, it can cause pyelo-ureteral necrosis leading to stenosis or urinary tract leakage [14].

7. The upper pole renal artery presents a significant danger, since it is often found high up the kidney, implying that in most cases surgeons may confuse it with surrounding connective tissue and accidentally cut through it. This would subsequently cause massive bleeding in the intraoperative field, which frequently prompts a lethal result [15].

Knowledge about early branching of the renal artery is vital in renal transplantation since surgeons need at least 1.5-2.0 cm length of main renal artery trunk before branching for effective arterio-arterial anastomosis [2].

The variable number of renal arteries is based on the development of mesonephric arteries. On either side of the Aorta, these mesonephric arteries supply to the kidneys, suprarenal glands and gonads from the sixth cervical vertebra to the third lumbar vertebra, this region known as rete arteriosum urogenitale. As the development advances these mesonephric arteries degenerate, leaving behind only one main renal (mesonephric) artery. The existence of more than one mesonephric artery forms multiple renal arteries due to the non-obliteration of these mesonephric arteries [16]. The multiple renal arteries can also form during an ascent of the kidney because as the kidney ascent from the pelvis to the thoracolumbar region it receives blood supply from its adjacent arteries like the common iliac and aorta [17].

Clinical implications of renal vein variations: The supplementary renal veins can be vulnerable to injury and danger during Abdominal surgeries particularly during kidney transplantation and retroperitoneal region. These veins increased the risk to donors due to multiple vessels anastomosis, prolonged ischemia time, and inadequately controlled hypertension from segmental infarcts of the allograft [14]. The retro aortic left renal vein might be compressed between the aorta and the lumbar spine prompting left renal venous hypertension which is known as Posterior Nutcracker Condition which is represented by the left flank and abdominal pain with or without hematuria [18]. In the case of circumaortic renal vein, there are more chances of injury because in the presence of the preaortic segment of the renal collar surgeons can mislead this with the belief that the renal vein is normal and this misconception may cause injury to the retro aortic part which leads to hemorrhage and death during retroperitoneal surgery [19]. In the literature, it is found that retroaortic or circumaortic left renal vein may have a connection with the pelvic varicocele and is additionally reported hypertension, hematuria and thrombosis that might be because of an increase in tension in the retro aortic left renal vein [20,21].

Awareness of the renal vein variations is significant in the patients who will have to place IVC filters or in RV catheterization for renin examining.

Variations of renal veins can be explained based on their development. It develops from three pairs of veins Posterior cardinal, Subcardinal and Supracardinal veins, that form in succession from 4-6 weeks of IUL. Renal collar is formed by dorsal Intersupracardinal anastomosis, Ventral intersubcardinal anastomosis and Lateral supra-subcardinal anastomosis. Primitive anterior and posterior renal veins drain into Supra-sub cardinal anastomoses.

The right renal vein develops from the Anterior limb of the primitive right renal vein. Left renal vein forms from Intersubcardinal anastomosis, Left supra-sub cardinal anastomosis and Anterior limb of the primitive left renal vein. Dorsal renal veins of both the sides and Dorsal Intersupracardinal anastomosis usually regress. The unusual persistence of veins that are normally regressed results in renal vein variations [22].

A comparison of our results regarding renal vessels morphometry with previous other researchers is discussed as follows: Gumus H et al (2012) [23] documented variations of renal artery in which extrarenal artery (ERA) were found in 27% and early division (ED) in 26.7% of the patients. In another study conducted by Raman SS et al (2007) [24] found supernumerary and early-branching renal arteries were present in 16% and 21%, of left kidneys and 22% and 15% respectively, of right kidneys.

Majos M et al (2018) [25] analyzed variations of the renal artery were single renal artery (RA) found in 43.35%, single renal artery with prehilar branching in 37.30% and multiple renal arteries in 19.35%.

Zainel MA et al (2020) [26] in the Iraqi population, conclude that 26.3% of the population had aberrant renal arteries. It is more common on the left side (32.1%) than on the right side (20.7%). Bolatli G et al (2021) [27] conducted their study on the Turkey population and detected (25.3%) renal artery variations. Of these 25.3% variations, (17.8%) were early branching and (7.5%) were extrarenal arteries.

In comparison to the above-mentioned studies, the present study was conducted on 108 patients in the North Indian Population. Supplementary renal artery was found in 43.5% and early bifurcation of the renal artery in 15.74% cases. 14.81% of cases had supplementary renal artery on both sides and 1.85% cases had an early bifurcation of renal arteries on both sides. Supplementary renal arteries on the right side were found in 28.70% of cases while in 29.62% of cases on the left side. Early bifurcation of the renal artery was present in 8.33% and 9.25% on right and left sides respectively.

Famurewa OC et al (2018) [28] their study in the Nigerian population and concluded that the inferior polar artery was the most common type of accessory renal artery. In contrast to this, we found hilar supplementary renal artery was the commonest type of supplementary renal artery observed on both sides. Venous variations were late confluence found in 3.0% on right and 2.5% left. Multiple veins were seen 2.5% on both sides and retroaortic left renal vein was seen in 2.0%.

Vedaraju KS et al (2018) [29] found the most prevalent venous variation, is late venous confluence into the IVC, which is more common on the left side (14 out of 20). There were two cases of retroaortic left renal vein and one case of circumaortic left renal vein.

Kumaresan M (2016) [30] analyzed renal veins in 23 individuals from the 100 kidney donors. In this 19 had accessory renal vein and 4 individuals had retro aortic left renal vein.

Jose N et al (2021) [31] found 80.7% had a single renal vein and supernumerary renal veins were found in 17.5%. In contrast to this in the present study single renal vein was found in 91.6% of the patients on the right side and in 100% of patients on the left side. Supernumerary renal veins were found in 8.3% only on the right side which is less frequently found in our study. The Late venous confluence of the renal vein is the commonest renal vein variation, which is mainly found on the right side and no case of circumaortic vein was seen. 2 cases of retroaortic vein were observed same as observed in the given study.

CONCLUSION

The present study has shown that anatomical variants of the renal vessels are a frequent finding among the North Indian Population of India. Variations of the renal artery are comparatively more as compared to the renal vein. Supplementary renal artery is the most frequent type of renal artery variation and late renal vein confluence is the most common type of renal vein variation found in the present study. The morphometric evaluation of renal vessels is useful for planning and performing the endovascular, laparoscopic and urological procedure, using renal fragments for transplantation and medical device development. Knowledge of all the recognized renal vessel variants has important clinical implications in surgical planning, choosing operation side and selection of donors for the renal transplant surgeries.

Author Contributions

Manu Gupta – Concept & Design of the Study and Data Collection, Manuscript preparation.

ORCiD: 0000-0002-5403-6805

Nisha V Kaul: Concept & Design of the Study, Supervision.

Ashish Kumar Shukla- Interpretation of findings and Results

Conflicts of Interests: None

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How to cite this article:

Manu Gupta, Nisha V Kaul, Ashish Kumar Shukla. A Contrast-Enhanced MDCT Study on the Morphology of Renal Vessels, Their Variations and Clinical Implications. Int J Anat Res 2022;10(1):8275-8282. **DOI:** 10.16965/ijar.2021.204