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Evaluation of Renal Arterial Anatomy in Horseshoe Kidney Using Contrast-Enhanced Computed Tomography (CECT)

Research Article

Abhighna G[1*], Vidhyarani R[2], Kushal M[3] and Anughna G[1]

[1]*Junior Resident, Department of Radio diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka, India*
[2]*Professor, Department of Radio diagnosis, Department of Radio diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka, India*
[3]*Senior resident, Department of Radio diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka, India*

***Corresponding author:** Dr. Abhighna G, Department of Radio diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka, India. E-mail id: abhighnag98@gmail.com

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Abstract

Background: Horseshoe kidney (HSK) is one of the most common congenital renal fusion anomalies, characterized by fusion of the lower poles of both kidneys, with an estimated prevalence of 0.25–0.5%.[1] Vascular abnormalities, particularly involving the renal arteries, are frequently associated with this condition and may complicate surgical planning, kidney transplantation, and interventional procedures [2,3]

Objective: This study aims to evaluate the renal artery anatomy in patients with HSK using contrast-enhanced computed tomography (CT) imaging.

Materials and Methods: A prospective analysis of 10 patients diagnosed with HSK was conducted using multi-phase contrast-enhanced CT imaging. Renal arterial variations in number, origin, and course, along with their relationship to the anatomical features of horseshoe kidneys, were systematically examined and analyzed using descriptive statistics to report the incidence of specific variations.

Results: Among the 10 patients evaluated, substantial variability in renal arterial anatomy was demonstrated on contrast-enhanced CT. According to the Graves classification, Pattern II was the most frequent arterial configuration (4/10, 40%), followed by Pattern III (3/10, 30%). Pattern I, Pattern V, and Pattern VI were each observed in 1 patient (10%), while Pattern IV was not identified. Multiple accessory renal arteries were documented in 5 patients (50%), early or late branching in 3 patients (30%), anomalous arterial origin in 1 patient (10%), and normal arterial anatomy in 1 patient (10%). Distinct arterial supply to the renal isthmus was demonstrated in few patients, including vessels arising from the anterior abdominal aorta and the common iliac artery.

Conclusion: Computed tomography offers a highly effective tool for evaluating renal artery variations in horseshoe kidneys, facilitating accurate diagnosis and preoperative planning. Recognition of these variations is crucial for optimizing management strategies in both nephrectomy and renal transplantation procedures.

Keywords: Horseshoe Kidney, Renal Artery Variations, Accessory Renal Arteries, Congenital Renal Anomalies, Renal Vascular Anatomy, Multi-Phase Contrast-Enhanced CT, Renal Vascular Anomalies, Vascular Anatomy, Renal Fusion Anomalies

Introduction

Horseshoe kidney (HSK) is one of the most common congenital renal fusion anomalies and occurs due to fusion of the lower poles of the kidneys during embryological development. It is associated with abnormal renal ascent, malrotation, and variations in vascular anatomy, particularly involving the renal arteries. [1] These vascular variations are of considerable clinical importance because they may complicate surgical, interventional, and endovascular procedures involving the kidneys and abdominal aorta. [2,3]

Contrast-enhanced computed tomography (CECT) has enabled detailed evaluation of renal vascular anatomy and is particularly useful for demonstrating variations in the number, origin, and course of renal arteries in horseshoe kidneys. [4,5]

The present study aims to evaluate the renal arterial anatomy in relation to horseshoe kidneys using contrast-enhanced computed tomography.

Place of study

The study was conducted in the Department of Radio diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka.

Method of Data Collection

Study Design and Study Setting: This was a prospective observational study conducted in the Department of Radio Diagnosis, Sapthagiri Institute of Medical Sciences, Bengaluru, Karnataka, India. The study was carried out over a period of 18 months, from June 2024 to december 2025. The study was undertaken to evaluate the renal arterial anatomy in patients with horseshoe kidney using contrast-enhanced computed tomography (CECT), with particular emphasis on the number, origin, branching pattern, and course of the renal arteries and their relationship to the fused renal parenchyma and isthmus.

Table 1: Representing the different age groups (in years) involved in this study.

Age in years	Number	Percentage
21–30	3	30%
31–40	4	40%
41–50	1	10%
51–60	2	20%

Minimum age of patient included in the study was 22 years and the mean age of participants of the study is 38 years.

Table 2: Renal artery variation pattern.

Category	Cases	Percentage
Pattern I	1	10%
Pattern II	4	40%
Pattern III	3	30%
Pattern IV	0	0
Pattern V	1	10%
Pattern VI	1	10%

Study Population: The study included patients diagnosed or incidentally detected with horseshoe kidney who underwent contrast-enhanced CT examination during the study period. A total of 10 patients were evaluated. The demographic characteristics of the participants, including age and sex, were recorded.

The diagnosis of horseshoe kidney was established on CT based on the characteristic morphological appearance of fusion of the lower poles of the kidneys across the midline through an intervening isthmus. The position of the kidneys, degree of renal malrotation, location and morphology of the isthmus, and relationship of the fused renal components to the major abdominal vessels were also assessed.

Data were collected prospectively during the study period. Relevant demographic details were recorded for each participant. All participants were informed about the purpose and nature of the study, and written informed consent was obtained in their native language before inclusion.

CECT images were systematically evaluated for the number, origin, course, and branching pattern of the renal arteries, including accessory arteries and vessels supplying the renal isthmus. The findings were documented for each patient, categorized according to the identified renal arterial pattern, and expressed as frequencies and percentages.

CT Evaluation of Horseshoe Kidney: Contrast-enhanced CT examinations were reviewed in axial and multiplanar reconstructed images. Coronal and sagittal reformatted images were used wherever required to delineate the renal arterial anatomy and its relationship to the kidneys, renal isthmus, aorta, inferior vena cava, and iliac vessels.

Three-dimensional volume-rendered (VRT) images were also assessed in the available cases to facilitate visualization of the renal arteries and their origins and branching patterns.

Results

Demographic Characteristics: A total of 10 patients with horseshoe kidney were evaluated during the study period. The patients ranged in age from 22 to 60 years, with a mean age of 38 years.

The largest age group was 31-40 years, comprising 4 patients (40%). Three patients (30%) were aged 21-30 years, two patients (20%) were aged 51-60 years, and one patient (10%) was aged 41-50 years. The minimum age of the participants was 22 years.

The demographic distribution is summarized in (Table 1).

Distribution of Renal Arterial Patterns: Considerable variability in renal arterial anatomy was identified on contrast-enhanced CT.

According to the six arterial supply patterns described by Graves, Pattern II was the most frequently observed configuration, occurring

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Table 3: Renal artery variation and pattern.

Cases	Right side renal arteries	Left side	Variation type
1.36Y/M	2 arteries	1 renal artery with subsequent division into 2 branches	**PATTERN II**
2. 39 Y / F	1 Right renal artery directly arising from anterior aspect coursing and supplying the isthmus and the right kidney	2 renal arteries	**PATTERN II**
3. 22Y/M	1 Artery , 1 renal artery with subsequent division into 2 branches	2 arteries	**PATTERN II**
4. 23 / M	1 artery , Another directly arising from anterior aspect coursing & supplying isthmus	1 renal artery with subsequent division into 2 branches	**PATTERN III**
5. 55Y / M	1 renal artery with subsequent division into 2 branches, Another directly arising from anterior aspect coursing and supplying the isthmus	1 renal artery with subsequent division into 2 branches (late branching)	**PATTERN III**
6. 35/ F	1 renal artery with subsequent division into 2 branches, Another directly arising from anterior aspect coursing and supplying the isthmus	1 renal artery with subsequent division into 2 branches	**PATTERN III**
7. 22Y/M	1 artery , 1 renal artery with subsequent division into 2 branches	2 arteries	**PATTERN II**
8. 60Y / F	2 arteries	1 artery	**PATTERN V**
9. 40Y/F	Both kidneys are fused near midline at L4-5 intervertebral disc level with right kidney lower in position in hypogastrium/pelvis. one right renal artery originating from proximal portion of right hypogastric artery	Two left renal arteries originating from lower most portion of abdominal aorta just before bifurcation & seen originating after origin of inferior mesenteric artery	**PATTERN VI**
10. 48Y/M	1 renal artery with subsequent division into 2 branches (late branching)	1 renal artery with subsequent division into 2 branches	**PATTERN I**

in 4 of the 10 patients (40%). Pattern III was the second most frequent configuration and was identified in 3 patients (30%).

Pattern I was identified in 1 patient (10%). Pattern V and Pattern VI were each identified in 1 patient (10%). Pattern IV was not identified in any patient in the present series.

Therefore, 9 of the 10 patients demonstrated arterial configurations other than Pattern I. The distribution of the six arterial patterns is summarized in (Table 2)

Detailed Patient-wise Arterial Findings

Patient-wise evaluation demonstrated considerable variation even among patients belonging to the same arterial pattern.

Case 1: into two branches, while two renal arteries were identified on the right side. The overall configuration was categorized as Pattern II.

Case 2: a 39-year-old female, demonstrated an artery arising directly from the anterior aspect of the abdominal aorta and coursing toward the renal isthmus to supply the fused renal tissue. Two renal arteries were also identified on left side. The configuration was categorized as Pattern II.

Case 3: a 22-year-old male, demonstrated one renal artery with subsequent division into two branches on the right side, with two arteries identified on the left side. This configuration was categorized as Pattern II.

Case 4: a 23-year-old male, demonstrated one renal artery on one side and an additional artery arising directly from the anterior aspect of the aorta and coursing toward the renal isthmus. The contralateral renal artery subsequently divided into two branches. The arterial configuration was categorized as Pattern III.

Case 5: a 55-year-old male, demonstrated a renal artery that subsequently divided into two branches together with another artery arising directly from the anterior aspect of the aorta and supplying the isthmus. On the contralateral side, one renal artery demonstrated late branching into two branches. The overall configuration was categorized as Pattern III.

Case 6: a 35-year-old female, demonstrated a renal artery undergoing subsequent division into two branches and an additional artery arising from the anterior aspect of the aorta and supplying the isthmus. The contralateral renal artery also demonstrated subsequent division into two branches. This was categorized as Pattern III.

Case 7: a 22-year-old male, demonstrated one renal artery on the right side and two renal arteries on the left side. The configuration was categorized as Pattern II.

Case 8: a 60-year-old female, demonstrated two renal arteries on one side and one artery on the contralateral side, with an additional branch arising from the right common iliac artery and supplying the renal isthmus. The arterial configuration was categorized as Pattern V.

Case 9: a 40-year-old female, demonstrated low-positioned fused kidneys, with the right renal component extending into the hypogastric/pelvic region. Two left renal arteries arose from the

Table 4: Percentage of renal artery variations.

Category	Cases	Percentage
Multiple accessory	5	50%
Early / Late branching	3	30%
Anomalous origin	1	10%
Normal	1	10%

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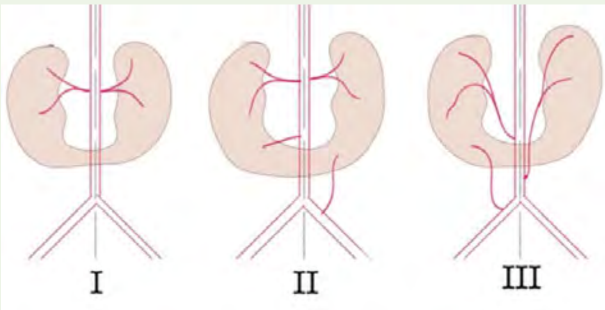

Figure 1: variant arterial anatomy in horseshoe kidney (type 1 renal arteries arising from normal position, type 2 one or more ectopic renal arteries arising from distal aorta or iliac arteries in addition to normal orthotopic renal arteries, type 3 all renal arteries arising ectopically).

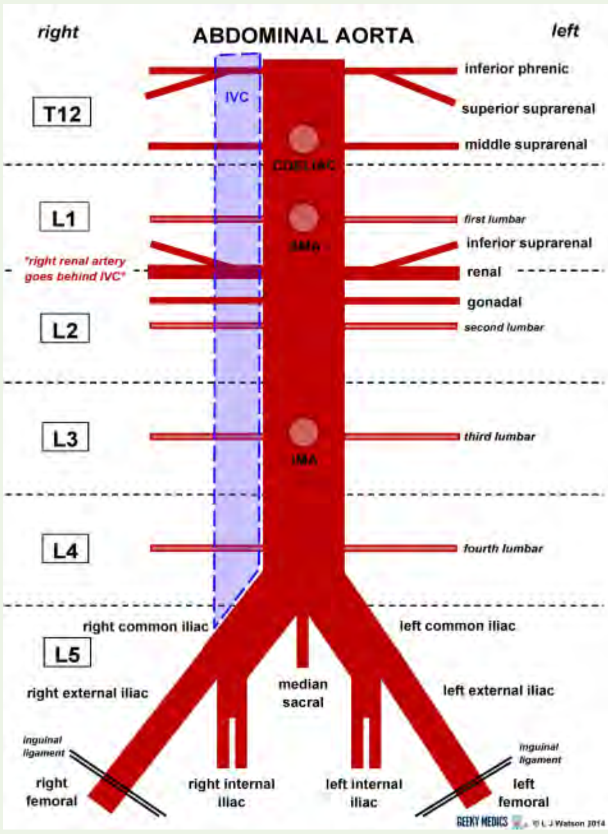

Figure 2: Normal renal artery anatomy.

lowermost portion of the abdominal aorta immediately proximal to its bifurcation and distal to the origin of the inferior mesenteric artery. A right renal artery arose from the proximal portion of the right hypogastric artery. This represented Pattern VI.

Case 10: a 48-year-old male, demonstrated renal arteries with subsequent branching into two branches, and the overall configuration was categorized as Pattern I.

These patient-wise observations demonstrate that the arterial supply of horseshoe kidney cannot be reliably predicted solely from the external renal morphology, and detailed vascular assessment is required to identify the individual arterial configuration.

Accessory Arteries, Branching Patterns and Anomalous Origins

When the arterial findings were grouped according to the major types of vascular variation, multiple accessory renal arteries were identified in 5 patients (50%), making this the most frequent vascular variation in the study.

Early or late branching of the renal arteries was identified in 3 patients (30%). These branching variations included arteries that divided into two branches after their origin and a case demonstrating late branching.

Anomalous arterial origin was identified in 1 patient (10%). In this patient, renal arterial supply arose from unusually low arterial levels, including the hypogastric artery, with additional renal arterial origins from the lowermost abdominal aorta.

One patient (10%) demonstrated the reported normal renal arterial configuration.

Thus, the overall vascular assessment demonstrated that the majority of patients had some form of renal arterial variation, with accessory vessels and altered branching patterns being the

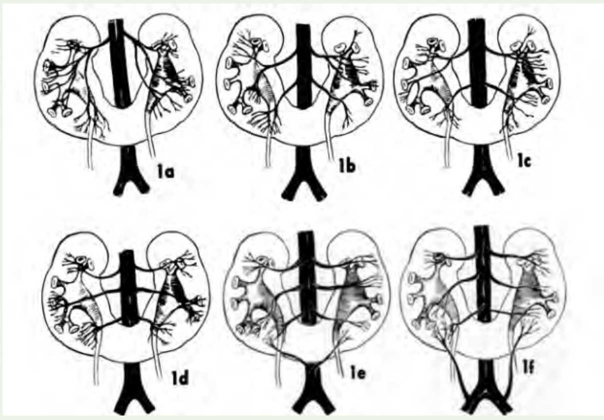

Figure 3: Graves basic patterns.
Graves 6 basic patterns.
PATTERN I The pattern of the blood supply similar to normal kidneys with a single artery supplying the upper, middle and lower segments (Figure. ia).
PATTERN II The upper and middle segment of each kidney supplied by a single artery , each lower segment gets a vessel from the aorta separately (Figure. ib).
PATTERN III The arteries to the lower segments arise from aorta by a common trunk. (Figure.ic)
PATTERN IV The upper and middle segments supplied by single or multiple arteries one either side (Figure id).
PATTERN V Fused segment supplied by arteries which arise below the isthmus. These maybe unilateral / bilateral & may originate from the aorta independently or by a common trunk (Figure. ie).
PATTERN VI Fused lower segments supplied on one or both sides by branches from the common iliac ,rarely from the hypogastric or middle sacral arteries.

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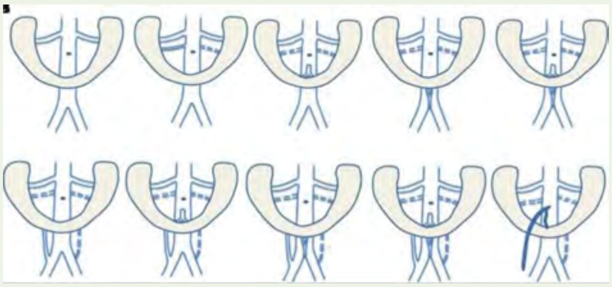

Figure 4: Type 1a-no accessory arteries.
(A) Type 1b-accessory artery from the lateral aorta
(B) Type 2a - accessory artery as the median artery from the anterior of the aorta
(C) Type 2b- accessory artery from the sacral artery
(D) Type 2c-accessory arteries from both the median artery and the sacral artery
(E) Type 3- presence of accessory artery from iliac artery
(F) Type 4a- presence of accessory arteries from the median and common iliac arteries
(G) Type 4b-presence of accessory arteries originating from the sacral and common iliac arteries
(H) Type 4c-accessory arteries originating from median, sacral and common iliac arteries
(I) Type 5- presence of accessory artery from IMA.
Dashed lines indicate the presence of an accessory artery.
Coutesy :Hekimoglu A, Et al Evaluation of renal artery variations in horseshoe kidneys with computed tomography. Urol Res Pract 49: 125.

Figure 5: a. CECT axial section b. coronal section shows bilateral kidneys malrotated with lower poles of kidney fused (figure c shows isthmus) , with two renal arteries(arrow) from aorta ( ) supplying the upper pole of right kidney and one on left side. (pattern II)

predominant findings.

Arterial Supply of the Renal Isthmus

An important finding in the present study was the presence of separate arterial supply to the fused renal isthmus in several patients.

In Cases 2, 4, 5 and 6, additional arteries arising from the anterior aspect of the abdominal aorta were seen coursing toward and supplying the renal isthmus. In Case 8, the isthmus was supplied by a branch arising from the right common iliac artery. These findings demonstrate that the isthmus may have an independent arterial supply and should therefore be specifically evaluated during preoperative CT assessment.

In Case 9, the vascular anatomy was particularly complex, with low-origin renal arteries and a right renal artery arising from the proximal hypogastric artery. The fused kidneys were also positioned low in the abdomen, with the right kidney extending into the hypogastric/pelvic region.

Overall, contrast-enhanced CT demonstrated marked heterogeneity in the renal arterial number, origin, branching pattern, and distribution in patients with horseshoe kidney and these are tabulated in (Table 3) and (Table 4).

Discussion

Horseshoe kidney is a common congenital renal fusion anomaly. The kidneys fuse before their embryological ascent, resulting in an isthmus that is typically located below the level of the inferior mesenteric artery. The renal pelvis is frequently malrotated and may be oriented anteriorly.[1] The arterial anatomy is highly variable, with six blood supply patterns described by Graves in 1969.[7] More than two renal arteries may be seen in horseshoe kidneys, reflecting the

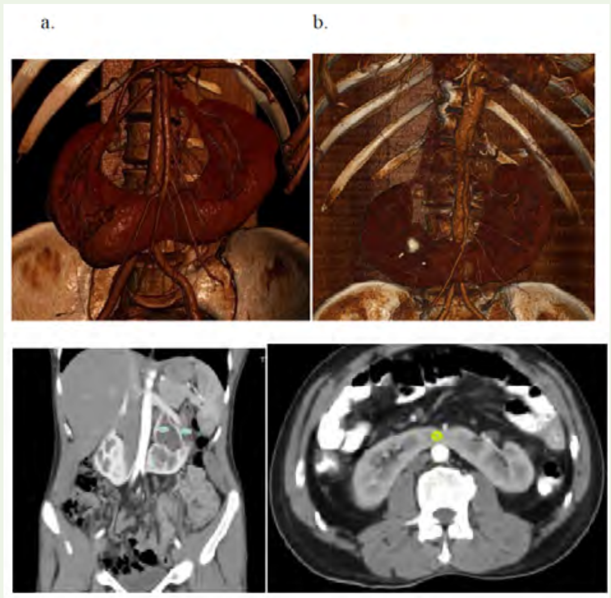

Figure 6: A and B show the VRT images showing horseshoe kidney configuration with lower pole of both kidneys seen pointing medially and fused across midline with anteriorly malrotated renal pelvis.
c and d: coronal and axial CECT images show Bilateral kidneys are fused at the lower pole ( )with two renal arteries supplying the upper and mid pole of left kidney(arrow), an artery from aorta supplying the isthmus. (pattern II).

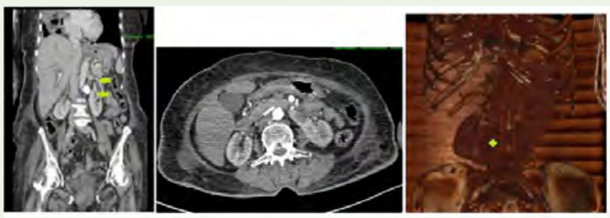

Figure 7: Coronal axial CECT images, VRT image showing horseshoe kidney fusion at lower poles, preaortic -precaval isthmus with 2 renal arteries supplying the left kidney(arrows) – PATTERN II.

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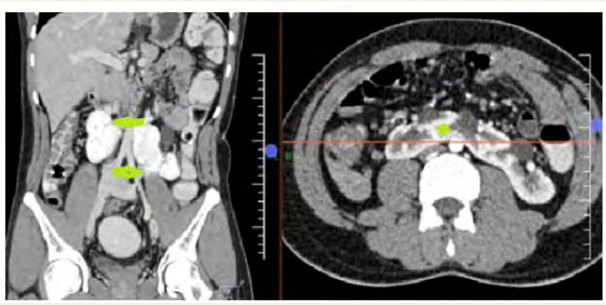

Figure 8: Coronal and axial CECT images showing bilateral kidney anteriorly malrotated hila with lower pole of both kidneys are fuse cross midline by an isthmus of normally enhancing functional renal tissue , 2 renal arteries and 1 artery directly supplying the isthmus – PATTERN III.

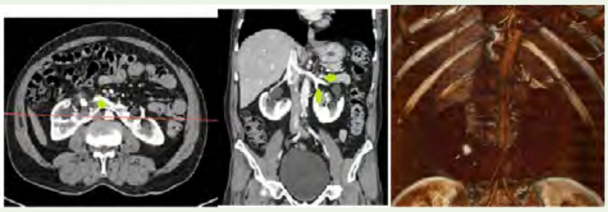

Figure 9: Axial , coronal CECT images , VRT imag ıowing horseshoe kidney with isthmus crossing anterior to aorta and IVC with 1 renal artery dividing into 2 arteries seen on left side(arrows) – PATTERN III.

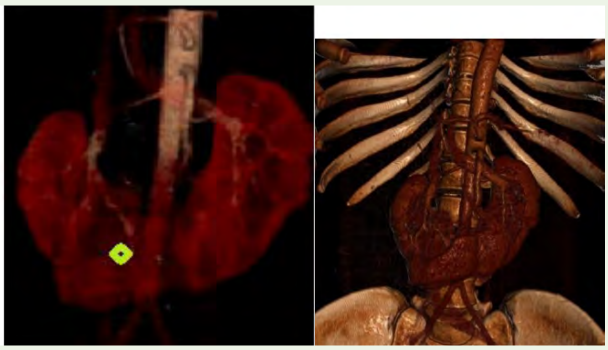

Figure 10: VRT images showing both re lower poles are seen pointing medially and are fused across the midline with 1 renal artery dividing into 2 on either side(PATTERN III) , with additional artery supplying the isthmus.

persistence of embryonic vessels during abnormal renal ascent. [3,7]

Renal arteries in horseshoe kidneys may originate from the abdominal aorta, common iliac arteries, inferior mesenteric artery, and, less commonly, the internal iliac arteries and middle sacral artery. [3,7] The isthmus may have a separate arterial supply, which is important to identify before surgical or interventional procedures. [3,5]

The vascular anatomy of horseshoe kidneys demonstrates considerable individual variation, and CT angiography/CECT is useful for accurately identifying the number, origin, and course of renal arteries. [4,5] This information is particularly important for surgical planning, renal transplantation, nephrectomy, and endovascular interventions. [2,4]

Associated vascular and venous anatomical variations may also occur in patients with horseshoe kidneys. [6,8]

Graves described the arterial anatomy of congenitally abnormal kidneys and emphasized the complexity of vascular patterns in

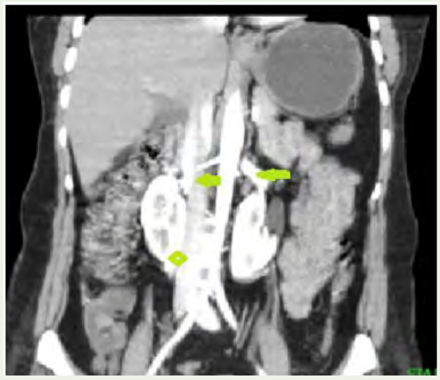

Figure 11: Case7: Coronal CECT image showing evidence of horseshoe kidneys, lower p s of both kidneys are fused with renal pelvis is rotated facing anteriorly with 1 renal artery on right side , 2 on left side- PATTERN II.

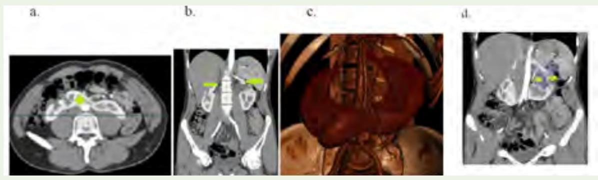

Figure 12: A,B,C,D :Axial , coronal (b, d)and VRT images showing the lower poles of both kidneys are seen pointing medially and seen fused across midline by an isthmus of functioning renal tissue at L3-4 intervertebral disc level, with anteriorly malrotated hila. The junction is in the midline, below the inferior mesenteric artery origin. The ureters arise from the kidneys anterior rather than medially. A branch from right common iliac artery (figure d)supplying isthmus -PATTERN V.

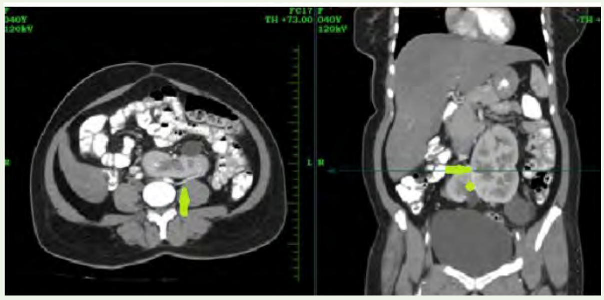

Figure 13: Axial and coronal CECT images showing both kidneys fused near midline at level of L4-5 intervertebral disc level with right kidney placed lower in position in the hypogastrium/pelvis. (Two left renal arteries(arrows) are seen originating from the lower most portion of abdominal aorta just before the bifurcation & seen originating after the origin of inferior mesenteric artery; one right renal artery(arrows)is seen originating from the proximal portion of the right hypogastric artery)– PATTERN VI.

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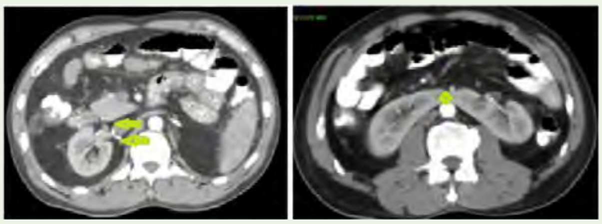

Figure 14: Case 10: Axial CECT images showing horse shoe shaped kidneys with fusion of their lower poles along midline with 1 renal artery dividing into 2 on right side , 1 renal artery on left side – PATTERN I.

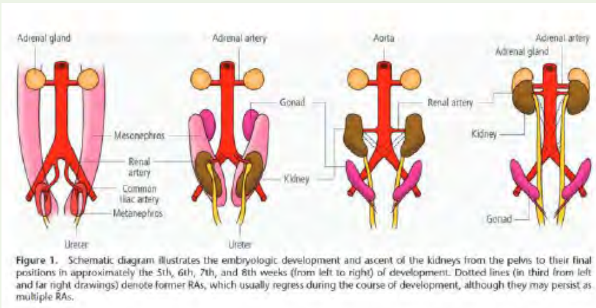

Figure 15: Schematic diagram showing embryological development and ascent of kidneys from pelvis to final position ~ 5, 6 7, 8 th week of development courtesy: langman textbook of embryology.

horseshoe kidneys.[7] Similarly, Boatman et al. demonstrated significant diversity in the arterial supply of horseshoe kidneys through radiological evaluation.[3] Earlier clinical analyses by Glenn also highlighted the association of horseshoe kidneys with various anatomical and pathological abnormalities.[9]

White et al. emphasized the importance of understanding renal arterial anatomy and its variations for accurate diagnosis and safe endovascular management.[2]

The findings of the present study are consistent with the previously described variability in renal arterial anatomy in horseshoe kidneys. The presence of multiple accessory renal arteries and anomalous arterial origins in our study highlights the importance of detailed preoperative vascular assessment using contrast-enhanced CT. [4,5]

Ethical considerations

This study was approved by the ethics committee of Sapthagiri Institute of Medical Sciences.

Limitations

Our study had a small sample size of 10 patients; hence, the findings may not represent the larger population.

Additionally, the study was conducted at a single centre, which may introduce biases related to the specific patient population and healthcare practices at our institution.

Conclusion

Computed tomography offers a highly effective tool for evaluating renal artery variations in horseshoe kidneys, facilitating accurate diagnosis and preoperative planning.

Recognition of these variations is crucial for optimizing management strategies in both nephrectomy and renal transplantation procedures.

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