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Original Research Article

AN OBSERVATIONAL STUDY ON CADAVERS TO FIND THE PREVALENCE OF OCCURRENCE OF ACCESSORY RENAL ARTERIES

Amita Sarkar[1], Barnali Mukherjee[2], Ankita Pal[3]

[1]Professor and HOD, Department of Anatomy, K.P.C. Medical College and Hospital, Kolkata, India.
[2]Associate Professor, Department of Anatomy, K.P.C. Medical College and Hospital, Kolkata, India.
[3]Ex Assistant Professor, Department of Anatomy, K.P.C. Medical College and Hospital, Kolkata, India.

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Corresponding Author:
Dr. Ankita Pal,
Email: palankita85@gmail.com

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ABSTRACT

Background: Accessory renal arteries (ARA) are defined as additional vessels arising from abdominal aorta, either above or below the main renal artery. Understanding these variations is essential for procedures like kidney transplantation, renovascular surgery, interventional radiology and managing medical conditions like renovascular hypertension and abdominal aortic aneurysms. The prevalence of ARAs varies by ethnicity and study methods (cadaveric or imaging based), indicating the need for further investigation to improve clinical decision-making. **Aim:** This study aims to assess the prevalence, origin, number, positional relation of ARA with main renal artery and termination of ARAs in East Indian cadavers and discusses their clinical implications. **Materials and Methods:** This descriptive study examined 30 embalmed adult cadavers (22 male and 8 female) from KPC Medical College and Hospital in Kolkata, West Bengal. Data on the presence, origin, number, termination and relationship of ARAs with the main renal artery were collected and analyzed using descriptive statistics. The Chi-square test was used to determine the significance of the difference in the distribution of accessory arteries between the sides and male and female subjects. **Result:** Of 30 cadavers, 5 (4 male, 1 female) exhibited ARAs, yielding a prevalence of 16.6%. Out of 60 kidneys examined, 5 (4 left-sided and 1 right-sided) showed the presence of ARAs, representing 8.3%. No multiple ARAs or variations in the origin of ARAs from sources other than the aorta were noted. All ARAs had an aortic origin, were singular, and terminated at the renal hilum. Most ARAs originated below the main renal artery. Statistically, the higher origin of left-sided ARAs was significant ($p = 0.02$). **Conclusion**: Awareness of ARAs is crucial for surgeons, radiologists, and nephrologists to optimise surgical outcomes, especially in renal transplantation, endovascular abdominal aortic aneurysm repair, as well as effectively managing associated pathologies like renovascular hypertension.

INTRODUCTION

The renal arteries typically arise as a single pair of vessels from the abdominal aorta to supply the kidney. However, anatomical variations in the renal vasculature are common and are not simply an academic curiosity. Among these, accessory renal arteries (ARA), also known as supernumerary or multiple renal arteries, represent one of the most frequently observed variations. Arising directly from the aorta, these extra vessels supply a portion of the renal parenchyma. Their occurrence is not rare, with prevalence estimates in the general population ranging significantly, with some traditional anatomy textbooks reporting figures as high as 30% of individuals.[1]

Historically, knowledge of ARAs was primarily limited to academic discussions, but with the rise of modern diagnostic imaging techniques and complex renal interventions, their clinical relevance is now widely recognised in a wide range of fields from nephrology and radiology to vascular transplant and surgery. In case of renal transplantation, precise mapping of donor's renal vasculature is critical, as failure to identify and revascularize an ARA can lead to partial kidney infarction and graft failure.[2] Furthermore, ARAs, particularly those that cross and compress the ureter have been implicated as a potential cause of ureteropelvic junction obstruction.[3] In the context of endovascular procedures for abdominal aortic aneurysms, the presence of ARAs must be considered to avoid potential postoperative renal complications.[4] Beyond their surgical complications, the potential association between ARAs and hypertension has been a subject of ongoing research and debate. As diagnostic and therapeutic technologies advance, a comprehensive understanding of ARA anatomy, including its origin, course and termination, is essential for optimising clinical outcomes and advancing treatment strategies.

Objectives

Several studies have been conducted in India regarding the prevalence of ARAs, but there is no data available relating to the same from the eastern part of India, especially West Bengal; hence, this cadaveric study aims to investigate the prevalence of ARAs, their origin, course, termination and their clinical applicability. The possible aetiology of this variation has been explained embryologically.

MATERIALS AND METHODS

The study was conducted on 30 formalin-fixed adult human cadavers irrespective of sex in the Department of Anatomy of KPC Medical College and Hospital, Kolkata, West Bengal. Ethical clearance was obtained from the institutional Ethical Committee before the conduction of this study. Twenty-two (22) male cadavers and eight (8) female cadavers used for undergraduate teaching were used for this study. During the course of the dissection, various abdominal viscera were removed to gain free access to the posterior body wall. The kidneys and the ureters were identified bilaterally. The abdominal aorta, renal artery and its branches, inferior vena cava and renal veins were dissected. The artery arising from the aorta with the largest diameter and reaching the renal hilum was considered the principal renal artery, and all other arteries reaching the kidney were regarded as ARA. All 60 kidneys were carefully observed for the presence of ARAs. If found, the origin of ARAs was classified by the method used by Merklin and Michels,[5] and Budhiraja et al.[6]

i) ARAs arising from the abdominal aorta
ii) ARAs arising from the main renal artery
iii) ARAs arising from other arteries

Additional information about the ARAs, regarding their number, termination and their position relative to the main renal artery and ureter was carefully observed and documented. A descriptive analysis was conducted, and categorical variables were presented as frequencies, percentages. The Chi-square test was employed to assess differences in the distribution of ARAs between the right and left sides and according to gender.

RESULTS

1. Number

Dissection of the posterior abdominal wall was carried out on 30 embalmed cadavers. 60 kidneys (30 right and 30 left kidneys) were observed for the presence of ARAs. ARAs were observed in four left kidneys (13.3%) and in only one right kidney (3.3%) – Table 1. In this study, ARAs were more commonly observed on the left side. The accessory renal arteries were single in all cases, and multiple renal arteries were not observed. The ARA was not found to arise from any other sources like the coeliac trunk, common iliac, testicular, ovarian, etc. The higher occurrence of ARAs on the left side was statistically significant compared to the right side (Chi-square statistic = 5.2, p = 0.02).

Table 1: Side of Occurrence of Accessory renal arteries

Presence of ARA	Number of Left kidneys (Total = 30)	Number of Right Kidneys (Total = 30)	Total number of kidneys= 60
ARA present	4 (13.3%)	1(3.3%)	5 (8.3%)
ARA absent	26 (86.7%)	29 (96.7%)	55 (91.7%)

ARA: accessory renal artery

2. Origin

All accessory renal arteries originated from the abdominal aorta (100%), with none originating from other sources as mentioned earlier.

3. Relation to the main renal artery

The main renal arteries arise normally from the abdominal aorta in all cases. Out of the 4 accessory renal arteries seen on the left side, three of them originated from the abdominal aorta below the main renal artery (Figure 1 and Figure 2), and one took origin from the abdominal aorta above the main renal artery (Figure 3). The accessory renal artery on the right side originated from the abdominal aorta below the main renal artery (Figure 4). These observations have been summarised in Table 2.

Table 2: Relation of Accessory renal artery to main renal artery as per origin from the abdominal aorta

	Above origin of MRA	Below origin of MRA	Total Number of ARAs
Left kidney	1	3	4
Right kidney	0	1	1
Total	1 (20%)	4 (80%)	5

MRA: main renal artery, ARA: accessory renal artery

4. **Termination**

Although ARA can have diverse forms of entry into the kidney, in this study, all the ARAs entered the kidney through the hilum. No accessory polar (superior or inferior) arteries were reported.

5. **Course of Accessory renal arteries**

Out of the 3 left-sided ARAs which were arising from the abdominal aorta below the main renal artery, 2 accessory renal arteries ascend in front of the ureter to reach the hilum (figure 2). Furthermore, in two cases, the testicular artery was found to branch off from accessory renal arteries arising below the main renal artery (Figure 2 and Figure 4). The accessory renal artery, which arises above the main renal artery descends in front of the main renal artery to reach the renal hilum without crossing the ureter (Figure 3). The accessory renal artery on the right side, after passing in front of the inferior vena cava, crosses in front of the ureter to reach the renal hilum. (Figure 4)

6. **Distribution of accessory renal arteries according to gender**

Out of the 22 male and 8 female cadavers studied, 5 cadavers (16.6%) showed the presence of ARAs (4 male cadavers and 1 female cadaver). Despite the higher occurrence of accessory renal arteries in males, this difference was not statistically significant (Chi-Square statistic = 0.13, p = 0.71)

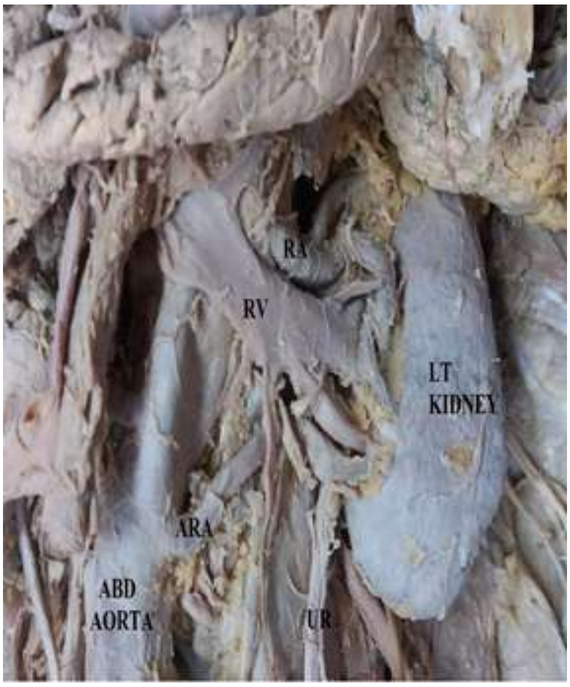

Figure 1: Left Kidney with ARA arising from ABD AORTA and inferior in position to RA. ARA has not crossed the UR in this case

***ARA: accessory renal artery, RA: renal artery, RV: renal vein, UR: ureter, ABD AORTA: abdominal aorta**

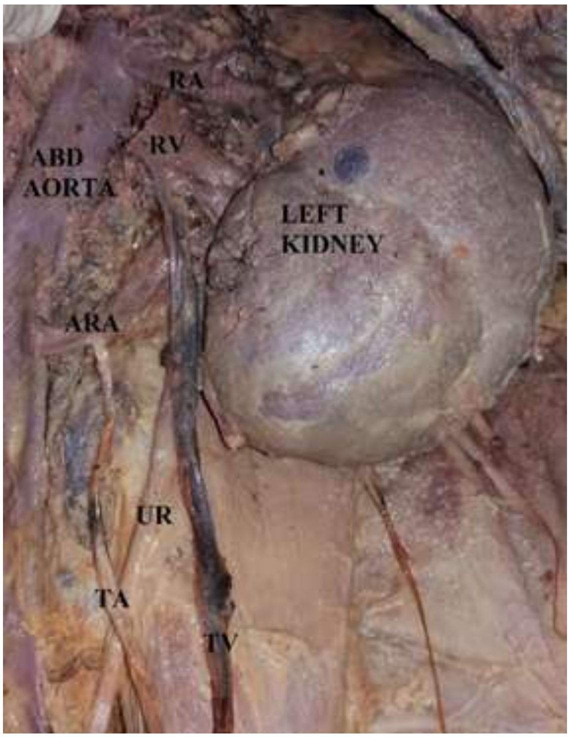

Figure 2: Left kidney showing hilar ARA arising from ABD AORTA below the renal artery and ascending infront of the UR. Left TA is arising from ARA. The left RV receiving left TV has been partially removed for proper exposure of RA.

***ARA: accessory renal artery, RA: renal artery, RV: renal vein, UR: ureter, ABD AORTA: abdominal aorta, TA: testicular artery, TV: testicular vein**

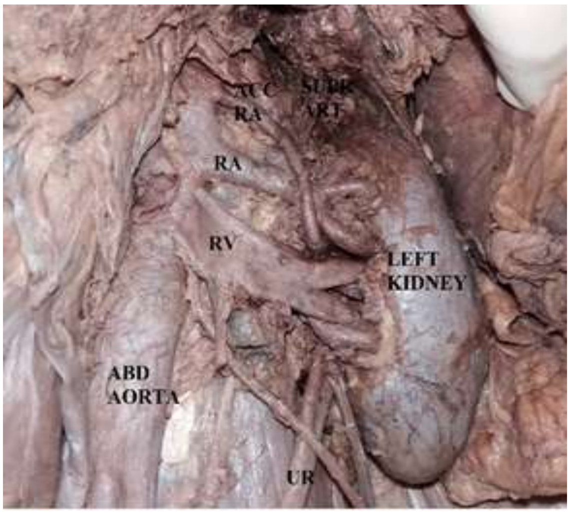

Figure 3: Left kidney showing hilar ACC RA arising from ABD AORTA above RA and not crossing the UR

***ACC RA: accessory renal artery, SUPR ART: Suprarenal artery, RA: renal artery, RV: renal vein, UR: ureter, ABD AORTA: abdominal aorta**

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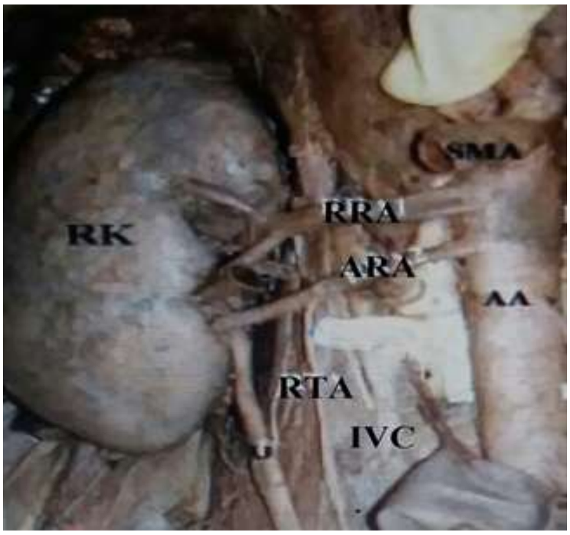

Figure 4: RK showing precaval ARA arising from AA and passing in front of U to reach hilum. RTA arises from AA. SMA has been cut at its origin from AA for proper exposure

***ARA: Accessory renal artery, RRA: Right renal artery, U: ureter, RK: right kidney, ARA: accessory renal artery, SMA: superior mesenteric artery, AA: abdominal aorta, IVC: inferior vena cava**

1. Termination

Although ARA can have diverse forms of entry into the kidney, in this study, all the ARAs entered the kidney through the hilum. No accessory polar (superior or inferior) arteries were reported.

2. Course of Accessory renal arteries

Out of the 3 left-sided ARAs which were arising from the abdominal aorta below the main renal artery, 2 accessory renal arteries ascend in front of the ureter to reach the hilum (figure 2). Furthermore, in two cases, the testicular artery was found to branch off from accessory renal arteries arising below the main renal artery (Figure 2 and Figure 4). The accessory renal artery, which arises above the main renal artery descends in front of the main renal artery to reach the renal hilum without crossing the ureter (Figure 3). The accessory renal artery on the right side, after passing in front of the inferior vena cava, crosses in front of the ureter to reach the renal hilum. (Figure 4)

3. Distribution of accessory renal arteries according to gender

Out of the 22 male and 8 female cadavers studied, 5 cadavers (16.6%) showed the presence of ARAs (4 male cadavers and 1 female cadaver). Despite the higher occurrence of accessory renal arteries in males, this difference was not statistically significant (Chi-Square statistic = 0.13, p = 0.71).

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DISCUSSION

Accessory renal arteries are one of the most frequently encountered anatomical variations in the human body's vascular system. Traditional anatomy textbooks have described ARAs as usually arising from the aorta above or below (most commonly below) the main renal artery and following it to the renal hilum.[1]

The global prevalence of accessory renal arteries (ARAs) shows considerable variability, depending on the methodology used in studies, such as cadaveric dissections and imaging techniques. Research conducted on populations in Bosnia,[7] Brazil,[8] Caribbea,[9] Sudan,[4] and Colombia,[10] reported prevalences of ARAs at 46.2%, 61.5%, 36.1%, 6%, and 24.9%, respectively. Studies from various regions of India consistently indicate a high frequency of ARAs, typically aligning with global observations. Table 3 presents the frequency of accessory renal arteries found in different regions of India. Our study reported a prevalence of 16.6% for accessory renal arteries, which is lower than the rates observed in other regions of India. The differences in findings may be attributed to factors such as sample size and population demographics.

Table 3: Frequency of Accessory renal arteries in different regions of India

Authors/ Reference	Prevalence of ARA	Mode of study	Region of India
Srivastava et al.[11]	25%	CT based	North
Budhiraja et al.[6]	62.2%	cadaveric	North
Patra et al.[12]	30%	cadaveric	North
Singh et al.[13]	30.5%	cadaveric	North
Jonnalagadda et al.[14]	23%	CT based	South
Manoharan et al.[15]	27.7%	cadaveric	South
Jamkar et al.[16]	24.9%	cadaveric	West
Karmalkar et al.[17]	38%	cadaveric	West
Current study	16.6%	cadaveric	East

The prevalence of accessory renal arteries (ARAs) on one side of the body is a topic of debate. Some studies, such as those by Manoharan et al,[15] Saldarigga et al,[10] and Singh et al,[13] suggest that accessory renal arteries are more commonly found on the left side. Conversely, other research conducted by Budhiraja et al,[6] Talovic et al,[7] and Mohammed et al,[4] indicates that right-sided accessory renal arteries are more predominant. Several studies have even reported bilateral ARAs as seen by Dhar and Lal,[18] Saldarigga et al,[10] and Srivastava et al.[11] In the present study, only unilateral renal arteries were seen with left-sided accessory renal arteries being the most prevalent. Furthermore, a statistically significant difference in the side-wise distribution of ARAs was observed in this study. However, other studies,

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including those by Manoharan et al,[15] Srivastava et al.[11] and Prevljak et al,[19] reported that the difference in side-wise distribution was statistically insignificant. Moreover, the present study indicated that there is no statistically significant difference in the occurrence of accessory renal arteries between genders. This finding aligns with the results of Saldarigga et al,[10] Mohammed et al,[4] and Srivastava et al,[11] all of whom reported similar outcomes. In contrast, Jonnalagadda et al,[14] observed a statistically significant higher incidence in males compared to females.

Using the classification by Merklin and Michels,[5] we evaluated the origins of accessory renal arteries (ARAs). We found no cases of an accessory artery originating from the main renal artery, which aligns with the original findings reported by Merklin and Michels. However, other studies have indicated that renal arteries can originate from the main renal artery in 8% (Budhiraja et al,[6]) 14% (Talovic et al,[7]) and even 37.6% of cases (Manoharan et al.[15]) In our study, all of the ARAs originated from the aorta, a rate higher than what is reported in the literature, where the incidence of aortic takeoff ranges from only 30.8% (Talovic et al,[7]) to 47.3% (Budhiraja et al.[6])

Additionally, ARAs can also arise from other sources, such as the superior mesenteric artery (as reported by Patra et al,[12]) the coeliac trunk (documented by Johnson et al,[9]) and the common iliac artery (as observed by Prevljak et al.[19]) The presence of an accessory renal artery (ARA) originating from the aorta on the right side is particularly significant, as it is passing in front of the inferior vena cava (precaval ARA). Precaval ARAs can cause potential compression of the inferior vena cava during procedures like stent placement and endovascular embolization.[15] Presence of multiple ARAs is quite common, with some authors,[10,15,13] reporting as many as double ARAs and even triple ARAs. Nevertheless, these studies also showed that the occurrence of a single ARA was more common than double and triple ARAs. In our study, the ARAs were single in all cases, and no cases of double or triple ARAs were seen.

In the current study, the only type of accessory renal artery (ARA) observed was hilar. While it has been noted that hilar ARAs are the most prevalent, the existence of superior and inferior polar arteries has also been reported by several authors [15,6,12,13,17,7,9]. In contrast, a study conducted on the Sudanese population by Mohammed et al. found that upper polar arteries are actually the more common type of termination compared to the hilar variant. Accessory arteries supplying the inferior pole, which run anterior to the renal pelvis or ureter, may lead to hydronephrosis.[3] This occurs due to obstruction of urine flow at the pelvic-ureteric junction or the proximal ureter. The upper polar accessory renal artery is a significant surgical risk as well as it is often located high on the kidney. Surgeons may confuse it with surrounding tissue and accidentally cut it, leading to severe bleeding and potentially fatal outcomes.[20] The presence of accessory polar arteries poses additional challenges during renal transplantation. Since ARAs are end arteries,[3] consequently, if accessory polar arteries are damaged or lost during the harvesting process, it can result in ischemia of the affected segment and subsequent necrosis of the ureter.[21]

The anatomical relationship between accessory renal arteries (ARAs) and the main renal artery indicates that inferior ARAs are more prevalent, comprising 80% of cases, compared to superior ARAs, which account for 20%. Sykes,[22] has noted that inferior accessory renal arteries are more common. In contrast, Olsson,[23] has stated that superior accessory renal arteries are also frequently encountered.

This study found that the testicular artery instead of originating from the abdominal aorta can arise from the inferior accessory renal artery (ARA). The most common variation in the origins of the gonadal arteries (GAs) is their branching from ARAs, particularly the lower polar ARAs. Research by Panagouli et al,[24] and Shoja et al,[25] indicates that testicular arteries usually emerge from the inferior polar artery. The surgeon should be aware of this possible variation to prevent inadvertent injury to the gonadal artery during retroperitoneal surgeries. Both kidneys and gonads develop from the intermediate mesoderm of the mesonephric crest,[26] with their blood supply originating from the lateral mesonephric branches of the dorsal aorta.[26] The mesonephric arteries are divided into cranial, middle, and caudal groups, with GAs mostly arising from the caudal group, which may persist as accessory renal arteries.

As the embryo develops, the kidney ascends while the gonads descend. When they cross paths, the testis receives two primary branches—one above and one below the kidney—with the lower branch typically atrophying in the final position of the organs.[27] Anomalies during the degeneration of these primitive arteries might lead to above seen variation.

There are two schools of thought regarding the embryological basis of accessory renal arteries (ARAs). The first, most widely accepted theory, proposed by Felix,[28] in 1912, explains the formation of ARAs as follows: The urogenital organs receive blood supply from nine sets of mesonephric arteries that originate from the aorta. These arteries extend toward the mesonephric fold, where their terminal branches create a network known as the rete arteriosum urogenitale. By the time the embryo reaches 18 millimetres in size, this network intersects with vessels entering the renal sinus, establishing a connection between the aorta and the mesonephric arteries. These mesonephric arteries gradually organise into three distinct groups: the cranial group (comprising the first two pairs), the middle group (consisting of the third and fourth pairs, as well as the left fifth artery), and the caudal group (which includes the fifth and sixth arteries on the right side and the sixth and ninth arteries on the left side).

Together, these groups provide vascular support to the developing kidneys. The renal artery originates from the middle group, while the other branches undergo regression. Retention of the remaining arteries in the middle group leads to the formation of accessory renal arteries, typically found between the eleventh thoracic and fifth lumbar vertebral levels.

The second theory,[3] suggests that the metanephric kidneys initially lie in the sacral region. As the abdominal wall grows differentially, the kidneys ascend through the iliac fossa to reach their final position in the lumbar region. In parallel with the ascent of the kidneys, the renal arteries are initially branches of the common iliac artery. Eventually, the kidneys begin to receive blood supply from the distal end of the aorta. Ultimately, the most cranial arterial branches become the renal arteries, which arise from the abdominal aorta. Normally, the caudal primordial branches regress and disappear. However, if these caudal arteries persist, they form accessory renal arteries.

Accessory renal arteries (ARAs) typically do not cause symptoms and are usually identified during screenings or surgeries. Understanding variations in kidney vascular anatomy is crucial, particularly since laparoscopic nephrectomy is the favoured technique for kidney harvesting, which limits visibility and makes it challenging to assess renal vessel details.[29,30] Ideally, a kidney with long renal vessels branching near the hilum is preferred. The left kidney, regardless of whether it has one or two renal arteries, is commonly harvested from living donors. However, if multiple accessory arteries are present, a right nephrectomy might be a better choice.[15] Having more than two accessory renal arteries is often a contraindication for transplant surgery.[2] Since ARAs are end arteries, these arteries must be re-implanted, which requires multiple anastomoses, potentially increasing ischemic time and the risk of renal failure, graft rejection, and reduced graft function.[2] Thus, thorough preoperative knowledge of kidney anatomy is essential for selecting suitable donors, ensuring successful transplants, and minimising complications.

Accessory renal arteries can significantly impact the repair of endovascular abdominal aortic aneurysms. If these arteries are present, adjustments may need to be made during graft deployment and seating. In cases of open aneurysmorrhaphy, careful planning of aortic cross-clamp placement is necessary to avoid inadvertently occluding these critical end arteries, which could lead to renal ischemia.[31,32] This may require modifications to surgical techniques, and the informed consent process should be updated to reflect the increased operative risk. For this reason, computed tomography (CT) is well-established as the primary modality for evaluating abdominal aortic aneurysms, both for diagnosis and treatment planning.[33,34]

The association between accessory renal arteries (ARA) and hypertension has been a controversial topic for years. However, recent research has increasingly provided evidence supporting this connection.[35,36] According to Hagen–Poiseuille's law, Glodny et al. proposed that a longer and narrower ARA may cause a greater drop in blood pressure. This drop results in reduced pressure at the distal end of the ARA, which could lead to hypoperfusion in the renal segment supplied by the ARA. This hypoperfusion may ultimately contribute to increased renin release and hypertension.[37] Additionally, Von Achen et al. discovered that the presence of an ARA is associated with a poorer response to renal denervation (RDN) and a higher prevalence of ARAs among individuals with refractory hypertension.[35]

Non-traumatic renal bleeding from accessory renal arteries though is very rare, can prove to be life-threatening. As an accessory renal artery is tenuous, the diagnosis and localization of the haemorrhage are difficult. New techniques, such as multidetector CT angiography (MDCTA), which can clearly show the accessory renal arteries, provide better approaches for the accessory renal artery disease.[38]

A recent study found a significant link between the presence of ARAs in patients with clear cell carcinoma of the kidneys. It showed that the presence of ARA in kidneys affected with clear cell renal cell carcinoma was associated with larger tumours and higher grades on the Fuhrman grading system, indicating that ARA is a key predictor of high-grade tumors.[39]

CONCLUSION

In this study, we found that 16.6% of cases had accessory renal arteries (ARAs). These arteries typically originated from the abdominal aorta, below the main renal artery, in the majority of cases. All of them were single in number and terminated at the renal hilum in all instances, showing a significant difference in occurrence between the left and right sides, with left-sided accessory renal arteries being commoner than right-sided ARAs (Chi-square statistic 5.2, $p = 0.02$). We also observed that the testicular artery could anomalously originate from an accessory renal artery, which may have implications during retroperitoneal surgical procedures. Advanced imaging technology facilitates the early detection of ARAs, enabling clinicians to inform patients about potential risks such as secondary hypertension and renal cell carcinoma. The presence of accessory renal arteries plays a crucial role in donor selection for renal transplantation, as well as in procedures like renal denervation therapy, endovascular embolisation, and stent placement surgeries. Therefore, this study is particularly important for surgeons, interventional radiologists, nephrologists, and vascular surgeons.

Conflict of interest: There are no conflicts of interest.

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Approval of Institutional ethical review board: Ethical approval for this study was obtained from Institutional Ethics Committee vide letter No. KPCMH/IEC/2022-23/113 dated 07.06.2022.
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