# THE CT ANGIOGRAPHY PATTERN OF RENAL ARTERIAL ANATOMY AMONG AFRICANS AND ITS IMPLICATION ON RENAL TRANSPLANTATION

**A CROSS SECTIONAL DESCRIPTIVE STUDY AT KENYATTA NATIONAL HOSPITAL.**

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## DEDICATION

*This work is dedicated to my father Mzee Erasto Sungura and my dear mother Isabella Ngeleja for their distinguished care and support in the milestones of these achievements.*
*They will always be remembered for how seriously and patiently they struggled for my educational pursuits.*
*It was out of their endless efforts that I became the 1st child to undergo University study from this family of 10 children and also the 1st young man to obtain a degree in Medicine in our village.*
*May God bless them exceedingly.*

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## LIST OF ABBREVIATIONS

KNH – Kenyatta National Hospital

CT- Computerized Tomography

MDCT – Multi Detector Computerized Tomography

MSCT – Multi Slice Computerized Tomography

CTA - Computerized Tomography Angiography

MPR – Multiplanar Reformats

MIP – Maximum Intensity Projection

SSD – Shaded Surface Display.

VR – Volume Rendering

MRI- Magnetic Resonance Imaging

SPSS- Statistical Package for Social Sciences

MBChB- Bachelor of Medicine and Bachelor of Surgery

MMED- Masters of Medicine

NBI- Nairobi

MRA – Magnetic Resonance Arteriography (Angiography)

Vs - Versus

IV-DSA – Intravenous Digital Subtraction Angiography

IA-DSA – Intra-arterial Digital Subtraction Angiography

3D – Three Dimensional

ESRD – End Stage Renal Disease

SD – Standard Deviation

IVU – Intravenous Urography

ARAs – Accessory Renal Arteries

ALARA – As Low As Reasonably Achievable (radiation exposure dose)

BMI- Body Mass Index

# ABSTRACT

**Background**

Renal transplantation is the preferred treatment of patients suffering from end stage renal disease. Apart from improving patients' quality of life, transplantation also confers longevity. Because challenges in performing vascular anastomosis increase significantly in variant renal anatomy knowledge on renal vascular anatomy is very important in the pre surgical workup of potential kidney donors. Ischemic changes commonly occur following attempts to sacrifice extra branches in patients with multiple renal arteries. Other complications may include thrombosis and stenotic lesions increasing the risks of dysfunction in the transplanted kidney. Bleeding is a common complication during laparascopic harvesting of kidneys with multiple arteries. Anatomical patterns of renal arteries vary geographically and ethnically.

**Objective**

The aim of this study was to determine the pattern of renal arterial anatomy among Africans, and its implication on renal transplantation.

**Methodology**

The study was a three-year cross sectional descriptive study conducted at Kenyatta National Hospital from June 2008 to June 2011.

**Findings**

A total of 204 cases including 103 (50.5%) females and 101 (49.5%) males were recruited for CTA. The mean age of participants was 47.16 years (SD 18.32). The prevalence of accessory arteries was 11.3% and prevalence of left sided accessory arteries (7.4%) was higher than right-sided accessory arteries (4.9%). Most normal sized kidneys with accessory arteries had smaller main renal arterial diameters. Extra renal branching occurred in 14.7% of cases.

**Conclusion:** The current value of Renal CTA cannot be easily replaced by simpler noninvasive modalities for indirect and accurate study of renal vascular anatomy of potential kidney donors.

## BACKGROUND AND LITERATURE REVIEW

The kidneys are a pair of excretory organs of the body, situated in the retroperitoneum, one on each side of the vertebral column. [1]

The vascular anatomy of kidneys is very important both medically and surgically, especially since the advent of renal transplantation procedures.

Classically, each kidney is supplied by a single renal artery and a single renal vein, arising from the abdominal aorta and draining into the inferior vena cava, respectively. Renal arteries typically originate from the aorta at the level of L2 below the takeoff of the superior mesenteric artery, with the vein anterior to the artery. Both artery and veins then course anterior to the renal pelvis before entering the medial aspect of the renal hilum. The right renal artery typically demonstrates a long downward course to the relatively inferior right kidney, traversing behind the inferior vena cava. Conversely, the left renal artery, which arises below the right renal artery and has a more horizontal orientation, has a rather direct upward course to the more superiorly positioned left kidney. In addition, both renal arteries course in a slightly posterior direction because of the position of the kidneys.

Anatomical variation is a common finding in renal vasculature where more than one artery supplying a kidney is the most common arterial variation, and this is seen in about 24% of cases [2]. These arteries are divided into two groups: hilar (accessory) and polar (aberrant) arteries. The accessory arteries enter the kidney from the hilum along with the main renal artery, whereas the aberrant arteries enter the kidney directly from the capsule outside the hilum. These accessory/aberrant renal arteries usually originate from the abdominal aorta or iliac arteries; however, they can, on rare occasion, arise from the lower thoracic aorta or from the lumbar or mesenteric arteries.

Early arterial branching or prehilar branching is diagnosed when the first renal branch arises within 1.5 cm of the renal artery ostium. Early branching is seen in about 12% of the population [2].

Presence of Accessory renal arteries however has shown diverse prevalence with different ethnic and geographical variation, for example it has been reported that there are differences in the incidence of ARAs according to ethnic origin (African, 37.1%; Indian, 17.4%; Caucasian, 35.3%; and "Colored" 18.5%. [3]
In Korea the incidence of multiple renal arteries has been reported as 18 to 30% in cadaveric organ procurement. [4]

Renal transplantation is one of the most important clinical applications of renal vascular anatomy.
Renal transplantation is the treatment of choice for people who suffer from End Stage Renal Failure, a medical condition which is increasingly being seen in all corners of the World including Sub Saharan Africa and Kenya.
At End-stage renal disease, the organ(s) failure is so advanced that it cannot be reversed. End-stage renal disease cannot be treated with conventional medical treatments such as drugs. Repeated dialysis and renal transplantation are the only treatment options for these patients to survive. [5]
(i) Dialysis is the term for several different methods of artificially filtering the blood. People who require dialysis experience inconveniences related to their dialysis schedule, fragile health, or maintenance cost.
(ii) Kidney transplantation means replacement of the failed kidneys with a working kidney from another person, called a donor. Kidney transplantation is not a complete cure, although many people who receive a kidney transplant are able to live much as they did before

their kidneys failed. People who receive a transplant must take medication and be monitored by a physician who specializes in kidney disease (nephrologists) for the rest of their lives.

Since the first successful transplant of a kidney from one twin to another in 1954, renal transplantation has moved from being at the cutting edge to being a mature technology. Registry data show that the current survival rates for grafts from cadavers are around 88% and 60% at 1 and 10 years after transplantation, respectively, while comparable rates for grafts from living donors are in excess of 95% and 70% of 1 and 10 year survival rates respectively. [6]
In Kenya, the first Renal transplant was done in 1978 at Nairobi hospital. However many patients have been sent to India for such services over many years now. Currently Renal transplantations are also done at Kenyatta National hospital, Aga Khan Hospital and possible other centers will be coming up in near future. [7]

Renal transplantation is a preferred long term treatment option for patients with End Stage Renal Disease (ESRD). In many places attempts have been made to expand the kidney donor pool following an increasing number of patients requiring renal transplant.
Normally the left kidney is preferred in both Laparoscopic and Open nephrectomies due to their longer renal vein which provide more optimal vessel for venous anastomosis in the recipient. It is however known that not all potential donors have favorable anatomy conducive for left sided laparoscopic donor nephrectomy. Complex vasculature such as multiple renal arteries have been cited as the indication to disqualify a person for renal donation or to consider right sided donor nephrectomy. However, the right sided donor nephrectomy has technical challenges of exposing the right hilum and has shorter renal vein making anastomosis difficult. [8]

Radiology has an important role in initial evaluation of renal anatomy and their vascular pattern for those who are considered to be potential kidney donors. There are two types of Donors

(i) Living Donors - living individual who are willing to donate one of their two healthy kidneys to someone whose kidneys have failed.

A living donor can be a family member or friend who is over 18 years old. The donor is tested, and must be healthy enough to donate a kidney. The donor does not need to be related to a recipient, but relatives will have a higher likelihood of tissue matching.

(ii) Cadaveric Donors – These are those people who have suddenly died, shortly enough before their kidneys are damaged by ischemic changes. [9]

Radiological investigations are mandatory requirements for surgeons to know the pre operative anatomy of the kidney to be donated as well a pre operative planning of the procedure. This radiological anatomy can be achieved by judicial selection of the imaging modality depending on issues of availability, affordability, sensitivity and specificity of the imaging modality. The issues of radiation protection and minimization should always be remembered bearing in mind about 20% of potential kidney donors may be disqualified as living donors due to their complex vascular anatomy associated with presence of accessory renal arteries especially when minimum invasive surgery is to be used for kidney harvesting. [10]

Few studies have been carried out regarding Kidneys and their vascular anatomy. Although Ultrasonography is operator dependent some findings [11] suggest the possibility of using simple and affordable imaging tools like Ultrasonography to predict the presence of accessory renal arteries. This fact can be used to screen potential kidney donors and minimize their exposure to high ionizing radiation such as that emitted by Multi detector CT scan as an initial way of qualifying and disqualifying potential donors. A study by, Suat K. Aytac et al (2003) [11] found a relation between diameter of the main renal artery and presence of accessory renal arteries. In their study they made use of cases undergoing renal intra-arterial digital subtraction angiography for any reason, those with no renal arterial disease detected on digital subtraction angiography were included in the investigation. Accessory renal arteries were disclosed by digital subtraction angiographic examinations. The dimensions of the kidney were measured sonographically. The lowest, highest, and mean values of diameters of main renal arteries were determined by sonography and angiography in both the group with accessory renal arteries and the group without accessory renal arteries. The results of kidneys with sonographically normal dimensions, angiographic evaluation was made in 107, and sonographic evaluation was made in 97, the renal arteries of which could be visualized optimally. Both radiological methods showed that diameters of main renal arteries were significantly smaller in the presence of the accessory renal artery ($P < .001$, Student t test, Mann-Whitney U test, and receiver operating characteristic curve). Sonographically it was concluded that, the presence of the main renal artery with a diameter smaller than usual in a kidney with normal dimensions is indicative of the presence of an accessory renal artery. Taking this into account, we can obtain higher rates of detection of accessory renal arteries in sonographic examinations

Subhash Bernajee et al agrees with the findings of Suat K. Aytac et al. They commented that Accessory renal arteries are found in approximately 15% of patients and may arise from a variety of locations, such as the distal infra-renal abdominal aorta, as in this case. Early anatomic studies considered early main renal artery branching or small renal vessels arising from other vessels (inferior phrenic, adrenal, internal spermatic or ovarian artery) to be accessory renal arteries. The currently accepted convention to define an accessory renal artery is used to indicate more than one renal artery, with each artery arising as a separate branch from the aorta or iliac artery. Detection of these accessory arteries is of great importance when the accurate depiction of renal arterial anatomic structures is required, such as in cases of renal transplantation, surgical reconstruction of the abdominal aorta, renovascular hypertension, and as demonstrated by this report, in planning endovascular peripheral interventional procedures. Though most accessory renal artery dimensions are smaller than that of the main renal artery, the presence of the main renal artery with a diameter smaller than usual in a kidney with normal dimensions is indicative of the presence of an accessory renal artery. [12]

CT scan and other radiological investigations can miss some accessory vessels. In a study done by J. R Ayuso et al; Forty-four percent of candidates had multiple renal arteries in at least one kidney. Seventy-one percent of right kidneys and 76% of left kidneys had a single arterial pedicle. Early branching was observed in 7.8% and 15.7% of right and left kidneys, respectively. Venous variants were present in 17.5% and 13.7% on the right and left side, respectively. Sensitivity, specificity and accuracy of CT to detect accessory arteries were 89%, 100% and 97%, respectively, when compared to DSA. Correlation with surgical data was 93% for the presence of arterial variants. [13]
In another study, N Upendra Kumar et al concluded that Helical CT and 3-D reformatting allows improved vascular imaging and has the potential for future single imaging method for donor evaluation. It just

needs a dedicated radiologist for interpretation. About 10% of renal arteries are not seen on helical CT renal arteriogram when compared with findings at surgery.

In the prospective study done between January 2001 and December 2002, 28 donors were evaluated through pre-operative CT angiography and 20 minute IVU film. The results were compared with intraoperative findings during nephrectomy to determine the accuracy of CT angiography. Donors constituted 21 females and 7 males and all were related donors with mean age of 35.5 years (19 to 55 years).
Results: Intraoperative findings correlated in 25 out of 28 patients (88.75%). Among the other 3 patients, one patient had an upper polar accessory artery, another had a lower polar artery and the third patient had an early branching respectively [14].

Bladimir Saldarriaga et al studied renal artery diameters using direct anatomical examination through cadaveric specimen from the half caste population in Bucaramanga, Columbia and found that there were no significant findings regarding gender but further they noted that Left-hand side renal artery diameter in cases of single renal artery had an average 4.93 mm diameter and 4.8mm on the right-hand side. The main renal artery presented a 3.98 mm diameter (0.86 SD) in kidneys presenting additional renal arteries on the right-hand side and 4.28 mm (0.92 SD) on the left-hand side. These diameters were significantly less than those for kidneys presenting a single renal artery (p= 0.0000).
Regarding renal arteries diameter, this was greater in taller individuals, correlation not being significant between these two parameters = 0.1641 and 0.1876 for the right and left sides, respectively). Taking

the distance from the renal arteries emergence to the origin of the superior mesenteric artery as reference, it was observed that the right renal artery was proximal related to the left one, this difference not being significant in relation to gender. The right renal artery emerged proximally in 60 (49.2%) of the 122 renal blocks having a single bilateral artery; the left was proximal in 20 of them (16.4%) and both arteries emerged at the same level in the remaining 42 specimens (34.4%). The distance in the aorta vertical axis separating the origin of the right renal artery from the left one was 2.9 mm on average. The difference in single renal artery diameter (4.87 mm) was evident in relation to that of the main renal artery when additional arteries were presented (4.15 mm). This characteristic is very important for predicting the presence of accessory renal arteries. The presence of additional renal arteries is very probable (98.8% specificity) when the main renal artery has a diameter of less than 4.15 mm. Kidneys presenting a main renal artery diameter greater than 5.5 mm very probably do not present additional renal arteries (Aytac *et al*). [15]

Pre operative detection of Accessory arteries remains to be a challenge. A study that was done in China suggests that a Multi Detector CT scan can miss those Accessory arteries that are below 1.5mm in diameter. But when they are larger than 1.5mm then depiction is 100% as per study by Zhan Ji-qing et al [16]. It was noted that MDCT images accurately displayed the anatomic structure of the main renal arteries and veins as well as the upper ureters, except in one case with horseshoe kidney. The prevalence of accessory arteries revealed in images was 27.2% (28/103) and early branching was found in 12.6% (13/103). Compared with findings during surgery, the detection of accessory arteries in MDCT images was 85.7% (6/7), and the detection of larger accessory arteries (>1.5 mm in diameter) was 100%. Detection of early branching was 100%. [16]

Another study has shown that the overall agreement between Doppler sonography and angiography was 75%. [17] While CTA outperformed Doppler sonography in this study, there was no significant difference between CTA and sonography in identifying patients whose stenoses required surgery. This lack of significance most likely reflects the relatively small study population, only 28 patients and 56 arteries , study by Link et al as quoted by Peter M. Mac Eneaney et al. [17]

CTA has been proposed as the method of choice for investigating potential kidney donors. Its vascular capabilities include identification of accessory vessels, early branching of the renal artery, and aberrant venous anatomy with an overall accuracy of 95% compared with surgical findings. 25 Axial images alone may be sufficient for evaluation, although 3D reconstructions (MIP and SSD) facilitate identification of important accessory renal vessels. The scan range extends to pelvic inlet to ensure identification of accessory arteries. Typical parameters: 3 mm collimation, pitch of 1.2 to 2, and 100 to 180 mL of contrast at 3 to 5 mL/sec [17]. At Kenyatta National hospital contrast amount used is around 120 mls.

Different modalities have different efficiency in depicting presence of accessory arteries, it is common to miss small accessory arteries which eventually can be realized intra operatively, those which are very small can be ligated without ischemic problems but when they are large then preservation is advocated, David Shaffer et al compared preoperative imaging with intraoperative findings. In patients who underwent preoperative DSA, an accessory renal artery was found intraoperatively in 14% of patients that was not visualized preoperatively. Of 75 patients who underwent preoperative CTA, 9 (12%) had an unexpected accessory renal artery found on the side of the donor nephrectomy. A missed accessory renal artery was noted in 1 of 4 patients who underwent MRA.

Of 26 kidneys with accessory renal arteries not visualized on preoperative imaging studies, 18 (69%) accessory arteries were thought by the recipient surgeon to be insignificant and were ligated. However, 8 (31%) were believed to be large enough or to supply enough renal parenchyma to require preservation. [18]

Preoperative CT and MR angiography of the renal arteries in renal donors demonstrate substantial agreement. Inter observer disagreement in the interpretation of CT and MR angiograms is related to 1-2 mm diameter vessels. Ethan J. Halpern et al performed a comparative study between CT and MR Angiography and found that, CT demonstrated 33 supernumerary arteries in 19 patients, bilateral solitary arteries in 16 patients, and 18 proximal arterial branches in 16 patients. MR demonstrated 26 supernumerary arteries in 15 patients, bilateral solitary renal arteries in 20 patients, and 21 proximal arterial branches in 16 patients. Inter observer agreements for MR ($\kappa = 0.74$) and CT ($\kappa = 0.73$) were similar to the agreement between MR and CT ($\kappa = 0.74$). Among the kidneys chosen for nephrectomy, one small accessory artery and one proximal arterial branch were missed with CT and MR. Two of the accessory arteries suggested at CT were not found at nephrectomy. By averaging data for both modalities, supernumerary arteries were present in 49% of kidney donors and were bilateral in approximately 17%. Proximal arterial branches were present in 46% of kidney donors. [19]

Uday D. Patil et al performed a study which suggests presence of more multiple renal arteries to the left side than the right side. [20]
These kidneys with multiple arteries are not preferred because they may be damaged during their harvest mandating pre transplantation reconstruction procedures to be done. Choi SS et al noted that the incidence of multiple renal arteries has been reported as 18~30% in cadaveric organ procurement. There have been many cases in which the reconstructions of renal arteries were needed because of the use of donor kidney with multiple renal arteries or the injuries of renal arteries during organ harvest. They studied graft survival and function following pre transplantation reconstruction of multiple renal arteries. Between January 1990 and December 1996, they performed 500 renal transplants, among which 65 cases (13%) of the multiple renal arteries were encountered either from the multiple number of donor renal artery itself or from the injury of renal artery during harvest. This again needs skills for vascular surgery. [21]

Renal transplantation is accepted as the preferred treatment for most cases of end-stage renal disease. Despite improvement in surgical and diagnostic techniques, vascular complications following kidney transplantation remain an important clinical problem that may increase morbidity, hospitalization and costs. Post-transplant vascular complications include stenosis or thrombosis of the transplant renal artery or vein, hemorrhage or arteriovenous fistulas after biopsy. Impaired arterial perfusion of the transplant may be an important cause of graft dysfunction or refractory hypertension. Therefore, knowledge of the incidence, clinical manifestations and management of vascular complications is necessary for all kidney transplant surgeons.

In view of this, Salehipour M et al [22] conducted a retrospective study on 1500 consecutive renal transplanted patients (4-70 years old) who received a living or cadaveric donor kidney between December 1988 and July 2006 in a regional transplant center (Nemazee Hospital in Iran). This period was relatively homogenous in terms of general clinical management following kidney transplantation. All transplants were performed by the same experienced surgical team, which was sufficiently trained for performing kidney transplantation. Patients were divided into three groups depending on their donors: Living related, living unrelated and cadaveric. The anatomy and number of renal arteries were noted from the angiography reports, which was performed for all living donors before the operation, and from the operation notes. Vascular complications were diagnosed by using color Doppler sonography that was performed within the first 24 hours in all recipients as well as angiography or surgical exploration, which were performed in clinically suspected cases. The immunosuppressive protocol used in their transplant unit comprised of cyclosporine, Imuran or cellcept, and prednisolone in all study patients. The surgical technique used for all transplantations was the accepted standard procedure of placing the allograft in either the right or the left iliac fossa by using an extra-peritoneal approach. Among the 1500 patients who were in the study, the male: female ratio was 2.05 (1008 males, 492 females). The mean age was 33.92 ± 13.02 years. A total of 1203 patients (80.2%) received kidneys from living donors (616 cases were from living related donors, 587 were from living unrelated ones) and 297 patients (19.8%) received kidneys from cadaveric sources. Vascular anatomic variations noted in the allograft were as follows: 1264 allografts (84.3%) had only one renal artery, 222 (14.8%) had two arteries and 14 allografts (0.93%) had more than two arteries. Furthermore, 1441 kidneys (96.1%) had only one renal vein, and 58 (3.8%) had two veins. One allograft was found to have four renal veins while four kidneys had four renal arteries each.

Clinically apparent vascular complications were seen in 8.86% (n = 133) of all study patients. The most frequent vascular complications were hemorrhage seen in 6.1% (n = 91) of the cases followed by renal arterial stenosis seen in 1.7% (n = 26), renal artery thrombosis in 0.6% (n = 9), and renal vein thrombosis seen in 0.5% (n = 7) of the patients. Rare vascular complications included arteriovenous fistulas and aneurysms (each less than 0.1%). Among the 1204 recipients of living donor kidneys, 96 patients (7.97%) had vascular complications while 37 (12.5%) of the 296 recipients of cadaveric kidneys developed vascular complications (P= 0.017). The frequency of occurrence of vascular complications was significantly higher among recipients of renal allografts with multiple arteries rather than single artery (12.3% versus. 8.2%; P= 0.033). Additionally, only 8.2% of recipients of allografts with single renal vein developed vascular complications while 25.4% of those with multiple veins experienced vascular complications (P< 0.001). There was no significant difference in the frequency of vascular complications between male and female recipients (8.1% versus. 10.4%; P= 0.17). From this study it is suggested that the knowledge of the vascular anatomy is very important for renal transplantation consideration.

Different methods of vascular anatomy studies have been suggested ranging from invasive to less invasive techniques, however among all these methods, Catheter angiography remain to be the gold standard in terms of image sharpness and specificity. Santosh Kumar et al [23] performed a study to assess the accuracy of spiral CT compared with catheter angiography for the assessment of potential renal donors. It was found that Spiral CT angiography has the potential to achieve the diagnostic accuracy of conventional angiography without the risks of catheter angiography. In this study all the patients were accepted for donor nephrectomy. 27 arteries were reported by spiral CT as well as by the conventional angiography (100% accuracy). Review of the axial images, thin MIP and SSD showed all the 27 arteries. Maximum intensity projection and SSD images should be always viewed in conjunction with axial images to avoid missing small arteries. Multiple arteries were reported on spiral CT angiography and digital subtraction angiography in 5 donors (two patients had bilateral double vessels). Early prehilar branching of renal artery was seen in two renal units of the same patient by both spiral CT angiography and DSA. The arteries were assessed for the presence of calcification and stenosis. The details of the venous anatomy were clear in spiral CT angiograms.

Details of the adrenal, gonadal and the lumbar vein joining the left renal vein is seen clearly by viewing reformatted images of the spiral CT at the workstation which is very useful to the surgeon planning a laparoscopic donor nephrectomy. Vascular images of the donor kidneys seen on both the conventional and spiral CT angiography were confirmed for the side that underwent donor nephrectomy. A simple renal cyst was noted on both spiral CT and conventional angiogram in one donor. There were no complications encountered with the conventional as well as the spiral CT angiograms in this series.

It was concluded that Helical CT arteriography is accurate and highly specific for arterial and venous anatomy. It provides vital information needed for the surgical team before open or laparoscopic live donor nephrectomy. At Christian Medical College and Hospital in India, this imaging modality has replaced conventional angiogram and IVU in evaluation for live donor nephrectomy. Helical CT arteriography can become the primary imaging modality for preoperative assessment of potential renal donors. Conventional renal angiography is still the gold standard for identification of arterial multiplicity and fibromuscular dysplasia, and should be used adjunctively if there is an ambiguity.

In addition, MDCT Angiography has shown to be much more useful when a planned nephrectomy is through laparoscopic surgery. [24] Infact ever since it was introduced in 1995, laparoscopic nephrectomy in living renal donors has emerged as a preferred alternative to open nephrectomy. Compared with open nephrectomy, the laparoscopic procedure offers advantages for the donor, including less morbidity, less postoperative pain, less convalescence time, and improved cosmesis. However, laparoscopic donor nephrectomy is technically challenging in part because of the limited surgical field of view compared with open surgery. Accurate preoperative imaging of renal donor anatomy is critical in triaging potential laparoscopic living donors and for anticipating vascular anomalies or variants. Preoperative knowledge of donor renal vascular anatomy and variants helps minimize risk of bleeding to the donor and vascular injury to the renal graft.

William H. Cho et al [25] performed a renal vascular study using Digital Subtracted Angiography (DSA) on series of 52 living renal donors for preoperative evaluation. The preoperative angiographic interpretation was compared with the anatomy found in donor nephrectomy. Standard selective renal arteriography was found to be 100 per cent accurate in defining single or multiple renal arteries. Digital subtraction angiography (DSA) alone performed with an intra-arterial injection of contrast material was found to be 82 per cent accurate in determining the number of renal arteries. In five kidneys with multiple renal arteries, only two had the correct number of vessels identified. The errors are inherent in the DSA technology. It was noted that DSA at the present time is not accurate enough to replace the standard arteriogram in the evaluation of the donor nephrectomy patient.

A study done by A A. Shokeir et al [26] showed that Intra Arterial DSA is superior to Intra Venous DSA though the later may as well be an effective alternative of vascular study.
In the study, Intravenous digital subtraction angiography (IV-DSA) combined with excretory urography (IVU) were utilized to study the renal anatomy of 1000 potential live-kidney donors. In the entire series, 712 donors (71.2%) had bilateral single renal arteries, whereas 255 (25.5%) had unilateral multiple, 26 (2.6%) had bilateral multiple, and 7 (0.7%) had unilateral hypoplastic or absent renal arteries determined by IV-DSA. Major renal abnormalities that might be potentially significant for safe renal donation were detected in 76 donors (7.6%) by combined IV-DSA and IVU studies. In 10% of the potential donors, Intra Arterial digital subtraction angiography (IA-DSA) was required because of the equivocal results of IV-DSA. Of the 1000 potential donors, 700 underwent nephrectomy and the number of renal arteries at nephrectomy was compared with both IV-DSA and IA-DSA reports. Analysis of data revealed a sensitivity of 96% versus 95%, a specificity of 57% versus 75% and overall accuracy of 93% versus 90% for IV-DSA and IA-DSA, respectively. Both IV-DSA and IA-DSA were accurate enough in identification of single renal arteries. However, the accuracy of IA-DSA was better than that of IV-DSA in visualization of double (84% versus 64%) and triple (66% versus 33%) renal arteries. It was concluded that IV-DSA combined with IVU is an effective technique for the evaluation of potential kidney donors. In cases where IV-DSA is equivocal, IA-DSA is recommended for confirmation.

MRA is another possible modality in studying vascular anatomy. It can be done by selecting the proper sequence that can show the vascular structures; normally Time of Flight and Phase Contrast are employed for this purpose. A study done by S. P Tan et al [27] using Three-dimensional (3D) contrast-enhanced magnetic resonance imaging (MRA) has suggested MRI as a noninvasive replacement. In the study they assessed the possibility of using MRA in live renal donors in Malaysia whereas twenty-six consecutive live renal donors were recruited from 2000 to 2002. All potential donors underwent evaluation of the renal arteries using both techniques. Angiographic findings from both modalities were subsequently compared with surgical findings at the time of donor nephrectomy. The total number and diameter of the arteries and the presence of early branching and renal abnormalities were noted.

Both angiographic modalities were able to detect multiple renal arteries with catheter angiography having a sensitivity of 100% and MRA a sensitivity of 97%. MRA missed one 1-mm artery due to a low index of suspicion. Renal artery caliber measurements were not significantly different between the two methods. However, both techniques tended to overestimate the caliber of the renal arteries when compared with measurements taken at surgery. Early branching was found in two arteries at the time of surgery, but only one was detected by both techniques. Renal cysts seen on MR were not detected by catheter angiography.

These findings suggested that noninvasive MRA is a promising substitute for catheter angiography to evaluate the renal arteries of live donors.

Knowledge of kidney size is important for clinical assessment of renal disease. However, there are few studies on methods of assessing kidney size. Kiw Yong Kang et al [28] performed a study with the

purpose of determining the usefulness of body index and radiological measurements for prediction of kidney size.In the study one hundred and twenty five donors were enrolled. The sizes of donor kidneys obtained after nephrectomies for kidney transplantations were documented and the correlation coefficient between kidney length and body index was calculated. Kidney length was estimated from the distance between the first and third lumbar vertebrae (L1-3), intravenous pyelograms (IVPs), abdominal ultrasonography (US), and abdominal computed tomography (CT).
The results of normal adult kidneys were 11.08 ± 0.96 cm long, 6.25 ± 0.67 cm wide, 4.73 ± 0.65 cm thick and weighed 196.3 ± 41.0 g. Correlation coefficients between kidney length and body height, body weight, body surface area and total body water content were 0.29, 0.31, 0.26, and 0.32, respectively. The difference between actual and predicted kidney lengths was −0.6 cm for L1-3, +1.2 cm for IVPs, −0.7 cm for abdominal US, −0.8 cm for transverse CT section, and −0.5 cm for coronal CT section.  Abdominal coronal CT section predicted kidney length more accurately than other radiological methods, but all radiological methods were associated with prediction errors. As kidney length was correlated with body index, it is suggested that body index is the most useful and simplest method of estimating kidney size as an adjunct to treatment decisions concerning renal disease.

Similarly other methods that are suggested include Ultrasonography and Intravenous Urography as shown in the study done by Errol Lewis et al [29] who studied the relation between renal length (L) and the distance between the first four lumbar transverse processes, (4TP) as measured by sonography and intravenous urography, as it was studied in 20 adults with normal urograms. The ratio of L/4TP (Mean ± 2.S.D.) was 1.04 ± 0.22 for sonograms and 1.25 ± 0.26 for urograms. The possible reasons for these differences include issues of magnification.

It is suggested that measurement of the distance between the 4TP is a simple method for estimating expected normal renal size in patients referred for renal ultrasonography.

Variant anatomy of renal arteries is important in renal transplantion, vascular reconstruction, and uroradiological procedures. The variations show ethnic and population differences. Data from Africans are scarce. However recently there has been a study done by Julius A. Ogeng'o et al [30] at the University of Nairobi to cover information about the Kenyan population.

The main objective was to describe patterns of origin, trajectories and branching of renal arteries in a Kenyan population. In this Descriptive cross-sectional study three hundred and fifty six kidneys from 178 cadavers and postmortem specimens were used in the study. Aorta, renal arteries and kidneys were exposed by dissection. Number, trajectories, level of branching, number of branches and point of entry into the kidney were recorded. Data was analyzed using SPSS version 16.0, and presented using macrographs, tables, and bar charts. The results showed Additional arteries in 14.3% of the cases. In 82.4% of these, there was one additional artery. Fifty nine point five per cent of the double renal arteries were parallel and 7.1% crossed. Of the 305 single arteries, 76.4% showed hilar, 21.6% prehilar and 2% intraparenchymal branching. In the hilar branching, ladder type was present in 65% and fork type in 35%. Bifurcation and trifurcation were present in 59.6% and 33.1% respectively. Polar arteries were present in 16.9% cases. It was concluded that over 14% of the Kenyan population may have additional renal arteries while more than 20% show early branching. It was noted that several trajectories and hilar branching patterns exist of which renal transplant surgeons and radiologists should be aware of to avoid inadvertent vascular injury.

According to the applied renal vascular anatomy the first 2 cm from abdominal aorta is surgically very important as most of procedures require at least 2 cm length of the main renal artery from aorta for adequate control of anastomosis. [31]

The following are imaging modalities that can be used to evaluate potential kidney donors, the primary goal is to locate the kidneys, and exclude both anatomical and vascular anomalies.

1. Ultrasound Scan – This is non-ionizing modality, cheap and widely available. It can locate kidneys, measure size, and exclude renal parenchymal disease. The Main renal artery can also be assessed with the aid of color Doppler. It is however limited in direct depiction of accessory renal arteries. [32]
2. Intra venous Urography – It is another imaging method, mainly to locate kidneys and assessing the excretory function. It has ionizing radiation but this is three times less than that of spiral CT scan. [33] It is one of the methods used to estimate kidney size; it does not demonstrate renal arteries.
3. Conventional Angiography – It is an invasive procedure of opacifying renal arterial system, to get images of the renal arterial supply. It is preferably performed as a flush aortogram. It has very sharp arterial images, done as a dynamic study but can have complications related to contrast reaction and technical complications such as hemorrhage, infection, embolism, cardiac arrhythmias, catheter impaction, aneurysm formation and vasovagal syncope. It uses ionizing radiations and involves long exposures to radiation. However studies have shown that this dose is lower than that of Multi slice CT angiography which goes up to more than 14 mSv. [34]
4. CT Angiography – is a non-invasive technique which is widely used now. It has good images. However the technique requires a Multi detector CT to acquire those vascular images and obtain

reconstructed images. Such machines and software are expensive and not readily available in level I and II health facilities. It uses high radiation dose, and in fact CT scan contribute the largest radiation burden in medical exposure that calls for means of exposure reduction. [35] Most surgeons prefer CT Angiography especially when planning for laparoscopic nephrectomies. It has fewer complications compared to conventional angiography.

MRI Renal angiography – It is noninvasive, non-ionizing radiation method sometimes regarded as a One stop shop modality for the pre-operative evaluation of living Kidney donors[36]. However the modality is very expensive for the majority in developing countries. In this regard it may not be a cost effective screening tool in searching for candidates to donate kidneys.

## BASIC PHYSICS OF CT SCAN

CT scan is the medical imaging modality that employs the principle of tomography; The Scanner has an X- ray emitter that rotates around the patient in the axial plane.

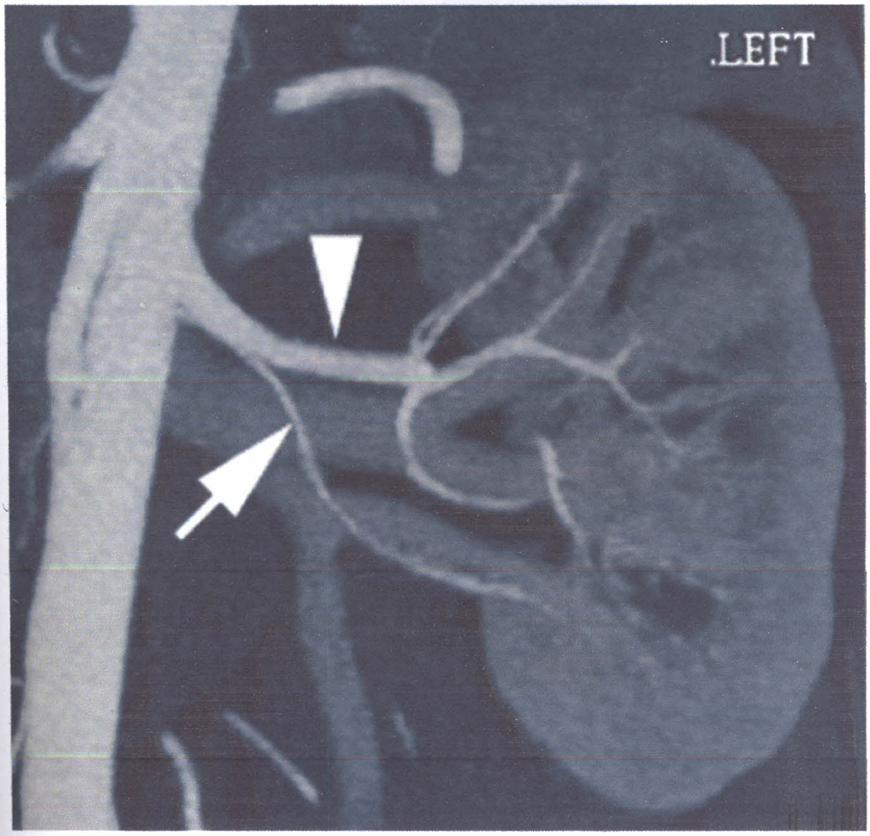
On the opposite side of the patient, 180 degree from this emitter there are electronic X- ray detectors receiving X- ray beam and measuring how much has been absorbed by the patient and how much has been transmitted through the patient. Numeric value is assigned by the computer following calculation of X – ray absorption of each voxel within the slice.

CT scan therefore produces a volume of data that can be manipulated through the process of windowing in order to demonstrate various body structures based on their ability to attenuate X- ray beam sometimes called differential attenuation. However modern CT especially the Multi Detector Scanners allows this volume of data to be reformatted and in various planes or even in volumetric (3D) representation of structures. [37]

## PRINCIPLES CT ANGIOGRAPHY

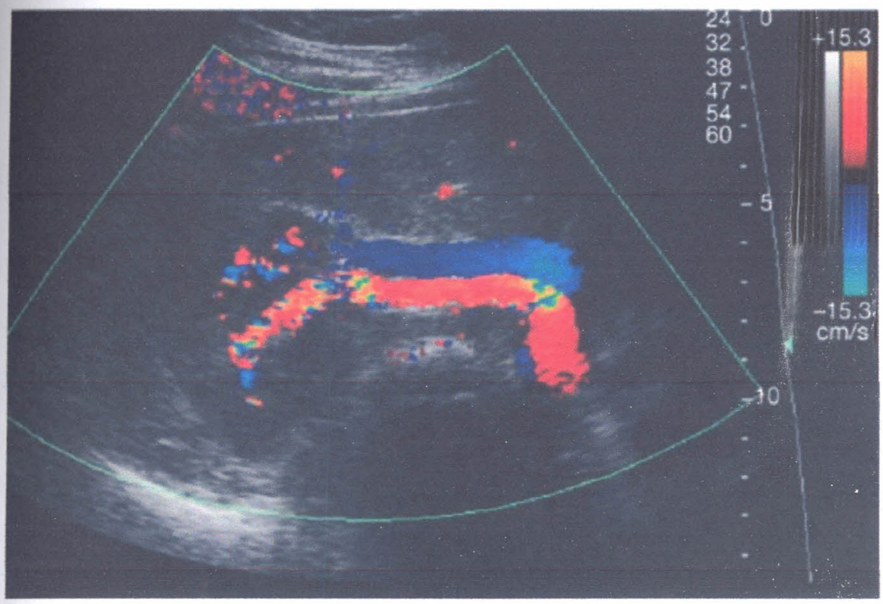
Refinements in detector technology allow new CT scanners to obtain multiple slices in a single rotation. These scanners, called "multislice CT" or "multidetector CT," allow thinner slices to be obtained in a shorter period of time, resulting in more detail and additional view capabilities. Modern CT scanners are so fast that they can scan through large sections of the body in just a few seconds. Such speed is beneficial for all patients but especially children, the elderly and critically ill. When contrast material is introduced to the bloodstream during the procedure usually around 100 to 150 ml of Iodinated contrast by pump bolus injection, [22] it clearly defines the blood vessels being examined by making them appear bright white due to high attenuating capacity introduced by contrast media. Scanning may include arterial phase, venous and delayed phase depending on the objective.

CTA image is basically acquired through Axial scans, however reformats may be needed in order to view pathology better in its long axis. These reconstructions modes include Multiplanar reformatting (MPR) which allow reconstruction along an oblique plane, Maximum Intensity Projection (MIP) which allow display of only brightest pixel at a given location and Shaded Surface Display (SSD) which shows data in 3D as presented by only pixels that are on the surface of an object. Volume rendering techniques (VR) use a combine advantage of MIP and SSD. [38] Volume rendering has emerged as the rendering technique of choice. With volume rendering, the user can actively interact with the dataset, editing and modifying the position, orientation, opacity and brightness of the image in real-time. For CT angiography, volume rendering is commonly performed with a window or level transfer function that results in high density material (for example, enhanced vessels or vascular calcifications) to appear bright and opaque, while less-dense structures appear dim and translucent. Overlying structures are easily removed with an interactive clip plane, and the vessels of interest are easily rotated into the best orientation for depiction of the region of interest. For evaluation of the renal hilum, axial, coronal, and sagittal views are often used in conjunction for optimal evaluation of the number, caliber, and course of the renal arteries and veins. Perspective rendering allow the user to view the dataset from within and around the vessel. [39]




Coronal MIPs from multidetector CT angiography in an adult renal donor showing dominant left renal artery (arrowhead) and small accessory artery (arrow).

Spiral computed tomography (CT) scan: creates detailed three-dimensional images




Renal duplex Ultrasonography. Oblique view of the entire normal right renal artery

## JUSTIFICATION OF THE STUDY

CT Angiography is a useful tool in preoperative assessment of potential kidney donors among imaging modalities with ionizing radiation.

There was a need to perform a study for surveying the pattern of renal vascular anatomy among the Kenyan population using this modality as it has high degree of accuracy and is less invasive compared to the gold standard Catheter Angiography. The modern CT Scans have many reconstructions options such as MIP and VR which provide better information, the option of windowing can as well help subtraction of masking structures like bones.

The need of such a study was further accelerated by the existing scarcity of such vascular data in most of African countries bearing in mind that renal arterial pattern have shown wide ethnic and geographic variations. Currently in Kenya the procedures of renal transplantation are done locally based on radiological information as mandatory initial investigation. The only study of renal vascular system for the local population was done through postmortem cadaveric specimens. It was vital then to do a similar study using imaging techniques to study the living cases, as the study that was done using cadavers did not involve measurement of renal arterial diameters neither did it involve measurement of kidney sizes.

It was presumed that if this study was to be done using CT scan, the findings could establish a roadmap for other studies possibly using modalities with non-ionizing radiation to establish an imaging protocol for investigating potential kidney donors. MRI Angiography is surely a known efficient alternative to modalities using ionizing radiation; nevertheless it cannot be afforded by most of Kenyans.

**CASE DEFINITION**

This study is aimed at evaluating the renal vascular anatomy of the cases brought as potential kidney donors. However as per the definition, potential kidney donor can be any person who avails him/ herself with consent to donate a kidney, also any other person who is in the state of proven brain death or has died just few minutes before and had a written will prior to his death or with full permission of his/her close relatives can be a candidate for kidney donation provided dangerous medical and surgical conditions have been excluded. [9]

It is in this regard therefore, that other patients who came for CT Angiography of other conditions were enrolled in this study provided that the protocol and the contrast given was able to give adequate information on the renal vascular anatomy in both primary axial scans and reconstruction techniques such as MIP and Volume Rendering.

At Kenyatta national hospital the Abdominal CT Angiography was achieved with Iodinated contrast of about 100 to 120 mls by pump injection [17].

Therefore cases included any person whose Abdominal CT angiogram demonstrates renal vasculature in absence of renal or vascular pathology and whose renal vascular anatomy has either evidence of Accessory or aberrant arterial supply or normal single renal arteries. It was important to be noted that in imaging the Abdominal Aorta one could use that advantage to study other Aortic branches such as renal arteries which are as well demonstrated simultaneously. [40]

## STUDY OBJECTIVES

### A. Broad Objective

1. To determine the pattern of the renal arterial anatomy among Africans, and its implication on renal transplantation.

### B. Specific Objectives

1. To determine the radiological prevalence of accessory arteries.
2. To determine which kidney (Right/Left) commonly presents with accessory arteries.
3. To determine the relationship between kidney size and the presence of accessory arteries.
4. To determine the main renal arterial caliber in relation to the presence of accessory renal arteries.

## MATERIALS AND METHODOLOGY

### Area of study

The study was conducted at Kenyatta National Hospital department of radiology. Kenyatta is a tertiary referral hospital, located in the area of Upper hill in the city of Nairobi.

### Study design

Cross Sectional Descriptive Study.

### Study population

These were all cases of patients who were sent to the departments of Radiology to undergo either CT Renal angiography as potential kidney donors or any other Abdominal CT angiography for other reason apart from kidney and vascular pathology as seen between the periods of June 2008 to June 2011.

**Sample size**

The sample size was obtained from the use of statistical formula by Fisher et al (1998) [41], at the confidence interval of 95% and a margin error of 5% and prevalence of presence of accessory renal arteries at 15% [12] [30]. The sample size was calculated as

$$N = \frac{Z^{2} * (p) * (1-p)}{c^{2}}$$

Where p = is proportion of prevalence

Z = standard normal distribution

C = the level of significance desired

When this formula applied at c = 0.05, z = 1.96 and p = 0.15

N = 195 cases

However 204 cases were sampled.

**Sampling methods**

Renal and other abdominal CTA images were retrieved from the computer system and carefully examined for their renal vascular anatomy.

## Exclusion Criteria

1. Patients who came for CT angiography but found to have gross renal disease.

2. Patients with CT angiography with evidence of ectopic kidney and other gross renal anomalies.

3. Patients with poor functioning kidneys or with associated hydronephrosis.

4. Patients with CT angiography but not of an African race in Kenya.

5. Patients with CT angiography under the age of 18 years and above 75 years old.

**Study Limitation**

1. Patients data collection and retrieval was seriously limited by the lack of long term computerized information archiving system such as PACS.

2. The study would be more informative if prospectively done over a long period of time with all other patient information including complications related to renal surgeries.

3. Lack of finance was a major limiting factor, since it could require a lot of funds to pay for the patients for other alternative imaging modalities in order to achieve a comparative study.

4. It was very difficult to achieve a representative sample size by performing this study specifically for those who will have come for purely CT renal angiography for pre transplantation evaluation, therefore recruitment of other patients who have been referred for other abdominal CT angiography to study renal vascular system may subject the study to some degree of errors due to presence of sub clinical medical conditions that may as well affect the quality of renal imaging.

## DATA MANAGEMENT

### Data collection

Patients data especially Inpatient/Outpatient numbers and type of examination were traced from the departmental registration book. Amount of contrast that was given was also traced from procedure book usually documented by the technologist on duty. Using this basic information the images of the patients were retrieved from the computer, scrutinized for its vascular anatomy, measurements done and the results documented in the designed data forms for analysis.

### Data analysis

Data analysis was conducted using statistical package for social sciences (SPSS) version 15. The characteristics of study participants e.g. age and sex were summarized using descriptive statistics. T-tests were used to compare renal findings between different patient groups. Data were presented in form of graphs, pie charts and tables.
Radiological images are presented for selected cases.

### Technique

Counterchecking that, the indication for Abdominal CT Angiography was primarily for renal arterial study or any other abdominal condition which does not interfere with the renal vascular anatomy.

## ETHICAL CONSIDERATION

Before commencement of this study, a research proposal was submitted to the Kenyatta National Hospital Ethical committee and a written approval was obtained.

In this regard patients' names were not recorded in order to ensure confidentiality. Information obtained from the patient was strictly confined to academic use only. There was no referral case made nor situations arise that necessitated a shared confidentiality during the study period.

Patients were not subjected to another payable examination for the sake of this research apart from a normal course of management as when it was needed by the clinicians.

## RESULTS

A total of 204 cases undergoing CT angiography at KNH were recruited in this study. The basic demographic characteristics of these cases are summarized in the section below.

### Demographic characteristics

The study sample comprised 103 (50.5%) females and 101 (49.5%) males giving a male-to-female ratio of approximately 1:1. The mean age of the cases investigated was 47.16 years (SD 18.32). The age range of the study cases was 18 years to 75 years. The average age of male patients was 47.92 years (SD 18.23) and the average age of female patients was 46.41 (SD 18.46). There was no statistically significant difference in the age of male compared to female patients, *t* statistic = 0.58, p value = 0.56. The percentage distribution of the cases is presented in Figure 4.1.

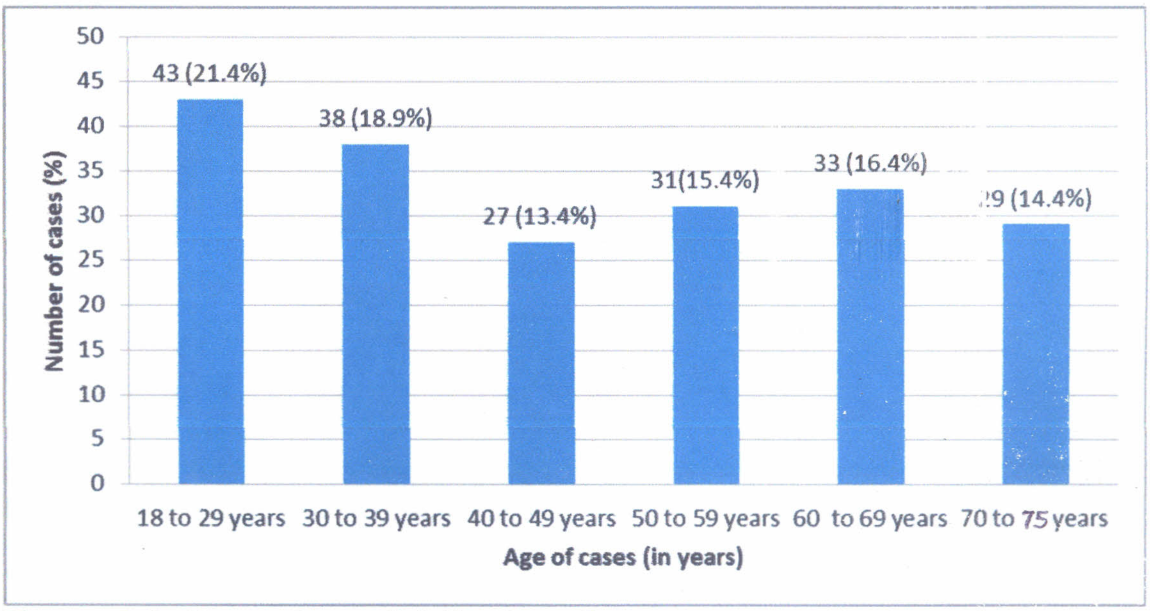



Figure 4.1: Percentage distribution of age among patients undergoing CT angiography in KNH.

The study cases were similarly distributed across the different age groups. Most of the cases were in the youngest age group below 30 years constituted 21.4% (n = 43) of the cases. The remaining age groups each had between 13.4% and 18.9% of the cases.

**Prevalence of renal accessory arteries**

The radiological prevalence of accessory renal arteries among the African cases included in this study was 11.3%. As shown in Figure 4.2 below this represented 23 out of the 204 participants. Among these 23 cases who had accessory arteries, 7 (3.5%) cases had unilateral left accessory arteries, 5 (2.5%) had unilateral right accessory arteries, two (0.98%) patients had bilateral accessory arteries and one (0.5%) case had two left accessory arteries.

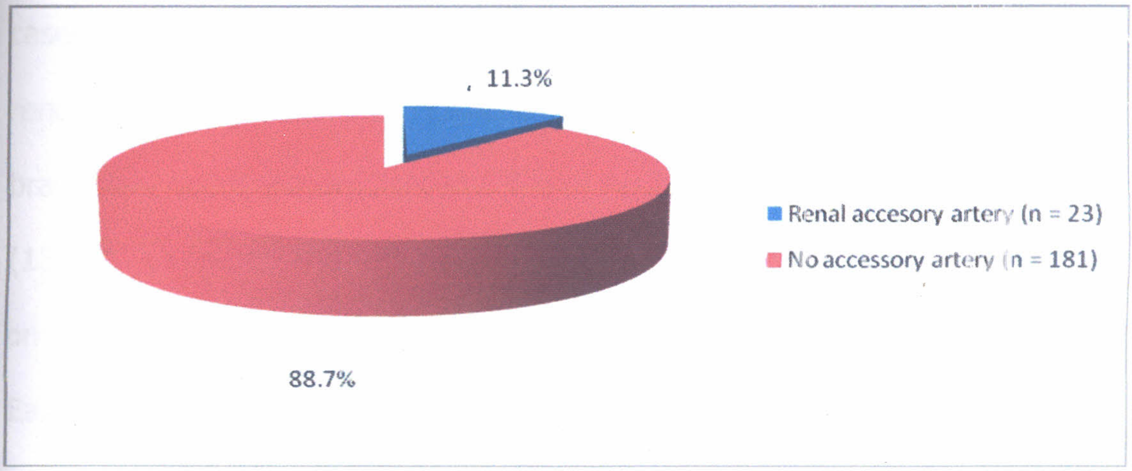



Figure 4.2: Prevalence of radiological confirmed accessory renal artery in African cases at KNH.

The overall prevalence of presentation with a left accessory renal artery was slightly higher among cases compared to the presentation with a right accessory renal artery. Fifteen (7.4%) of the cases had a left accessory artery compared to 10 (4.9%) of the cases presenting with a right accessory artery. However, this difference in the prevalence of presentation with right or left accessory arteries was not statistically significant when the percentages were compared using a two sample test of proportions (difference = 2.5%, $z$ statistic = 1.03, p value = 0.3).

**Extra renal branching**

Extra renal branching was identified in 30 out of the 204 cases representing a prevalence of 14.7%. Bilateral extra renal branching was seen more commonly than unilateral branching. Among the 30 cases with extra renal branching, 23 (11.3%) cases had bilateral extra renal branching while the remaining 7 (3.43%) cases of extra renal branching occurred unilaterally. Extra renal branching occurred in 27 (13.2%) cases on the left hand side kidney and in 26 (12.7%) cases on the right kidney.

Early extra renal branching was rare and occurred in only 5 (16.6%) out of the 30 cases. Most of the extra renal branching in both the left (24 out of 27) and right (24 out of 26) kidneys occurred more than 2 cm from the kidney.

**Kidney size and presence of accessory arteries**

Results of a two sample paired *t*-test comparison of the size of the left and right kidneys are presented in Table 4.1. On average, the left kidneys among the study cases were significantly larger than the right kidneys in terms of length ($p < 0.001$), height ($p = 0.05$), width ($p < 0.001$) and volume ($p < 0.001$).

Table 4.1: Average size of right and left kidney determined using CT angiography

| | Right kidney | Left kidney | Difference (95%CI) | t-test p value |
|---|---|---|---|---|
| Kidney size | Average (SD) | Average (SD) | | |
| Length (mm) | 94.1 (12.3) | 98.0 (13.1) | -3.9(-5.1 to -2.7) | < 0.001 |
| Height (mm) | 46.4 (8.0) | 47.3 (7.0) | -0.88(-1.8 to 0.001) | 0.05 |
| Width (mm) | 48.2 (7.9) | 51.4 (9.2) | -3.2(-4.3 to -2.0) | < 0.001 |
| Volume (mls) | 114.1 (39.2) | 127.2 (45.1) | -13.0 (-16.7 to -9.4) | < 0.001 |
| Main arterial diameter (mm) | 5.33 (1.28) | 5.92 (1.28) | 0.596 (0.48 to -0.71) | < 0.001 |

The length of the left kidney was greater than the right kidney in 144 (70.6%) of the cases in this study. The average difference in kidney lengths between the left and right kidney was -3.9 mm (95% CI, -5.1 to -2.7). In terms of height and width the left kidney exceeded the right kidney in 56.3% (n =115) and 67.2% (n = 137) of cases, respectively. The average difference in kidney height was -0.88 mm (95% CI, -1.8 to 0.001) and the average difference in width was -3.2 mm (95% CI, -4.3 to -2.0).

The results of a logistic regression to predict the presence of accessory arteries based on the size of kidneys only are shown in Table 4.2. These findings showed that it was not possible to predict the presence of an accessory artery based on kidney size alone.

Table 4.2 logistic regression analysis of kidney size and presence of an accessory renal artery

| | Odds Ratio | 95% Confidence interval | | P value |
|---|---|---|---|---|
| **Regression 1** | | | | |
| Left accessory artery | | | | |
| Length | 0.98 | 0.93 | 1.04 | 0.53 |
| Height | 1.00 | 0.88 | 1.14 | 0.98 |
| Width | 1.02 | 0.95 | 1.09 | 0.59 |
| Volume | 1.00 | 0.98 | 1.03 | 0.72 |
| **Regression 2** | | | | |
| Right accessory artery | | | | |
| Length | 1.02 | 0.92 | 1.14 | 0.65 |
| Height | 1.12 | 0.96 | 1.30 | 0.16 |
| Width | 1.06 | 0.90 | 1.24 | 0.51 |
| Volume | 0.98 | 0.94 | 1.03 | 0.51 |

**Main renal arterial diameter and presence of accessory arteries**

The average arterial diameter of left renal artery was on average greater than that of the right artery ($p < 0.001$). As shown in Table 4.2 above, the mean arterial diameter for the left side kidney among cases in the study was 5.92 mm compared to 5.33 mm recorded for the right artery diameter, difference = 0.596 (95% CI, 0.48 to -0.71). Figure 4.3 shows the association between mean arterial caliber and the presence of accessory arteries.

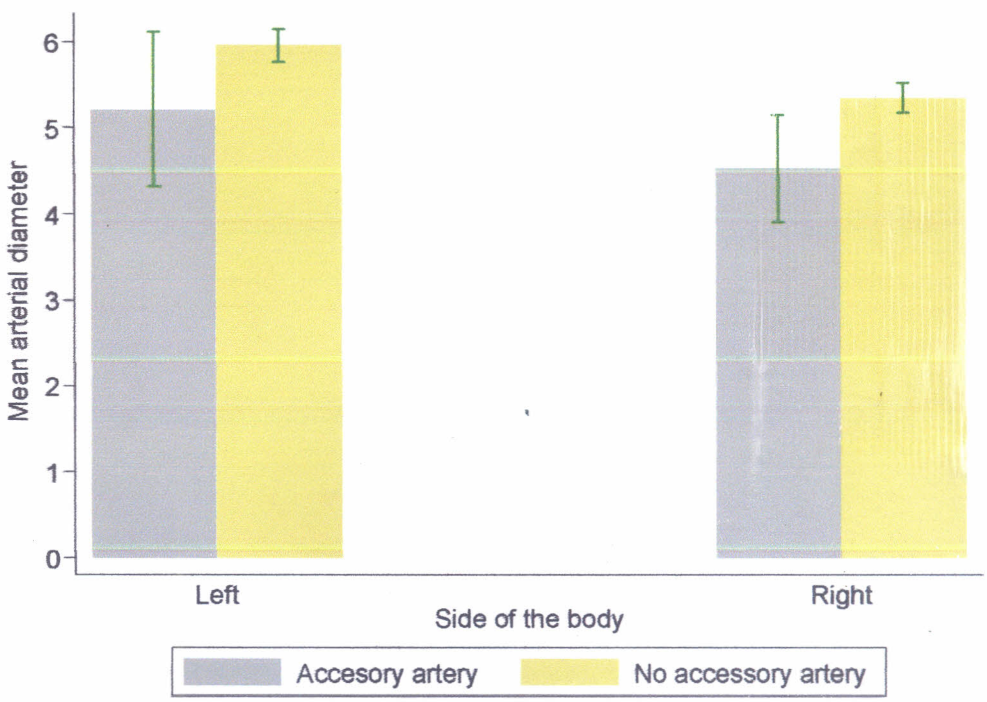



Figure 4.3: Main renal arterial diameter and its association with accessory artery presence

On average, the mean arterial diameter for patients with accessory arteries was less than that of patients without accessory arteries. These differences in main arterial caliber was statistically significant for the right sided kidney as presented in Figure 4.3 above (mean = 5.35 mm versus 4.53 mm, p = 0.016). There was evidence that the diameter of the main left renal artery was less in patients presenting with left  accessory arteries but this difference was marginally significant (mean = 5.96 mm versus 5.21 mm, p = 0.097). Similarly, it was observed that the right diameter were significantly less for females compared to males (p = 0.041), but the difference in left renal artery diameters was not statistically significant in relation to gender (p = 0.08)

**ILLUSTRATIONS**

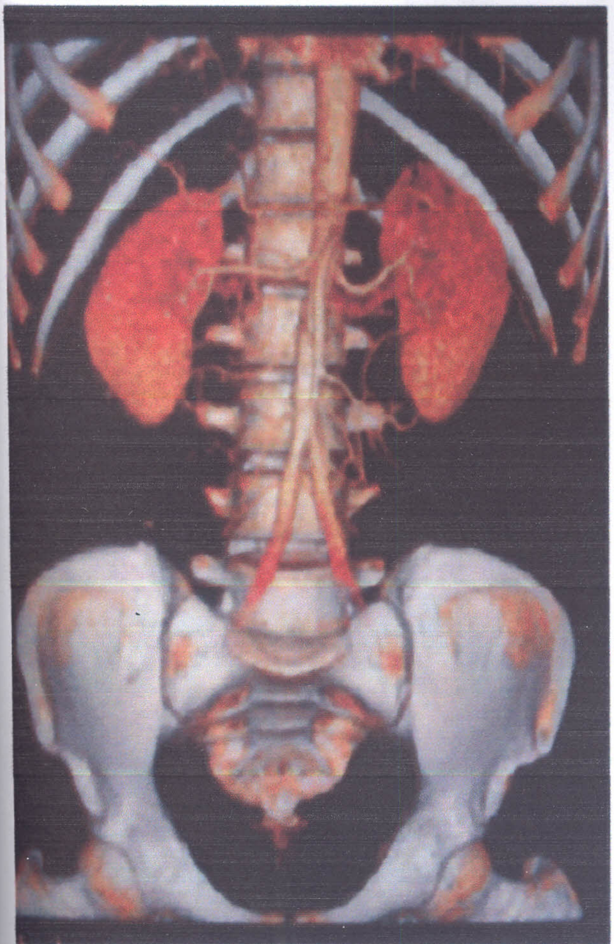


**Fig 4.4** Volume rendering image of normal Renal CTA.

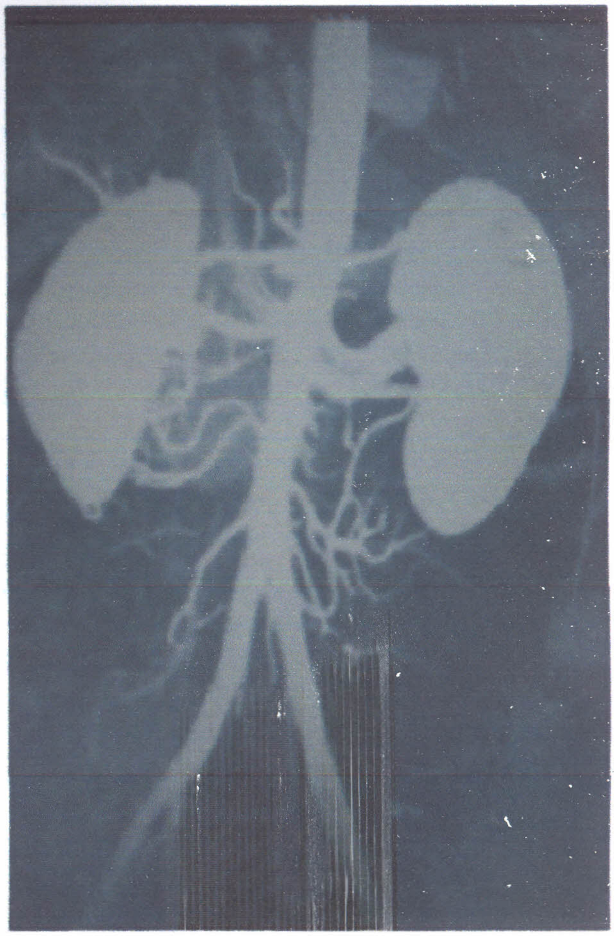


**Fig 4.5** MIP image of normal renal CTA demonstrating normal single renal arteries.

Both images were acquired from an adult 37 years male potential donor seen at KNH; a left nephrectomy was done thereafter.

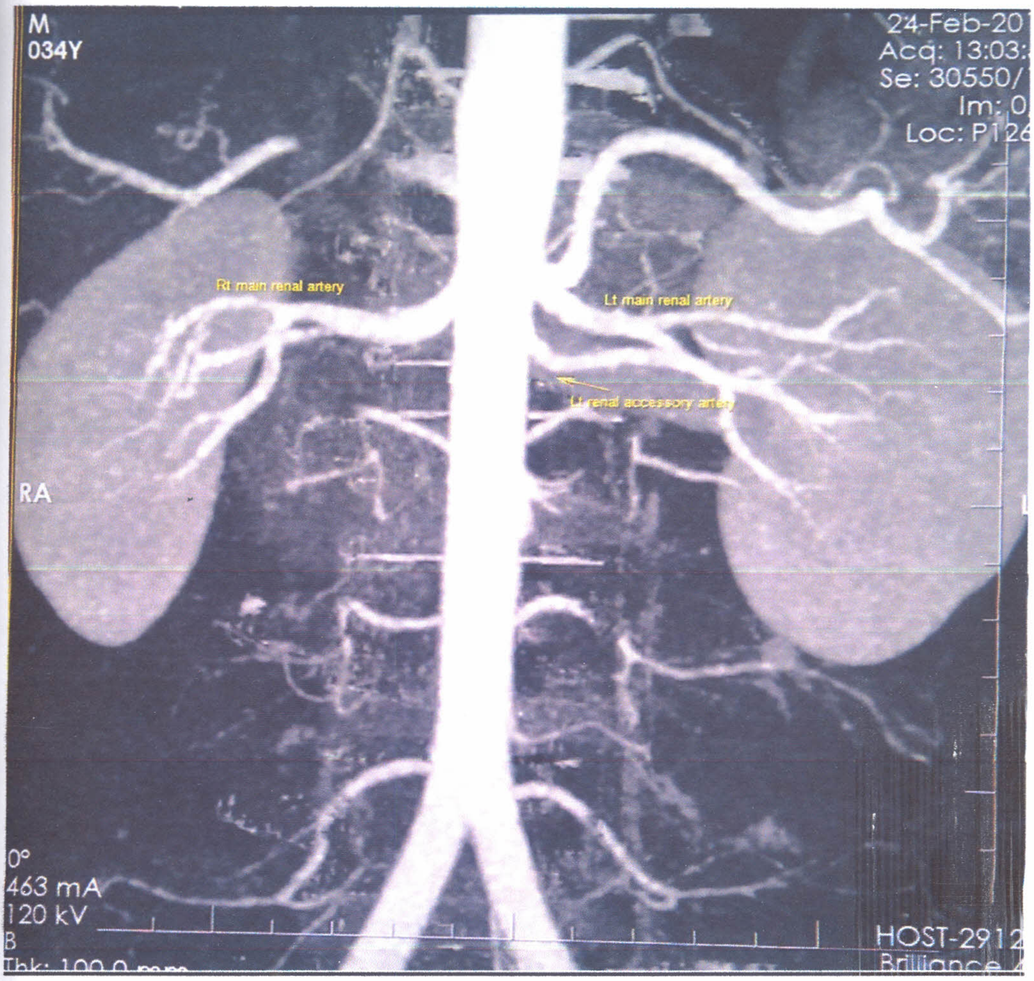



**Fig 4.6** MIP Renal CTA of an adult 34 years male potential donor with left accessory renal artery.

Right: Length x Height x width (9.83x4.59x4.38 cm) size

Main renal artery diameter = 4.8mm

Left: Length x Height x width (10.0x4.48x4.93 cm) size

Main renal artery diameter = 3.8mm

Accessory artery = 2.3mm.

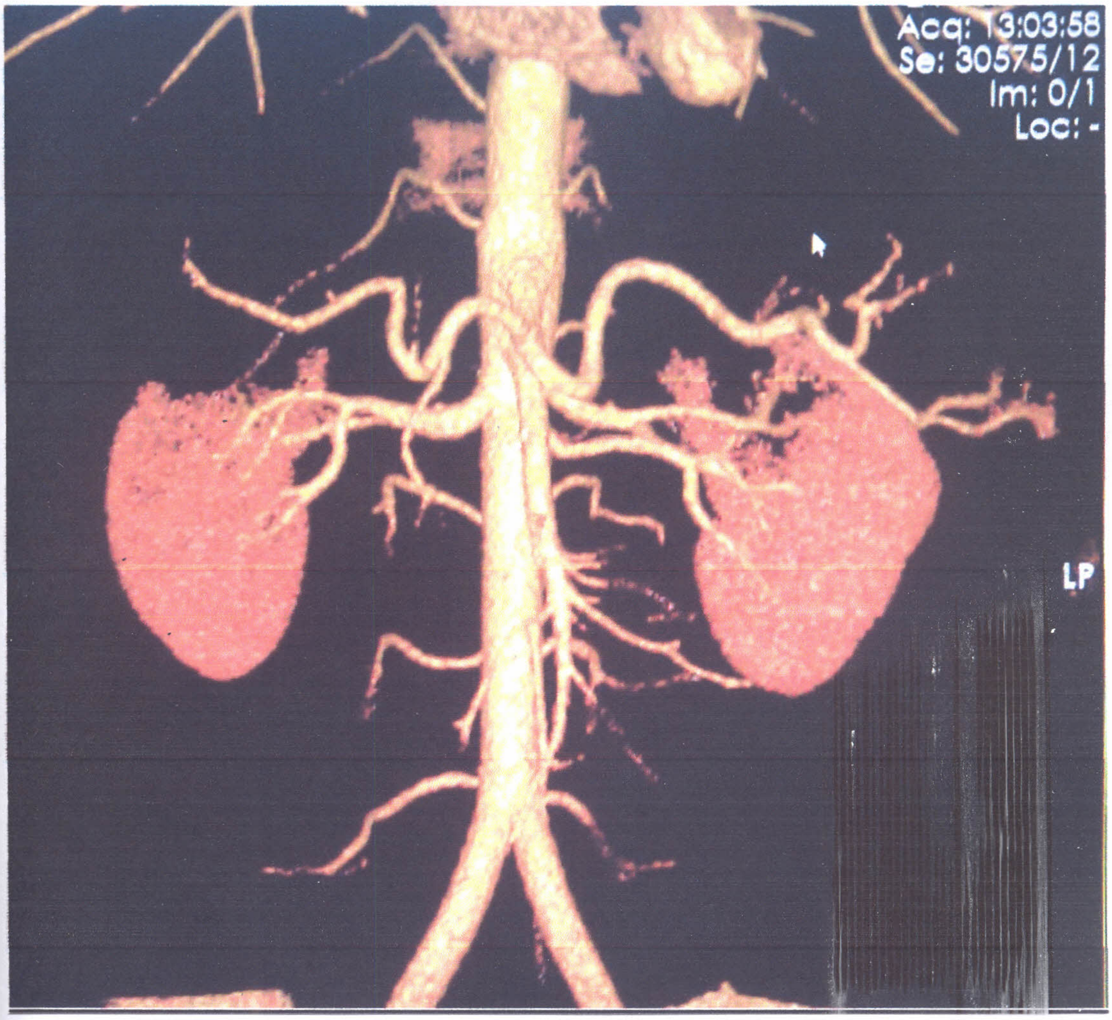



**Fig 4.7** Volume rendering Renal CTA image of an adult man 34 years old potential donor (Fig4.6) with significant large accessory renal artery on the left.

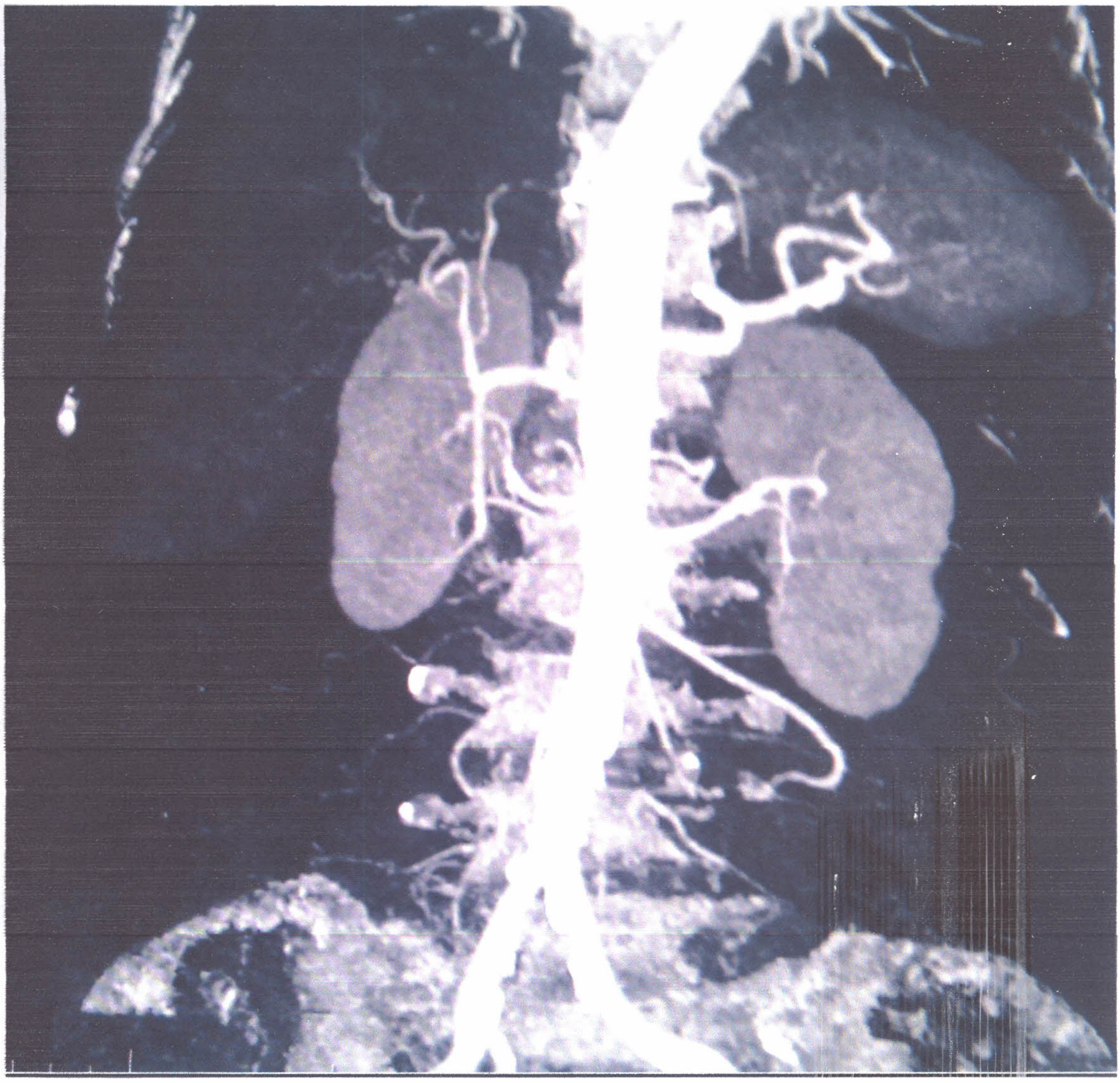


**Fig 4.8** MIP Renal CTA of an adult 47years female potential donor small right accessory renal artery.

Left: Length x Height x width (8.73x3.68x3.91 cm) size

Main renal artery diameter = 6.8mm

Right: Length x Height x width (8.7x4.7x5.29 cm) size

Main renal artery diameter = 5.0mm

Accessory artery = 2.8mm

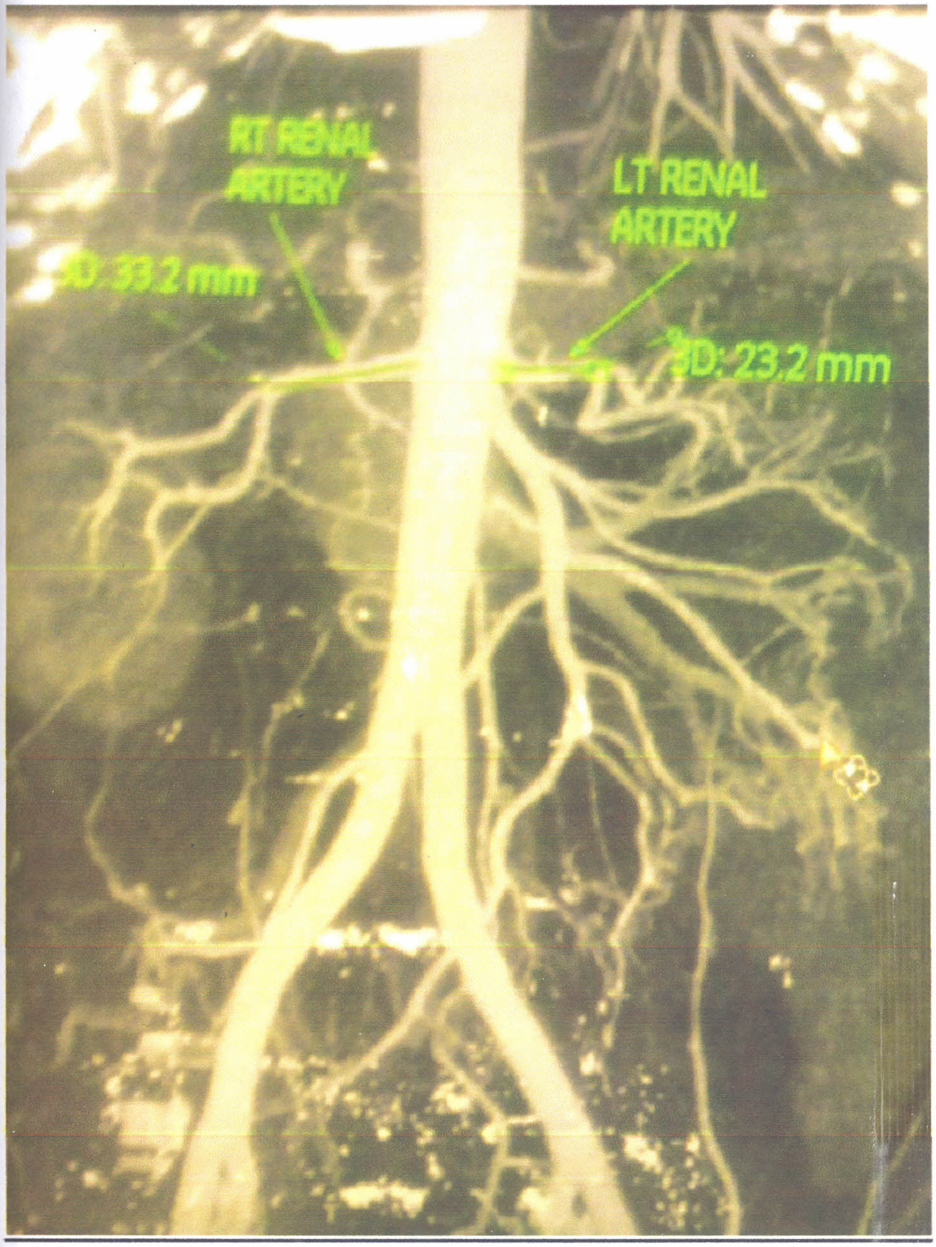



**Fig 4.9** Renal CTA of 56 years adult female potential donor at KNH.

She was found to have bilateral extra renal branching. The left branching is at 2cm and the right at 3cm from abdominal aorta.

Branching at 2cm or less is considered as early extra renal branching.

## DISCUSSION

A total of 204 cases were recruited in this three-year cross sectional study done at Kenyatta National Hospital in Nairobi, Kenya.

The sample was composed predominantly of adults with a mean age of 47.16 years (SD 18.32) and range of 18 years to 75 years and the ratio of male to female participants was 1:1. These findings are of clinical significance because renal donors are commonly adults with similar demographic characteristic to that reported in the current study. Thus the similarities reported above increases the relevance of the results from this study.

The Computerized Tomography Angiography findings from the study are discussed below under the following sub-headings: prevalence of accessory arteries; *relation between kidney side and accessory arteries; relation* between main arterial caliber and accessory arteries and extra renal branching.

### Prevalence of Accessory arteries

In this study it was found that the prevalence of accessory arteries among the black African population in Nairobi, Kenya is 11.3%. There was also a predominance of left-sided accessory arteries. The results reported above in general correlate with the findings in the study done by Ogeng'o et al [30] who observed 14.3% prevalence in a Kenyan autopsy study. The minor differences in prevalence between the two studies could possibly be explained by two factors. Firstly, the possibility that our study was specific for the black African Kenyans compared to all autopsy cases in Kenya regardless of their race. Secondly, autopsy and intraoperative studies involve direct visualization which could give high pick up rate compared to this radiological study. In fact studies have demonstrated that there is possibility of missing small accessory arteries at radiology which may be demonstrated intraoperatively. [16]

**Relation between Kidney side and Accessory arteries**

The study has shown that there is 46.6% unilateral Accessory to the left kidney, 33.3% to the right kidney and 6.6% occur as bilateral accessory arteries. These findings agree with the study by Patil et al who also found that there is presence of more multiple renal arteries to the left side than the right side. [20]

Further comparison has shown close agreement with the study by Cho et al [25] who used DSA and IVU in conducting a similar vascular study on 1000 potential kidney donors. In that study the correlation of imaging with intra operative findings, showed that a total of 288 donors had multiple renal arteries. Of these 255 (88.5%) had unilateral multiple arteries while 26 (9.1%) had bilateral arteries and the remaining 7 (2.4%) had hypoplastic arteries. In our study we have managed to specify the side with abundance of accessory vessels but we could not depict hypoplastic accessory vessels which could only be well depicted intra operative or during autopsy.

**Relation between Kidney size and Accessory arteries**

The findings of this study show that on average the left kidney size is larger than the right one in terms of length in at least 70% of donors. Similarly, height differences were demonstrated in 56.3% of donors, and width differences in 67.2% of donors.

The presence of accessory could not be deduced out of kidney size alone as a predictive indicator.

**Relation between Main Arterial caliber and Accessory arteries.**

The mean arterial diameter of the left main renal artery was 5.92mm and that of the right main renal artery was 5.33mm. The kidneys presenting with accessory arteries exhibited smaller diameter compared to those with no accessory arteries, the observation was more evidenced in the right kidney. Almost similar observation was also noted in the study by Aytac et al [11] who suggested that higher rates of detection of accessory arteries can be obtained sonographically when both kidney size and main renal artery diameters are considered. In our study the above fact has shown statistical significance in the right side (p=0.016), but it was not significant in the left side (p=0.097). These findings may suggest difficulty in arriving at a conclusion that presence of accessory arteries can accurately be picked from the kidney size and renal artery diameter radiologically. However, the two parameters when combined can give high index of suspicion about the presence of accessory arteries.

**Extra renal arterial branching**

This is arterial branching from the main renal arteries, considered to be a form of accessory arteries in the past, [12] but now termed as extra renal arterial branching.

In our study we found 30 cases out of 204 total cases giving a prevalence of 14.7%. An arterial branching found a distance of less than 2 cm from the aorta was considered to be an early extra renal branching.

Bilateral presentation of the extra renal branching was the commoner presentation.

In the study by Ogeng'o et al [30] on Kenyan population using autopsy they observed 21.6% prevalence of extra renal branching. This statistic again is higher than that from our radiological findings. The Possible explanations include technical issues like the limitation of MDCT to depict small diameter (<3mm) arterial branching [14]. Lack of standardized optimum protocol for running CT Angiography in view of patient BMI and pump injection rate which, can affect the opacification and pickup rate of small vessels.

Although autopsy is the gold standard in this renal-arterial anatomy, renal CT angiography is sensitive enough and the vessels missed are often smaller ones probably with no surgical significance.

The study by David Shaffer et al [18] suggests that small missed vessels during pre-operative imaging can be ligated surgically without significant ischemic injuries to the renal parenchyma.

## CONCLUSIONS

Based on the radiological findings of this study and the objectives that were set, the following conclusions can be reached.

(i) The radiological prevalence of Accessory renal arteries among Africans in Nairobi is 11.3% without gender predilection.

(ii) The left kidney commonly presents with unilateral accessory renal arteries more than the right kidney.

(iii) The presence of accessory arteries cannot be determined by the study of kidney sizes alone. However, most normal sized kidneys with accessory arteries have smaller main renal arterial diameters. In this observation, the likelihood of the presence of the left renal accessory artery is high when the left kidney size is larger than the right in the setting of paradoxical smaller left main renal artery than the right. This fact cannot replace the current value of CT Renal Angiography by other simpler noninvasive imaging modalities for indirect and accurate study of renal arterial anatomy for potential kidney donors.

(iv) There is prevalence of 14.7% for extra renal arterial branching, bilateral presentation is commoner. Early extra renal branching present rarely and account for 16% of all extra renal arterial branching.

## RECOMMENDATIONS

(i) A comparative study needs to be done in our set up to correlate radiological findings versus intra operative findings of the renal vascular anatomy for kidney donors for an acceptable period of time to cover wide sample size and assess the sensitivity of radiological tools like MDCT angiography. In such a study our protocol for Renal CTA can be revised to enable higher depicting rate.

(ii) This study was done using 16 Slice Helical CT Scan; a similar study can be repeated using a higher grade machine in order to find out whether different pickup rate can be demonstrated.

(iii) An objective role of Doppler Ultrasonography need to be studied in order to establish its predictive value for Accessory renal arteries based on Kidney sizes and Main renal arterial diameter in comparison to Renal CTA or Intra operative findings.

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## APPENDIX A

## PATIENT CONSENT FORM

My name is Dr. Richard Sungura I am pursuing Masters of Medicine degree in the department of Diagnostic Imaging and radiation medicine at the University of Nairobi.

I am doing my research study in the area of Blood vessels supplying the kidneys and its importance when considering kidney transplantation and donation.

I am requesting to use your data and findings so that the conclusions I am going to make can be used to help making treatment plan for people with kidney failure or those who volunteer to donate one .

No name is required and your information will be treated as confidential.

Please may it be known that your participation is voluntary and you have the right to refuse or withdraw from this study without being affected in the normal patient care provided at this hospital.

Signature ..................................................

Date ........................................................

I certify that the patient has understood and consented to participate in this study.

Dr. Richard E. Sungura

Signature .......................................

Date ........................................

## APPENDIX B

## FOMU YA RIDHAA (RUHUSA) YA MGONJWA

Jina langu ni Daktari Richard Sungura.
Ninasoma shahada ya uzamili katika idara ya uchunguzi wa magonjwa kwa mionzi (Radiolojia) ya chuo kikuu cha Nairobi.

Ninafanya utafiti katika eneo la mfumo wa kimaumbile wa mishipa ya damu ya figo na umuhimu wake katika maandalizi ya kutoa na kupandikiza figo kwa wagonjwa wenye magonjwa ya figo.

Ninaomba ridhaa/ruhusa yako, niweze kupata na kutumia taarifa zako katika utafiti wangu,ili hatimaye matokeo ya utafiti wangu yasaidie katika matibabu ya magonjwa ya namna hii.

Tafadhali fahamu ya kuwa taarifa zako ni za siri na una haki ya kukubali au kukataa kushiriki au kujitoa katika zoezi zima bila kuathiri huduma nyingine zitolewazo mahali hapa.

Sahihi... .......................................................

Tarehe .......................................................

Nathibitisha ya kwamba mhusika ameelewa na ameridhia kushiriki katika utafiti huu.

Daktari Richard E. Sungura

Sahihi.....................................

Tarehe.....................................

## APPENDIX C

**BUDGET**

| No. | Requirement | Cost in (Kshs) |
|---|---|---|
| 1. | Stationery, typing and photocopying | 25,000/= |
| 2. | Secretarial services | 10,000/= |
| 3. | Assistant data collectors | 20,000/= |
| 4. | Transport | 15,000/= |
| 5. | Data analysis | 30,000/= |
| 6. | Scanning/printing | 22,000/= |
| 7. | Contingency expenses | 20,000/= |
| | **TOTAL** | **152,000/=** |

## APPENDIX D

## QUESTIONARE; DATA COLLECTION FORM

1. Patient Number ........................

2. Age ____

3. Sex ____

4. History of Kidneys and Urological diseases YES NO

5. Any abnormal Renal function test noted YES NO

6. Any other related condition..........................................................................
..........................................................................................................
..........................................................................................................
..........................................................................................................

7. Amount of I.V contrast given in Volume ..........................................mls

8. **IMAGING FOR RENAL ARTERIAL ANATOMY**

**MDCT Angiographic findings**

| **Kidney and artery** | **Right** | **Left** |
|---|---|---|
| Kidney size – **L**ength<br>**H**eight<br>**W**idth<br>**Volume** | ...............<br>..............<br>..............<br>__________ mls | ...............<br>..............<br>..............<br>__________ mls |
| Number of Renal arteries | | |
| Number of Accessory arteries | | |
| Diameter of the Main Renal artery (within the 1st 1.5cm from Aorta) | | |
| Other findings | | |