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Accuracy Of Renal Angiography In Living Donor Kidney Transplantation

By

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DEDICATION

To the spirits
of
my parents
whom
are lighting my life
with
love and peace

And To whom they believe in love

Whoever does not love does not know GOD,
Because GOD is love (John 4;8)

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ABBREVIATION

END……..End stage renal disease
IVC……...Inferior vena cava
GFR……..Glomerular filtration rate
ADH……..Anti-diuretic hormone
CAVH…..Continuous arteiovenious treatment
CVVH…. Continuous venovenious treatment
PRA……..Panel reactive antibody
ATN……..Acute tubular necrosis
CTA……..Computed tomographic angiography
MRA…….Magnetic resonant angiography
DSA……..Digital subtracted angiography
SCVIR…..Society of cardiovascular and interventional radiology

ABSTRACT

This study was done to asses the accuracy of renal angiography in the actual living donors renal transplantation ,as compared to operative findings in renal transplant unit–Ahmed Gasim Hospital ,Khartoum North –Sudan.

A retrospective hospital data based study. It include (100) donors, males (67) and females (33), done within December 2000-dec.2004. The age ranged between (18-50years), while the majority (20-30 yrs.).The predominant number of donors originates from northern Sudan (50.6%).The 1st degree relationship between donors and recipients (91.8%), mainly brothers (56.4%) and sisters (21.8%)

Angiographicaly single renal artery was found in 92 (92%) in right kidney and 85 (85%) in the left. In all donors the length of the renal arteries was found to be normal. Also the caliber of the renal arteries was found angiographicaly normal for donation.

Based on angiographic finding the left kidney selected for donation in (84) donors while right in (16) only. After nephrectomy, surgically the donated kidneys was found of a single renal artery in (93.9%) compared to (6.1%) of a double renal artery. Surgically the length of renal arteries of all donated kidneys was found normal. Also the caliber of renal arteries found to be normal surgically.

Renal angiography was found very accurate in detecting the single renal artery in the right kidney (100%) while (96%) in the left kidney. Also in case of multiple renal arteries, renal angiography more accurate in right (100%) while (60%) in the left. This in comparison to surgical findings.

Accuracy of renal angiography in evaluating the length of the renal artery was (100%) accurate. Also was (100%) in

evaluating the caliber of the renal arteries as compared with the surgical findings.

Based on the accuracy of renal angiography, it can be used as radiological tools in evaluating the renal blood supply, as well as other organs in human body.

ملخص الأطروحة

أجريت هذه الدراسة لتقييم التصوير الوعائي الكلوي لمتبرعي الكلى الأحياء الفعليين مقارنة بالنتائج الجراحية لوحدة زراعة الكلى – مستشفى أحمد قاسم - الخرطوم بحري – السودان .

نوعية الدراسة مرجعية تعتمد على المعلومات من سجلات المرضى بالمستشفى .

شملت الدراسة (100) حالة للتبرع بالكلى أجريت في الفترة من ديسمبر 2000 الى ديسمبر 2004 م , بنسبة (67 %) ذكور و(33 %) اناث , تراوحت أعمار المتبرعين بين 18 – 50 سنة علماً بأن الأغلبية بين 20 – 30 سنة , أغلبية حالات المتبرعين من شمال السودان بنسبة بلغت (50.6 %) . صلة القرابة من الدرجة الأولى بين المتبرعين والمستقبلين كانت أعلى نسبة اذ بلغت (91.8 %) خصوصاً بين الأشقاء (56.4 %) والشقيقات (21.8 %) .

نتيجة التصوير الوعائي الكلوي أوضحت أن الكلى ذات الشريان الواحد هي الأكثر عند المتبرعين حيث كانت (92) حالة أي بنسبة (92 %) للكلى اليمنى و (85) أي بنسبة (85 %) للكلى اليسرى . كما أوضح التصوير الوعائي الكلوي أن طول الشريان الكلوي كان طبيعياً في (99) حالة متبرع . كما أوضح أن قطر الشريان الكلوي طبيعياً في جميع حالات المتبرعين .

استناداً على التصوير الوعائي الكلوي تم اختيار (84 %) للكلية يسرى و (16 %) للكلية اليمنى بغرض التبرع . جراحياً وبعد استئصال الكلى المراد التبرع بها وجد أن (93.9 %) منها لديها شريان واحد , بينما نسبة (6.1 %) لديها أكثر من شريان . كما وجد جراحياً أن طول الشريان الكلوي للمتبرعين طبيعياً في جميع الحالات , كذلك كان قطر الشريان الكلوي للمتبرعين طبيعياً في جميع الحالات .

مقارنة بالنتائج الجراحية وجد أن دقة التصوير الوعائي الكلوي في تحديد الشريان الكلوي الواحد بنسبة (100 %) للكلى اليمنى , بينما أقل دقة منها للكلى اليسرى (96 %) . كما كانت الدقة بالنسبة لتحديد تعدد الشرايين للكلى اليمنى (100 %) كانت الدقة أيضاً أقل بالنسبة للكلى اليسرى حيث بلغت (60 %) .

لدراسة دقة التصوير الوعائي الكلوي لتقييم طول الشريان الكلوي وجدت أنها دقيقة بنسبة (100 %) أيضاً وجدت انها دقيقة بنسبة (100 %) لتقييم قطر الشريان الكلوي , هذا مقارنة مع النتائج الجراحية لذات المتبرعين .

استناداً على نتائج هذه الدراسة والتي أظهرت أن التصوير الوعائي الكلوي ذات قدرة عالية على تحديد الأوضاع التشريحية للشريان الكلوي من حيث تحديد العدد

وتقييم الطول والقطر ويمكن استخدامها لتقييم وتوضيح الإمداد الدموي للكلى , وبعض الأعضاء الأخرى لجسم الإنسان .

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Chapter One

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION AND LITERATURE REVIEW

End-Stage Renal Disease

End-stage renal disease (ESRD) is a significant medical problem in the United States and the world over, with more than 220,000 patients suffering from this condition ([1]). With improvements in dialysis techniques, larger numbers of patients are being maintained for longer periods of time on dialysis. However, dialysis is no longer the most desirable form of management of ESRD because these patients have a mean life expectancy of 5 to 8 years at the age of 49 years, a statistic that represents approximately 25% of the life expectancy of the general population at this age. Because of the high mortality rate and limited quality of life while undergoing dialysis, renal transplantation is currently the preferred long-term management for patients with (ESRD). ([1])

Anatomy of the kidney and renal arteries:

{Anatomy is the only solid foundation of medicine. It's to the physician and surgeon what geometry is to the astronomer.}

(John Hunter,1763)

The urinary organs comprise the **kidneys,** which secrete the urine, the **ureters,** or ducts, which convey urine to the **urinary bladder**, where it is for a time retained; and the **urethra,** through which it is discharged from the body([2]).

The Kidneys (Renes)—The **kidneys** are situated in the posterior part of the abdomen, one on either side of the vertebral column, behind the peritoneum, and surrounded by a mass of fat and loose areolar tissue. Their upper extremities are on a level with the upper border of the twelfth thoracic vertebra, their lower extremities on a level with the third lumbar. The right kidney is usually slightly lower than the left, probably on account of the vicinity of the liver. The long axis of each kidney is directed downward and lateralward; the transverse axis backward and lateralward ([2])

Each kidney is about 11.25 cm. in length, 5 to 7.5 cm. in breadth, and rather more than 2.5 cm. in thickness. The left is somewhat longer, and narrower, than the right. The weight of the kidney in the adult male varies from 125 to 170 gm., in the adult female from 115 to 155 gm. The combined weight of the two kidneys in proportion to that of the body is about 1 to 240.

The kidney has a characteristic form, and presents for examination two surfaces, two boarders, and an upper and lower extremity ([2])

Embryology of aorta and renal arteries:

The first intraembryonic vessels are the paired primitive aortas. They begin as a continuation of the endocardial heart tube and are located ventral to the foregut. Each dorsal aorta gives off branches to the body wall (interseg-mental arteries), yolk sac (vitelline arteries), and placenta (umbilical arteries). The abdominal aorta originates as the termination of the fused dorsal aortas. Three groups of arteries arise from it: (1) A ventral group supplies the derivatives of the endodermal gut. They supply the splanchnopleural derivatives, namely, the celiac, superior mesenteric, and inferior mesenteric arteries. (2) A lateral group supplies the derivatives of the intermediate cell mass or nephrotome and forms the arteries of the kidneys, supra-renals, and gonads and the vessels of the wolffian and mullerian duct systems. (3) A dorsolateral group divides into dorsal and ventral branches and follows the segmental nerves. The dorsal branches supply the neural tube, the tissues surrounding it (paravertebral muscles, vertebrae, meninges), and the skin of the back. The ventral branches supply the body wall anteriorly and laterally and the intercostal and lumbar arteries.

The original renal blastema, the pronephros, differentiates into a urogenital ridge, which includes the mesoneph-ros and a rete of approximately 20 arteries arising from the lateral group of the dorsal aorta. The arteries consolidate from this rete as the mesonephros regresses and the meta-nephros develops in about the third month. Eventually, two major groups of vessels predominate: an upper group supplying the diaphragm and adrenal and a lower group becoming the renal, ureteral, and gonadal arteries. The long course of the testicular and ovarian arteries (and veins) is due to caudal migration of the gonads after these vessels have developed. ([3])

RENAL ARTERIES AND THEIR VARIANTS:

Renal arteries:

They are two large trunks, which arise from the side of the aorta, immediately below the superior mesenteric artery. Each is directed across the crus of the diaphragm, so as to form nearly a right angle with the aorta. The right is longer than the left, on account of the position of the aorta; it passes behind the inferior vena cava, the right renal vein, the head of the pancreas, and the descending part of the duodenum. The left is somewhat higher than the right; it lies behind the left renal vein, the body of the pancreas and the lienal vein, and is crossed by the inferior mesenteric vein. Before reaching the hilus of the kidney, each artery divides into four or five branches; the greater number of these lie between the renal vein and ureter, the vein being in front, the ureter behind, but one or more branches are usually situated behind the ureter. Each vessel gives off some small inferior suprarenal branches to the suprarenal gland, the ureter, and the surrounding cellular tissue and muscles ([4]).

. **Accessory renal arteries:**

One or two accessory renal arteries are frequently found, more especially on the left side they usually arise from the aorta, and may come off above or below the main artery, the former being the more common position. Instead of entering the kidney at the hilus, they usually pierce the upper or lower part of the gland ([4]).

Agenesis of the Renal Artery:

An absent renal artery, for all practical purposes, is associated only with renal agenesis. In such cases the adrenal gland, if present (95%) receives all its blood supply directly from the aorta. The contralateral solitary kidney is always enlarged with an enlarged renal artery as a result of compensatory hypertrophy. Although a renal artery is generally present in dysgenesis as well as in renal atrophy, such vessels may be extremely atretic and escape angiographic detection, thereby leading to an erroneous diagnosis of renal agenesis. The same is not true for the renal veins, however([5]) .

Multiple Renal Arteries:

In about 20% to 30% of cases, more than one renal artery supplies a Kidney; two arteries to a kidney occur in 22% of individuals three occur in 1%

to 2%, and four occur in 0.1%([6]). In a study of the blood supply of 200 cadavers (400 kidneys), a single renal artery supplied each kidney in 35% and in the remaining 65%, a unilateral or a bilateral renal arterial anomaly was found([7]).

An angiographic study of 444 prospective renal donors revealed multiple renal arteries to a kidney in 44% of the donors—unilateral, in 32% and bilateral in 12%.([8]). This study revealed multiple renal arteries originating from the aorta in 27% of the 888 kidneys. In a study of 100 renal donors by intravenous DSA, a bilateral single renal artery was found in 71%, bilateral multiple renal arteries in 2%, and unilateral multiple renal arteries in 27% ([9])

Single renal arteries always originate from the aorta at the level of LI to L2, whereas supernumerary renal arteries may have various origins. Unusual origins include the common iliac, superior mesenteric, inferior mesenteric, spermatic, ovarian and right colic arteries the supraceliac aorta, and the contralateral renal arteries [[6,7]]. In the presence of multiple renal arteries, the largest artery that originates from the aorta closest to the superior mesenteric artery and enters the kidney at its hilum is usually the main renal artery. Supplementary arteries may arise from the aorta anywhere below the T11 vertebra or from the iliac arteries .

Several terms have been used to describe multiple renal arteries, including “Aberrant,” “ectopic,” “accessory,” “polar,” "supernumerary," and "supplementary." The term "accessory" is used to describe any renal artery additional to the main renal artery, whereas the term "aberrant" has been applied to renal arteries arising from sources other than the aorta. According to their course, supplementary arteries can be categorized as either polar (piercing the kidney directly) or hilar (entering the kidney at the hilum]. The polar artery supplies either the upper pole of a kidney superior polar artery, 7%) or the lower pole (inferior polar artery, 5.5%) ([6]) Superior polar arteries are often small and can be easily overlooked on an aortogram. They have a horizontal or superolateral course, depending on the level of their origin, and may give rise to the inferior adrenal, superior capsular, or inferior phrenic artery before reaching the kidney. Polar renal arteries are often first appreciated when an incomplete nephrogram is observed after selective injection of the main renal artery. Conversely, when only selective arteriography is performed, small accessory vessels may be overlooked. Consequently, selective renal angiography is usually preceded by a midstream aortogram.

The superior polar and hilar arteries may cause a defect in the renal margin mimicking fetal lobation, renal scarring, or a cyst . The defect has been called an "accessory renal hilus ([10]). Inferior polar arteries may arise from the aorta anywhere between the main renal artery and the aortic bifurcation or from the iliac arteries. They usually run superolaterally toward the lower pole of a kidney. Differentiation from lumbar arteries is not ordinarily difficult.

The hilar supplementary artery usually arises from the aorta close to the main artery and enters the kidney through its hilum.

When two renal arteries to a kidney are equal in size, the superior one is usually the main artery. Each of the arteries supplies its own area. For example, the more superior vessels supply the upper portions of the kidney. The hilar supplementary arteries may impresses upon or occasionally even significantly compresses the ureteropelvic junction before reaching the lower pole of the kidney .

Multiple renal arteries are found in about 50% of cases of hydronephrosis secondary to obstruction at the ureteropelvic junction([6]). Identification of hilar arteries crossing the ureteropelvic junction before endoureteropyelotomy helps in the safe and appropriate performance of the procedure ([11]). Although angiography remains the most accurate means of identifying crossing arteries at the ureteropelvic junction, spiral CT, MR angiography, color Doppler ultrasonography, and endoluminal echograghy will become important alternative imaging methods ([12]).

The incidence of multiple renal arteries is higher in individuals with hypertension than in those with normal blood pressures ([13]). Supernumerary arteries may be involved by arteriosclerosis or fibromuscular disease arid cause reno-vascular hypertension. Detection of stenosis or occlusion of a small supplementary artery can be difficult and usually requires selective renal angiography for demonstration of a nephrogram defect and collateral vessels.

It is especially important to define the presence and location of supplementary arteries before surgery .for an aortic aneurysm ([14]). Aortography is usually performed preoperatively, and the extent of the aneurysm, its relationship to the renal artery, and the status of the mesenteric circulation are observed. Because, most aneurysms of the abdominal aorta are infrarenal (incidence of 95%), the relationship of the renal arteries to the superior extent of the aneurysm should be carefully evaluated by anteroposterior and oblique aortograms. Without a preoperative arteriogram aberrant aretries may be mistaken for lumbar vessels during aortic surgery and inadvertently ligated ([14]). Accidental ligation of these vessels may lead to renal infarction, renal failure, or hypertension. Pre-operative knowledge of the precise renal arterial anatomy and the location of aberrant renal arteries not only will save time-consuming dissection but also will aid in selection of the most appropriate surgical procedure. Spiral CT angiography and gadolinium-enhanced MR angiography also provide necessary information about the extent of aneurysms and the status of the renal and mesenteric circulation and are beginning to replace aortography in the pre-operative evaluation of patient with abdominal aortic aneurysm ([15, 16]).

Ectopic Renal Artery:

The term "ectopic renal artery" refers to a renal artery arising from a branch of the aorta or the iliac arteries. The term has also been used to describe any unusual renal artery origin (such as supraceliac or thoracic) ([17]).

In almost all patients with multiple renal arteries, the arteries have independent origins and supply the kidney separately. The blood supply to both kidneys may rarely come from a common renal artery originating from the aorta or its branches. Three such anomalous renal arteries have been reported. In all three cases in the literature and in our experience, multiple renal arteries to the upper poles of the kidneys were present in addition to the common renal artery. Ectopic renal arteries have also been reported to originate from the celiac, splenic, superior and inferior mesenteric, hepatic, lumbar, right colic, gonadal, hypogastric, middle sacral, and common renal arteries. Extrarenal collateral vessels in renal artery occlusion and parasitic blood supply to a kidney with renal cell carcinoma can be mistaken for ectopic renal arteries. These cases might have accounted for some of the previously noted ectopic origins of the renal artery reported in the older literature ([18]).

Arterial supply to anomalous Kidneys:

The kidneys may be anomalous in position (malrotation and ectopic) and in form (crossed-renal ectopy with fusion and horseshoe kidney). Such renal anomalies are associated with a great number of variations in the origin, number, and course of the renal arteries; multiple renal arteries are often found. In general, ectopic kidneys have an arterial supply from the adjacent aorta ([7]). A sacral kidney may receive its arterial supply from the lower aorta, whereas renal arteries to the pelvic kidney may come from the aortic bifurcation or from die inferior mesenteric, middle sacral, or iliac arteries ([6, 19, 20]).

Horseshoe kidney, the most common type of renal fusion anomaly, is characterized by fusion of the lower poles of the kidney anterior to the aorta at the level of the fourth lumbar vertebra. Horseshoe kidney, when associated with an aortic aneurysm, presents technical difficulty for resection because of associated anomalous renal arterial supply ([21]). Horseshoe kidneys may also be complicated by infection', stones, ureteropelvic obstruction, and tumors requiring surgery. Thus demonstration of renal arterial supply by angiography is important for appropriate surgical planning, ([20]). The blood supply to horseshoe kidneys is quite variable. Graves described six basic patterns([19]).The upper, middle, and posterior segmental arteries are the most constant in origin and position. Frequently, a single renal artery supplies each half of the kidney, similar to anormal kidney. The lower segmental artery, however, is nomadic in origin. It may arise from the aorta as paired or unpaired structure and supply a variable amount of the isthmus and renal parenchyma on each side of the midline. It may also arise from the iliac arteries alone or in duplicate. Any number of combinations of these various anatomical arrangements, may be seen.

Precise demonstration of the variations in arterial supply to ectopic kidneys requires careful angiographic studies. A biplane technique with injections at several levels should be used to perform aortograms. Selective catheterization of one or more of the renal arteries may be required for better delineation of the arteries and their intrarenal distribution ([22]).

Renal Arterial Anatomy:

Typically, a single renal artery supplies each kidney. These arteries originate from the lateral surfaces of the aorta at about the lower level of the first lumbar vertebral body . Considerable variation exists, however, with levels of origin varying from T12 to L2 ([23]). The caliber of the main renal artery varies with kidney size ([23]) When only a single renal artery supplies the kidney, luminal diameter, as determined angiographically, is 6.0 to 9.5 mm (mean, 7.9 mm) in men and 5 to 8 mm (mean, 6.4 mm) in women ([24]). A supplemental renal artery is present in 20% to 30% of kidney ([23]) and generally arises distal to and within 3 cm of the main renal artery. In older patients the aorta rotates, with the origin of the right renal artery moved to the anterolateral aspect and the origin of the left moved to the posterolateral aspect of the aorta.

The main renal artery gives rise to primary ventral and dorsal rami, which pass anterior and posterior, respectively, to the renal pelvis. The ventral ramus tends to be larger than the dorsal ramus and appears as a continuation of the main artery. Brandling patterns within the kidney vary considerably, but in general, the ventral artery supplies the entire ventral surface and some portions of the cranial surface on the dorsum of the kidney. The dorsal artery supplies the mid-dorsal region and variable caudal portions of the dorsum. The ventral artery can be identified angiographically by tracing back from the brandies that reach the lateral margin of the kidney in its mid-portion ([25]).

Branches of the primary rami course in the renal sinus and are termed "segmental arteries". Beyond the papillae, they penetrate the parenchyma, pass between medullary pyramids, and are termed "interlobar arteries." Interlobar arteries progressively branch, taper, and then terminate as arcuate arteries. Arcuate arteries, about 1 mm in diameter, demarcate the corticomedullary junction. They do not form a continuous subcortical arcade and do not communicate with each other. Instead, they branch, taper, and terminate near the center of the renal pyramid ([25]).

Along the course of the actuate arteries, thousands of interlobular arteries arise, 75 to 200 µm in diameter, and pass through the cortex perpendicular to the corticomedullary junction. These arteries are sufficiently small and numerous that they are invisible on most conventional arteriograms, but they can lie recognized as overlapping and superimposed arteries on good-quality magnified arteriograms ([26]). Each interlobular artery gives rise to about 20 afferent glomerular arterioles, each of which supplies one or more glomeruli. The afferent glomerular arterioles are invisible on clinical angiograms.

The normal kidney has about 1.5 million glomeruli distributed uniformly through the cortex. The mean glomerular diameter in adults is about 300 µm, a size large enough to the visualized arteriographically. The number and cross-sectional area of glomeruli suggest approximately 10-fold overlap in a two-dimensional projection. In a selective direct Rim arteriogram, good-quality magnified images show a granular pattern in the cortex. This pattern reflects, in a complicated manner, overlapping glomeruli ([26]).

Beyond the glomeruli, efferent arterioles pursue one of two courses. Of those originating from juxtamedullary glomeruli, many pass to the medulla and divide into bundles of vasa recta. The vasa recta are only 20 to 50 µm in diameter and cannot be discretely resolved on clinical arteriograms, although they do contribute to the density of the medulla in the nephrographic phase. The efferent glomerular arterioles of the outer cortex and the remainder from the juxtamedullary glomeruli do not contribute to the vasa recta but instead form a peritubular capillary plexus that nourishes the proximal and distal convoluted tubules([27]).

RENAL VEINS AND THEIR VARIANTS:

Anomalies of the renal veins may be associated with congenital anomalies of the inferior vena cava (IVC) and kidney. Knowledge of the renal venous anatomy and its congenital variations is important for renal venous renin sampling, preoperative evaluation of renal donors, spleno-renal shunt placement for portal hypertension, surgery of the kidney and aorta, vena cava filter placement, and staging of renal cell carcinoma ([28]).

Angiography (conventional and digital subtraction), direct phlebography, CT, MR angiography, and duplex Doppler sonography have been used for evaluation of the IVC and renal veins. ([29, 30]). Of these, only phlebography can demonstrate the flow pattern of the renal vein. And allow measurement of venous pressure. Intra-arterial injection of 10 microgram of epinephrine immediately before the injection of the contrast material into the renal vein facilitate the opacification of the proximal veins. To some extent, the renal veins are visualized during the venous phase of aortography or renal angiography, and their venous variations can usually be recognized ([28]).

Renal Function and structure:

The kidneys principal role is the elimination of waste material and the regulation of the volume and composition of body fluid. The kidneys have a unique system involving the free ultra filtration of water and non-protein-bound low-molecular-weight compound from the plasma and the selective reabsorption and/or excretion of these as the ultra filtrate passes along the tubules. ([31]).

The functioning unit is the nephron of which, there are approximately of one million in each kidney.

An essential feature of renal function is that a large volume of blood - 25% of cardiac output or approximately 1300 mL per minute - passes through the two million glomeruli.

A hydrostatic pressure gradient of approximately 10 mmHg (a capillary pressure of 45 mmHg minus 10 mmHg of pressure within Bowman's space and 25 mmHg of plasma oncotic pressure) provides the driving force for ultrafiltration of virtually protein-free and fat-free fluid across the glomerular capillary wall in to the Bowman's space and so into the renal tubule ([31]).

The ultrafiltration rate (glomerular filtration rate; GFR) varies with age and sex but is approximately 120-130 mL/min per 1.73 m^2 surface area in adults. This means that each day ultrafiltration of 170-180 L of water and unbound small-molecular-weight constituents of blood occurs. The 'need' for this high filtration rate relates to the elimination of compounds present in relatively low concentration in plasma (e.g. urea). If these large volumes of ultrafiltrate were excreted unchanged as urine, it would be necessary to ingest huge amounts of water and electrolytes to stay in balance. This is avoided by the selective reabsorption of water, essential electrolytes and other blood constituents, such as glucose and amino acids, from the filtrate in transit along the nephron. Thus, 60-80% of filtered water and sodium are reabsorbed in the proximal tubule along with virtually all the potassium, bicarbonate, glucose and amino acids. Further water and sodium chloride are reabsorbed more distally, and fine tuning of salt and water balance is achieved in the distal and collecting tubules under the influence of aldosterone and anti-diuretic hormone (ADH). The final urine volume is thus 1-2 L daily. Calcium, phosphate and magnesium are also selectively reabsorbed in proportion to the need to maintain a normal electrolyte composition of body fluids ([31]).

Renal failure:

The term renal failure means failure of renal excretory function due to depression of GFR. This is accompanied to a variable extent by failure of erythropoietin production, vitamin D hydroxylation regulation of acid-base balance, and regulation of salt and water balance and blood pressure([32]).

RENAL REPLACEMENT THERAPY

Approximately 100 individuals per million population reach end-stage renal failure per annum. The aim of all renal replacement techniques is to mimic the excretory functions of the normal kidney, including excretion of nitrogenous waste e.g. urea, maintenance of normal electrolyte concentrations, and maintenance of a normal extracellular volume([33]).

Haemodialysis:

Basic principles:

In haemodialysis blood from the patient is pumped through an array of semi-permeable membranes (the dialyser, often called an 'artificial kidney') which bring the blood into close contact with dialysate, flowing countercurrent to the blood. The plasma biochemistry changes towards that of the dialysate due to diffusion of molecules down their concentration gradients ([33]).

Haemofiltration

This removes plasma water and its dissolved constituents, e.g. K^+, Na^+, urea, phosphate, by convective flow across a high-flux semi-permeable membrane, and replacing it with a solution of the desired biochemical composition. Lactate is used as buffer in the replacement solution because rapid infusion of acetate causes vasodilatation and bicarbonate may cause precipitation of calcium carbonate. Haemofiltration can be used for both acute and chronic renal failure. High volumes need to be exchanged in order to achieve adequate small molecule removal; typically, a 22-litre exchange three times a week for maintenance treatment and 1000 ml/ hour in acute renal failure ([33]).

Haemodiafiltration

This is a combination of high-flux haemodialysis, using dialysate made from highly purified water for countercurrent dialysis, plus haemofiltration combined with infusion of replacement fluid. Advantages include a better small molecule clearance than with haemofiltration alone, a good clearance of middle molecules and an excellent haemodynamic stability. However, it is expensive ([33]).

Continuous treatments:

Continuous treatments are used in acute renal failure and have the advantage of slow continuous correction of metabolic and fluid balance. They are particularly suitable for patients with haemodynamic instability. Blood flow may be achieved either by using the patient's own blood pressure to generate flow through a dialyser (continuous arteriovenous treatment, CAVH), or by the use of a blood pump to draw blood from the 'arterial' lumen of a dual-lumen catheter placed in the jugular, subclavian or femoral vein, through the dialyser, and back to the 'venous' lumen (continuous venovenous treatment, CVVH).

Peritoneal dialysis:

Peritoneal dialysis utilizes the peritoneal membrane as a semi-permeable membrane, avoiding the need for extra-corporeal circulation of blood. This is a very simple, low technology treatment compared to haemodialysis. The principles are simple:

1. A tube is placed into the peritoneal cavity through the anterior abdominal wall.
2. Dialysate is run into the peritoneal cavity, usually under gravity.
3. Urea, creatinine, phosphate, and other uraemic toxins pass into the dialysate down their concentration gradients.
4. Water (with solutes) is attracted into the peritoneal cavity by osmosis, depending on the osmolarity of the dialysate. This is determined by the dextrose content of the dialysate.
5. The fluid is changed regularly to repeat the process.

For acute peritoneal dialysis a stiff catheter is inserted under local anaesthetic in the midline, one-third of the way down between the umbilicus and the symphysis pubis.

Chronic peritoneal dialysis requires insertion of a soft catheter, with its tip in the pelvis, exiting the peritoneal cavity in the midline and lying in a skin tunnel with an exit site in the lateral abdominal wall. This form of dialysis can be adapted in several ways .

Complications of long-term dialysis:

Cardiovascular disease and sepsis are the leading causes of death in long-term dialysis patients. Causes of fatal sepsis include peritonitis, complicating peritoneal dialysis and Staph aureus infection including endocarditis complicating the use of indwelling access device for haemodialysis ([33]).

Transplantation:

Successful renal transplantation offers the potential for complete rehabilitation in end-stage renal failure. It allows freedom from dietary and fluid restriction, anaemia and infertility are corrected, and the need for parathyroidectomy is reduced.

The technique involves the anastomosis of an explanted human kidney, either from a cadaveric donor or, less frequently, from a living close relative, on to the iliac vessels of the recipient. The donor ureter is placed into the recipient's bladder. Unless the donor is genetically identical (i.e. an identical twin), immunosuppressive treatment is needed, for as long as the transplant remains in place, to prevent rejection. Eighty per cent of grafts now survive for 5-10 years in the best centers, and 60% for 10-30 years ([33]).

Kidney Transplantation and Dialysis Access:

In the United States, more than 200,000 patients undergo dialysis and 70,000 patients have functioning kidney transplants. The prevalence of end-stage renal disease ESRD is increasing at 7% to 9% annually, making it likely to more than 350,000 patients with ESRD will be cared for in the United States by the year 2010. The annual incidence of ESRD is 242 cases per million population, although Blacks have disproportionately high incidence (758 per miIIion population per year) as compared with Whites (180 per million population per year) ([34]). Diabetes accounts for 35 % of newly diagnosed cases of ESRD, making it the most common cause of renal failure, followed by hypertension (30%). Other causes ESRD include glomerulopathy, cystic and interstitial renal disease, and obstructive uropathy

The average annual mortality from ESRD is 25% among patients being treated with dialysis ([34]). This death rate is 25% to 50% higher than in Japan and Europe ([35]), perhaps due to acceptance of older patients with more coexisting conditions for dialysis in the United States. The lower rate of kidney transplantation in Japan may be responsible for a healthier dialysis population in that country**.** ([36]). The 1-year mortality of renal transplant patients is 6% for cadaveric recipients and 3% for living-donor kidney recipients, reflecting the fact that they represent a relatively healthier subset of patients with ESRD compared to dialysis patients ([37]). Nevertheless, the death rate on dialysis is higher than after transplantation even after adjusting for patient characteristics ([38]). With both dialysis and transplantation, deaths are primarily caused by cardiovascular disease (50%), infection (15%), and malignancy (10%) ([36,39]).

Should Patients Be Dialyzed or Transplanted?

In patients with known renal disease in whom end-stage renal failure gradually approaches, there is time to anticipate and plan renal replacement therapy. If such a patient is fortunate to have a living donor, a renal transplant can be planned to occur when the recipient's renal failure reaches the critical point at which replacement therapy is necessary to control fluid volume or potassium. Such is the ideal setting, where transplantation occurs as primary treatment without the need for dialysis and where the availability of a living donor removes the indefinite waiting period for a cadaveric donor. It is necessary to wait until the serum creatinine is at least 3 mg/dl to be able to monitor kidney transplant function. The relative proportion of patients with renal failure proceeding directly to renal transplantation without dialysis has varied over time at the University of Wisconsin but averages 39% for recipients of living-donor kidneys and 12% for cadaveric recipients. Early referral for transplantation is largely responsible for this shift and is to be encouraged. Increasing reliance on living donation is also responsible and to be encouraged. Factors influencing waiting time for cadaveric renal transplantation include the patients blood type (with B blood type waiting the longest), panel reactive antibody (PRA), the rate of cadaveric organ donation, and the size of the waiting list. PRA measures recipient sensitization; the higher the PRA, the more difficult it is to locate immunologically compatible donors, A previous transplant, blood transfusion, or pregnancy may lead to allosensitization, raising the PRA. Often, patients initially present in end-stage renal failure and must begin renal replacement therapy immediately. Hemodialysis or peritoneal dialysis can be started immediately and can be used as; either definitive therapy when appropriate or as a bridge to cadaveric or living-donor renal transplantation. Patients with contraindications to renal transplantation are treated with dialysis. ([40]).

Comparative study between dialysis and transplantation:

Prospective studies comparing the costs, quality of life, and the expected length of life of patients on hemodialysis, peritoneal dialysis, and with renal transplants have been done ([41,42]) and serve as the basis of the following conclusions:

Quality of life with a renal transplant is superior to quality of life on peritoneal dialysis which in turn is superior to quality of life on haemodialysis. This conclusion is true because of the greater level of independence as well as greater sense of well-being physically and psychologically. Nevertheless, transplant patients do not rate their quality of life as normal. ([41])

. Despite the greater initial cost of renal transplantation compared to dialysis, cost-effectiveness studies have shown that if the renal transplant functions for at least 2-5 years, the transplant becomes less expensive than dialysis. ([43])

. Patient survival rates can be compared between hemodialysis, pentoneal dialysis, and renal transplantation overall as well as by specific disease etiology. On average, the annual mortality among patients being treated with dialysis is nearly 2&41 but depiends on disease etiology. Diabetics with renal failure who are treated with dialysis have a 2-year survival of 30% while those treated with renal transplantation have a 2-year survival of 70%. There is a clear benefit of renal transplantation when measured by survival. ESRD patients who are waiting for a suitable living donor or cadaver donor kidney or who have a contraindication to transplantation are maintained with dialysis. ([44])

Renal Transplantation:

Success of transplantation is affected by numerous factors:

Patient selection:

Because of increasingly successful outcome, renal transplantation indication has expanded continually, and the average age of renal transplant recipients has risen progressively. Careful attention should be paid to addressing cardiac risk factor, because cardiovascular disease account for the vast majority of deaths following renal transplantation ([45]).

Patient with malignancy:

Because immunosuppression favours the development of and recurrence of malignancy, patient with solid tumours are generally not transplanted unless they are free of disease at least two years following curative surgical excision. ([45])

Infection:

Patients with infection of any kind should have the infection treated completely before undergoing renal transplantation. ([45]). **Immunological considerations:**

Tissue typing:

All patients being considered for renal transplantation undergo tissue typing to determine their HLA class I and class II types. Because acute rejection is mediated predominantly by T lymphocyte which recognize MHC class I and II ([46]).

Antidonor antibody:

Before performing renal transplantation, recipient serum is tested against donor lymphocyte to assess the presence of performed antidonor antibody. Termed a crossmatch test. This can be done either by using standard NIH method or by using flow cytometry ([47, 48]).

ABO matching:

A donor-recipient pair must be ABO compatible. Otherwise, hyperacute rejection mediated by complement-fixing preformed. Natural antibody is very likely. ([45])

Renal transplantation:

Clinical consideration

In 1994, more than 25,000 people were awaiting renal transplantation in the United States ([49]). However, the number of renal transplants performed falls short of this requirement, with around 10,000 performed annually ([50]). One-year patient survival was more than 95%, and graft survival was 84% in 1994 ([50]). Living donor renal transplantation yields a slightly better projected graft survival at 1 year (around 91%) than cadaveric kidney transplantation (81%) ([51]). Estimated half-life is approximately 9 years for cadaveric kidneys and up to 24 years for living related HLA-identical donor kidneys The gradual improvements in patient and /allograft survival observed in the last decade have resulted primarily from improved immunosuppression, but also from more careful recipient evaluation and donor screening and better donor-recipient matching. ([52])

The major impediment to successful organ transplantation is allergic rejection. Over the last 40 years, significant progress has been made both in immunosuppressive protocols and in the understanding of the biology of allograft rejection. The development-of safe and effective immunosuppressive strategies has been one of the major challenges of renal and other organ transplantation. Initially, whole body radiation was used as the primary form of immunosuppression. The early protocols used a combination of corticosteroids and azathioprine. With the introduction of cyclosporine in 1983 and of tacrolimus (FK 506) more recently, allograft survival has improved considerably. ([53])

LIVING DONOR EVALUATION:

Donors are usually adults between the ages of 18 and 60 years, although older donors have been used successfully and minors may be used as well. Although most donors have traditionally been blood relatives of the recipient, a substantial number of living-unrelated renal transplants have been done, primarily between spouses, but sometimes between individuals with no emotional or personal relationship ([54]).

Currently, living donors account for approximately 20% of all kidneys transplanted in the United States ([53]). The shortage of cadaveric organs has highlighted the need for expansion of the living donor pool. The estimated mortality of living donation is less than 0.1% ([55]). Minor postoperative complications such as atelectasis and urinary tract infections can occur in another 10% to 20% ([56]). Hyperfiltration injury to the remaining kidney after unilateral nephrectomy has been described in animal models, but the incidence in living donors is low ([57,58,59]).

A thorough evaluation of the living related donor is mandatory. Several absolute contraindications to living donation exist. These include transmissible disease (such as human immunodeficiency virus and hepatitis B) and malignant disease (other than carcinoma in situ of the cervix or skin tumors).

Relative contraindications include hypertension requiring medical therapy, diabetes, obesity, significant co morbid conditions such as severe cardiac or pulmonary disease, and psychological disorders([60]).

Donor evaluation includes a detailed history and physical exam with particular attention paid to the past medical history, prior urological surgery, medical renal disorders, and medications. Laboratory studies including screening chemistry, renal function tests, and coagulation profile are routinely obtained.

A creatinine clearance of more than 80 mL per minute and absence of proteinuria on a 24-hour urine collection are criteria for adequate renal function in the donor ([60]).

Renal ultrasonography is obtained to rule out anatomical abnormalities. Arteriography is also performed to evaluate the renal vasculature. More recently, CT angiography has supplanted ultrasound and angiography in some centers (([61])). The longer vein of the left kidney makes this the preferred side for donor nephrectomy, because subsequent vascular anastomosis is facilitated. If one kidney has multiple renal arteries and the contralateral kidney has a single artery, the organ with the single artery is preferred for donor nephrectomy. However, multiple renal arteries do not preclude a kidney from being used for transplantation because the individual arteries can be reconstructed to permit a single vascular anastomosis. Although small upper-pole arterial branches may be sacrificed without significant parenchymal loss, lower-pole arteries should be preserved because they usually supply the upper ureter. ([60])

ABO blood group and HLA tissue-type matching and a final cross-match of recipient sera with donor cells are also performed between donor and recipient as part of the pre-transplanted evaluation. ([60])

CADAVERIC DONOR EVALUATION:

The age range considered for cadaver renal donation has gradually expanded, and it includes infants as well as donors who are more than 60 years old. A history of transmissible disease, such as human immunodeficiency virus and hepatitis B, and of malignant diseases other than superficial skin cancers or non-metastasizing brain tumors constitutes grounds for exclusion. Brain death may induce several metabolic changes such as a catecholamine surge leading to hypertension (Cushing,s reflex) and decreased antidiuretic hormone secretion. Adequate hydration and B-blockers or other antihypertensive agents may be required to protect potentially recoverable organs .The donor should be kept well perfused with a urine output greater than 1mL/kg/hr. until the time organ retrieval ([62]).

The technique of organ recovery varies, depending on the number and type of organs being retrieved. After a midline incision from the sternum to pubic is made, perfusion is begun through cannulas placed at the aortic bifurcation and in the inferior vena cava (IVC). The heart and the liver are recovered after ligating the aorta and dissecting the celiac axis and the superior mesenteric artery respectively. The ureters are dissected and are divided at a point as low as possible. The kidneys are then flushed and removed, retaining a patch of aorta (Carrell's patch) along with each of the renal arteries. The right renal vein is removed along with a segment of the I VC, whereas the left renal vein is divided from the IVC before removing the kidney. The organs are flushed using preservation solutions such as Euro-Collins or University of Wisconsin solutions ([63, 64]). These solutions, which are similar in electrolyte composition to intracellular fluid, are also used for storage, and the retrieved organs are either transported on ice or are placed on pulsatile perfusion. Cadaveric kidneys should be transplanted within 48 hours. Wedge biopsies of the kidneys can be performed to evaluate the pathological features and viability of the organ ([62]).

NON-HEART BEATING DONORS:

Interest has been renewed in using organs from non-heart beating donors for transplantation. These donors are the only source of cadaveric kidney in Japan. Candidates who fall into this group include patients with severe central nervous system disease who are on life support but have an extremely poor prognosis. These patients may not meet the immediate criteria for brain death, and withdrawal of life support should be imminent. In these situations, consent is obtained from the family, cooling cannulas are placed, and life support is withdrawn, usually in the operating room. Once cardiac death has occurred, organs are rapidly retrieved, thus limiting worm ischemia time. This method of organ retrieval has been used more commonly in Europe and is the source of up to 20% of the cadaveric kidneys in some countries ([65]). However, the ethical and legal issues involved have limited widespread use of this method of organ retrieval in the U.S.

LIVING UNRELATED DONORS:

The continued shortage of transplantable organs has resulted in a situation in which less than 50% of eligible recipients receive a kidney transplant each years. This shortage has broadened the search for alternative organ sources. Transplants have been performed using kidneys from spouses, friends, and even unrelated strangers. With the use of modern immunosuppression, results of such living unrelated transplants have been excellent and approximate those of living related and cadaveric transplants in well-selected cases ([66]). Living unrelated transplants accounted for 0.9% of all transplants in the United States in 1990 ([67]). Overall 1-year and 4-year graft survival rates of 88% to 100% and 80% to 87%, respectively, have been reported ([68]). However, much trepidation exists about widespread use of living unrelated donors for kidney transplantation because of the potential for commercial exploitation, as has occurred in some developing countries.

ABO-INCOMPATIBLE KIDNEY TRANSPLANTS:

A cardinal rule of renal transplantation was that the donor and recipient had to be ABO blood group compatible; otherwise, the risk of graft loss from hyperacute rejection would be unacceptably high. More recent studies demonstrated that successful kidney transplantation can be performed even in the face of ABO incompatibility ([69, 70]). This requires sequestration of any preformed antibodies against the A and B blood group antigens through ultrafiltration, plasmaphoresis, or immunoadsorption. Splenectomy may also need to be performed in conjunction with the kidney transplantation. Using cyclosporines-based immunosuppression, 1-year graft survival of up to 83% has been achieved. ([70]). The number of patients undergoing this type of renal transplantation is small, and further studies are required to refine selection criteria before the procedure becomes generally applicable.

Imaging the transplanted kidney

Renal transplant recipients survive longer and enjoy a better quality of life than do patients undergoing dialysis. It is no surprise then that, in 1995, more than 12,000 renal transplantations were performed, and 29,000 patients were on transplant waiting lists in the United States. Despite its advantages over dialysis, certain disadvantages persist. There is a chronic shortage of donors. Because the supply of healthy cadaver kidneys is limited, the increasing trend has been to use related living donors and, more recently, unrelated living donors ([71]). Immunosuppression, although greatly improved, remains a problem after renal transplantation. In addition to the increased rates of infections and tumors, transplant recipients also have to contend with the real possibility of rejecting their allograft. Thus, although it is the preferred method of renal replacement therapy, renal transplantation has much room for improvement.

. Imaging has always played an important role in the evaluation of renal transplantation. The role of imaging begins in the evaluation of potential living related donors. It is used in identifying rejection and acute tubular necrosis (ATN). Imaging is also important in the assessment of longer-term complications such as vascular and ureteric anastomotic stenoses, perigraft fluid collections, and ischemic and infectious complications of the transplant itself. ([72])

LIVING RELATED DONOR:

Living related donors provide a progressively larger proportion of the kidneys used in the United States for renal transplantation. Traditionally, the donor undergoes typing of major histocompatibility loci to determine suitability for donation. Increasingly, more major mismatches are acceptable as immunosuppression regimens improve and the supply of cadaveric allografts remains unable to meet demand([72]).

Anatomical imaging is important to:

1. Identify any preexisting renal masses
2. Identify any congenital anomalies that would render the donor without sufficient renal function.

3. Identify any arterial or venous anomalies that could complicate the transplantation procedure.

Until recently, the patient usually underwent ultrasound or computed tomography (CT) of the kidney to identify pre-existing renal masses or anomalies, a conventional angiogram to identify any accessory renal vessels, and a chest radiograph and stress thallium study. More recently, this combination of studies has been replaced with either CT angiography (CTA) or magnetic resonance angiography (MRA), which are capable of providing information not only about the renal parenchyma but also about arterial and venous anomalies([73,74]). Approximately 15% to 20% of kidneys have accessory renal arteries that need to be anastomosed separately. (This is of less concern in the cadaveric transplant because the surgeon can remove a cuff of aorta with the arteries. Retroaortic left renal veins and azygous continuation are examples of venous anomalies that are of great interest to transplant surgeons. Increasingly, renal cysts are no longer considered contraindications to transplantation. Incidental cysts do not affect renal function and therefore should not be used as excluding criterion. Thus, in many centers, a single CT or CTA study now replaces the combination of imaging studies formerly performed in living related donors([75,67,77]).

IMAGING TECHNIQUES OF THE RENAL VESSELS:

Thorough! Knowledge of the renal vessels and their variants is essential to the practice of radiology, surgery, and endourology. Many variations occur in the origin, number, and course of the renal arteries and veins. In fewer than half of all people do the renal arteries of both sides fit the textbook pattern of anatomy, that is, a single vessel supplying each kidney. Fewer variations occur in the drainage patterns of the renal veins. Only variants of the left renal vein may be of clinical significant. ([78]).

Several imaging technique are available for use in the evaluation of renal vascular anatomy, including angiography, conventional and spiral (helical) computed tomographic (CT) angiography, magnetic resonance (MR) angiography, color Doppler ultrasonography, and endoluminal sonography. Although angiography is the most accurate test for studying blood vessels, CT and MR techniques are used with increasing frequency in the identification of renal vessels because of their safety and cost advantages. Spiral CT angiography eliminates the risks and costs of arterial catheterization. MR angiography eliminates the risks of both arterial catheterization and iodinated contrast material. ([78])

Angiography:

Angiographic techniques that are currently used in the evaluation of renal vessels include:

1. Intravenous digital subtraction angiography (DSA),
2. Intra-arterial DSA.
3. Conventional cut film angiography.

Intravenous DSA uses an intravenous injection of contrast material to evaluate arterial disease. It requires high doses of contrast material for each run, thus limiting the number of runs to three or four in evaluation of the renal artery. Intravenous DSA is now infrequently used because of poorer resolution, superimposition of multiple vessels and imaging artifacts caused by motion and bowel peristalsis. Intra-arterial DSA, which entails infra-arterial injection of contrast material through a percutaneously introduced catheter, provides better resolution and fewer imaging artifacts than intravenous DSA does. Intra-arterial DSA has many advantages over conventional arteriography, including high contrast resolution, lower contrast doses, less discomfort, lower film costs, and shorter procedure time. CO_2 DSA involves the intra-arterial injection of gas for visualization of the abdominal aorta, renal arteries, and peripheral vessels, with the same technique used as for intra-arterial DSA. The most common indication for CO_2 DSA is to identify renal artery stenosis and peripheral arterial occlusive diseases in patients with renal failure and contrast allergy ([78]).

Spiral Computed Tomographic Angiography:

The development of new technology has led to the advent of volumetric CT scanning and three-dimensional reconstruction of the data. Spiral GT angiography uses the new spiral ct scanning technique for visualization of large vessels, such as the aorta and its branches. Spiral CT angiography can provide excellent anatomical detail of the abdominal aorta and its branches ([79, 80, 81]). This technique has been successfully used for screening potential renal donors with visualization of all main renal arteries, most accessory renal arteries, and variant renal venous anatomy ([82]).

Magnetic Resonance Angiography

MR angiography has rapidly become an accepted modality because there is no need for the use of iodinated contrast material and ionizing radiation. The technique is well suited to imaging large vessels, including the renal arteries and veins ([83, 84]). It will eventually replace most conventional diagnostic arteriographic studies that are used for studying large vessels. MR angiography is not easily performed in patients requiring life support equipment and cannot be performed in patients with implanted electronic devices | such as pacemakers, cochlear implants, or defibrillators.

Several pulse sequences are used for imaging the renal artery, The initial sequence is T_1-weighted spin echo imaging in which flowing blood appears black (Flow void, black blood imaging).

The next sequence called time-of-flight imaging. Images vessels by using a flow-related enhancement technique in which the inflowing blood appears bright (high signal intensity, "bright blood" imaging) against the stationary saturated tissue (low signal intensity).

The third sequence, called phase-contrast imaging, is used to image flowing blood by means of velocity-induced phase shifts in which the inflowing blood appears bright ("bright blood" imaging) as in the time-of-flight imaging. Problems with MR angiography, such as respiratory motion, vessel overlap, and the inherent complex flow patterns, have largely been solved with the advent of MR contrast agents (gadolinium). Gadolinium shortens the T1 relaxation time of blood to allow imaging of the vessels independent of flow. Gadolinium contrast images are similar to digital subtraction angiograms. A study comparing MR angiography with DSA in renal donors revealed similar accuracy in detecting accessory renal arteries ([84]).

Renal Angiography:

Modern angiography traces back to the mid-1950s, when Sven Seldinger invented percutaneous catheterization) ([85]). Key techniques and devices matured within a relatively few years: image amplifiers, reliable serial changers, safe contrast agents, pressure injectors, guide wires, and catheters. The clinical value of renal angiography soon became apparent, particularly in the study of renovascular hyper-tension and renal masses ([86, 87]). In the United

States before that time, renal arteriography was performed by intravenous or translumbar techniques; quality was poor by the standards of today, and the studies were stressful and hazardous.

High-quality direct film magnification arteriograms now show arteries as small as 150 µm, and images of glomeruli are usually apparent as well. Small catheters and modern contrast media have made the technique safe enough for outpatient use and safer for patients with renal insufficiency. Although technical advances in vascular imaging such as digital angiography, computed tomographic angiography (CTA), or magnetic resonance angiography (MRA) often increase the convenience and safety of angiography, they are introduced at the cost of considerable degradation of morphological resolution, often with the sacrifice of important diagnostic information. Optimal angiography as much as ever requires skilled hands and creative cognitive energy ([88]).

METHOD of RENAL ANGIOGRAPHY:

The methods of renal arteriography vary somewhat, depending on the indication and the functional status of the kidney. The following is effective as a standard technique for otherwise healthy patients suspected of having reno-vascular hypertension.

After catheterization of the aorta from a femoral artery, the renal arteries are localized during fluoroscopy by a small hand injection of contrast medium. A pigtail catheter is placed at the level of the highest visualized renal artery.

Contrast medium is injected after the first 8 seconds of performing a Valsalva maneuver in the inspiratory position. The Valsalva maneuver diminishes cardiac output, thereby improving opacification.

If the aortogram is completely normal and both kidneys are well shown, the procedure is terminated. If any ambiguity is noted, however, magnification arteriography after selective catheterization of the renal artery is performed, commonly in a contralateral posterior oblique projection to optimally demonstrate the segmental branches. If the films are exposed during expiration, alterations in arterial anatomy related to diaphragmatic movement)kinking or stretching) may be demonstrated .([89])

APPROACHES

Retrograde Femoral Approach

The retrograde femoral approach is the simplest and safest. It can be used even when the femoral pulses are reduced or the iliac arteries are tortuous. The puncture site should be made within a few millimeters of the inguinal crease, which is usually where the artery is most easily palpable and where the artery takes a fairly straight course over the femoral head. The artery should be punctured over the femoral head so that effective manual pressure can be applied when the catheter is removed. For this reason, fluoroscopic localization of bony landmarks can be helpful. After generous local infiltration of the superior and both lateral aspects of the artery with 1% to 2% lidocaine, a 1-to

3-mm incision is made at the site of puncture. With two fingers kept on the arterial pulse, a needle is advanced into the anterior wall of the artery until blood spurts from the needle hub. Alternatively, a stylet-cannula combination is advanced through both the anterior and posterior arterial walls. The stylet is removed and the cannula slowly withdrawn until an arterial spurt is encountered ([89]).

When arterial flow from the needle is brisk, a guide wire is advanced into the abdominal aorta. For flush aortography, a 5 F pigtail catheter is advanced over the wire. To visualize the renal arteries, the catheter tip should be placed at the upper level of the most proximal renal artery. A strong Valsalva maneuver for about 8 seconds before injection decreases cardiac output to about half and produces much denser vascular opacification. ([89])

Alternative Approaches

If the femoral approach is not feasible, the axillary artery can provide access to the aorta. Blood pressure should be measured in both brachial arteries. If not equal, the side with the higher blood pressure should be used. In the absence of blood pressure discrepancy, puncture of the left axillary artery is safer than puncture of the right because the catheter does not pass the carotid arteries.

Postarteriography bleeding can occur within the axillary sheath and result in chronic pain and nerve deficit ([90]). Great care must be taken to properly compress the puncture site after catheter withdrawal, to apply a pressure dressing, and to keep the arm immobilized in a sling for 24 to 48 hours. The patient should be monitored closely for 24 hours after arteriography to detect pain or neurological deficit. Should signs of nerve deficit develop, prompt surgical decompression of the axillary sheath is mandatory.

Translumbar aortography can be useful in patients who need aortography but whose femoral and axillary arteries cannot be punctured.

CONTRAST MEDIA:

lodinated Contrast Medium:

Despite continuing improvement, contrast media remain mildly nephrotoxic, and the desire for high contrast must always be balanced against kidney (and patient) tolerance ([91,92]). The incidence of significant impairment in renal function after radiographic contrast administration is between 0.6% and 1.4% among patients with normal renal function ([93,94,95,96]) Pre-existing renal insufficiency is the single most important risk factor; in such patients, reversible renal failure occurred in 15% to 44% in three series of patients undergoing either arteriography or intravenous urography ([92-94]) In one series, renal function deteriorated after intravenous urography in 5.6% of patients with pre-existing renal failure ([97]). Other risk factors include diabetes mellitus, multiple myeloma, and dehydration. Although diabetes has been considered a significant risk factor, Parfrey and colleagues found no nephrotoxicity in diabetics with normal renal function. ([98]).

The risk of nephrotoxicity can be reduced by hydration before and during angiography ([96, 99]). Eisenberg and co-workers infused normal saline before, during, and after the procedure and reported no instances of renal failure in 537 patients undergoing angiography. ([99])

Low-osmolar contrast media are approaching the older media in price and are probably safer ([100,101]). As their cost drops, they are increasingly becoming the contrast media of choice for most genitourinary angiography. Although it seems reasonable to presume that they are less nephrotoxic, this property has to date been difficult to document. ([90, 98, 102])

Patients at high risk for contrast reaction should be pretreated with a steroid regimen such as prednisone for 24 to 48 hours at a dose of 80 mg/day ([103,104]). Patients who have had mild reactions such as hives can be given low-osmolar contrast medium without pretreatment.

Carbon Dioxide

In renal arteriography, CO_2 is an alternative to iodinated contrast media in patients with renal insufficiency ([105,106,107,108,109]). Because gas rises, the vessels best shown are ventral in a supine patient. Although many use Co_2 as the primary contrast material for patients with renal failure, standard contrast media provide superior opacification and more reliable diagnostic information. DSA using small volumes of contrast medium and diligent hydration is safe and probably more accurate in patients with renal failure.

Gadolinium-Based Contrast Agents for Angiographic Use:

Recent MR studies describe the intra-arterial administration of a paramagnetic contrast agent with digital subtraction imaging in the evaluation of patients with impaired renal function ([110]). A small study involving animal subjects compared gadolinium dimeglumine (Gd-dieth-yienetriamine pentaacetic acid [DTPA]) arteriography of the kidneys with various dilutions of iodinated contrast material (iohexol) and carbon dioxide. The Gd-DTPA arteriograms were found to be comparable in image quality to iohexol, 12.5% and 25% dilution, and superior to carbon dioxide.([110]). The advantage to the use of Gd-DTPA over iodinated contrast material is that Gd-DTPA has no known deleterious effects on renal function. There is, however, one reported case of acute renal failure after angiography with a gadolinium-based contrast medium ([110]). Although an agent such as Gd-DTPA is usually reserved for magnetic resonance imaging (MRI and MRA), it may become an alternative contrast medium for arteriography in patients in renal failure.

Equipment for the Seldinger technique

Needles:

The technique of catheter insertion via double-wall needle puncture and guide-wire is known as the Seldinger technique. ([111]).

The original Seldinger needle consisted of three parts:

1. An outer thin-walled blunt cannula
2. An inner needle.
3. A stilette.

Many radiologists now prefer to use modified needles:

1. Double-wall puncture with a two-piece needle consisting of a bevelled central stilette and an outer tube.

2. Single-wall puncture with a simple sharp needle (without a stilette) with a bore just wide enough to accommodate the guide-wire.

Guide-wires

These consist of two central cores of straight wire around which is wound a tightly coiled wire spring. The ends are sealed with solder. One of the central core wires is secured at both ends -a safety feature in case of fracturing. The other is anchored in solder at one end, but terminates 5 cm from the other end, leaving a soft flexible tip. Some guide-wires have a movable central core, so that the tip can be flexible or stiff. Others have a J-shaped tip which is useful for negotiating tortuous vessels and selectively catheterizing vessels. The size of the J-curve is denoted by its radius in millimeters. Guide-wires are polyethylene coated but may be coated with a thin film of Teflon to reduce friction. Teflon, however, also increases the thrombogenicity, although this can be countered by using heparin-bonded Teflon. The most common sizes are 0.035 and 0.038 inches .diameter. A more recent development is hydrophilic wires. These are very slippery with excellent torque and are useful in negotiating narrow tortuous vessels. They require constant lubrication with saline. ([111]). .

Catheter:

Most catheters are manufactured commercially, complete with end hole, side holes, preformed curves and Luer Lok connection. They are made of Dacron, Teflon, polyurethane or polyethylene. Details of the specific catheter types are given with the appropriate technique.

Some straight catheters may be shaped for specific purposes by immersion in hot sterile water until they become malleable, forming the desired shape and then fixing the shape by cooling in cold sterile water. For, the average adult a 100-cm catheter with a 145-cm guide-wire is suitable for reaching the aortic branches from a femoral puncture. The introduction of a catheter over a guide-wire is facilitated by dilatation of the track with a dilator (short length of eroded tubing).

If the patient has a large amount of subcutaneous fat in the puncture area, catheter control will be better if passed through .in introducer set, and this is also indicated where it is anticipated that catheter exchange may be required. ([111]).

Taps and connectors

These should have a large internal diameter that will not increase resistance to flow and Luer Loks which will not come apart during a pressure injection ([110]).

FEMORAL ARTERY PUNCTURE:

This is the most frequently used puncture site providing access to the left ventricle, aorta and all its branches. It also has the lowest complication rate of the peripheral sites.

Relative contraindications

1. Blood dyscrasias.
2. Femoral artery aneurysm.
3. Marked tortuosity of the iliac vessels may prevent further advancement of the guide-wire or catheter. In such a case, high brachial artery puncture may be necessary. The clinical question may be answered by

contrast enhanced CT or MR angiography ([111]).

Technique:

1. The patient lies supine on the X-ray table. Both femoral arteries are palpated and if pulsations are of similar strength -the side opposite to the symptoms is chosen. The reasoning for this is that this leaves the symptomatic groin untouched so that, future surgery in this region is not made more hazardous. If all else is equal, then the right side is technically easier (for right-handed operators).
2. Before beginning, the appropriate catheter and guide-wire are selected and their compatibility checked by passing the guide-wire through the catheter and needle.
3. Using aseptic technique, local anaesthetic is infiltrated either side of the artery down to the periosteum. A 5 mm transverse incision is made over the artery to avoid binding of soft tissues oh the catheter. In thin patients the artery may be very superficial and, to avoid injury to it, a position is chosen and the skin reflected laterally before making the incision.
4. The actual point of puncture of the femoral artery must be considered. The femoral artery arches medially and posteriorly as it becomes the external iliac artery. Attempts to puncture the artery cephalad to the apex of the arch will result in either failure to

puncture the artery or puncture of the artery deep in the pelvis at a point where homeostasis cannot be secured by pressure. Correct puncture is made at the apex of the arch with the needle directed 45° to the skin surface and slightly medially.

5. The artery is immobilized by placing the index and middle fingers of the left hand on either side of the artery, and the needle is held in the right hand. The needle is advanced through the soft tissues until transmitted pulsations are felt. Both walls of the artery are punctured with a stab (single-wall puncture increases the risk of intimal dissection). The stilette is removed, and the needle hub is depressed so that it runs more parallel to the skin and then withdrawn until pulsatile blood flow indicates a satisfactory puncture.

   Poor flow may be due to:

   A; femoral vein puncture.

   B; the end of the needle lying sub-intimally.

   C; hypotension due to vasovagal reaction during the puncture. . D; atherosclerosis.

6. When good flow is obtained the guide-wire is inserted through the needle and advanced gently up the artery whilst screening. When it is in the descending aorta the needle is withdrawn over the guide-wire, keeping firm pressure on the puncture site to prevent bleeding. The

guide-wire is then wiped clean with a wet sponge and the catheter threaded over it. For 5-F and greater diameter catheters, particularly those which are curved, a dilator is recommended of a size marched to the catheter. The catheter is advanced up the descending aorta, under fluoroscopic control, and when in a satisfactory position the guide-wire is withdrawn.

7. The catheter is connected via a two-way tap to a syringe of heparinized saline (2500 units in 500 ml of 0.9% saline), and flushed. Flushing should be done rapidly otherwise the more distal catheter holes will remain un-flushed. Continuous flushing from a bag of heparinized saline or intermittent flushing throughout the procedure must be undertaken.
8. At the end of the procedure the catheter is withdrawn and compression of the puncture site should be maintained for 5 min. If continued bleeding becomes a concern, consideration should be given to neutralizing the effects of heparin by giving protamine sulphate, 1 mg for each 100 units of heparin ([111]).

GENERAL COMPLICATIONS OF CATHETER TECHNIQUE:

Due to the technique

Angiography is an invasive procedure and complications are to be expected. However, the majority of these are minor, e.g. groin haematoma.

Recommended upper limits for complication rates have been produced by the Society of Cardiovascular and Interventional Radiology (SCVIR) ([112]) and been supported by the Royal College of Radiologists. These rates are included in the following discussion.

Local:

The most frequently encountered complications occur at the puncture site. The incidence of complications is lowest with the femoral puncture site.

1. Haemorrhage/haematoma: The commonest complication, small haematomas occurring in up to 20% of examinations and large haematomas in up to 4%. The SCVTR threshold for haematomas requiring transfusion, surgery or delayed discharge is < 3.0%. Haematoma formation is greater with interventional procedures which employ larger catheters, more frequent catheter changes and heparin or thrombolytic agents. Haematoma formation is also greater when the femoral artery is punctured high because of inadequate compression of the artery following catheter removal.

2. Arterial thrombus May be due to:

a. stripping of thrombus from the catheter wall as it is withdrawn

b. trauma to the vessel wall.

Factors implicated in increased thrombus formation are:

a. large catheters

b. excessive time in the artery

c. many catheter changes

d. inexperience of the radiologist

e. polyurethane catheters, because of their rough surface.

The incidence is decreased by the use of:

a. heparin-bonded catheters

b. heparin-bonded guide-wires

c. flushing with heparinized saline.

3. Infection at the puncture site.

4. Damage to local structures: Eespecially the brachial plexus during axillary artery puncture.

5. Pseudoaneurysm: Rare. SCVIR threshold < 0.5%. Presents as a pulsatile mass at the puncture site usually 1-2 weeks after arteriography and is due co communication between the lumen of the artery and cavity within an organized haematoma. Arterial puncture below the common femoral artery bifurcation increases the risk of this complication. Some may require surgical repair.

6. Arteriovenous fistula. Rare SCVIR threshold < 0.1%. More common at the femoral puncture site when puncture is below the common femoral artery bifurcation because at this level the vein lies posterior to the artery and both are punctured in the standard double-wall technique. ([111])

Distant:

1. Peripheral embolus: from the stripped catheter thrombus. Emboli to small digital arteries will resolve spontaneously; emboli to large arteries may need surgical embolectomy. SCVIR threshold < 0.5%.

2. Atheroembolism: More likely in old people. J-shaped guide-wires are less likely to dislodge atheromatous plaques.

3. Air embolus: May be fatal in a coronary or cerebral artery. It is prevented by:

a. Ensuring that all taps and connectors are right

b. Always sucking back when a new syringe is connected

c. Ensuring that all bubbles are excluded from the syringe before injecting.

d. Keeping the syringe vertical, plunger up, when injecting.

4. Cotton fibre embolus. Occurs when, syringes are filled from a bowl containing swabs. This very bad practice is prevented by:

a. separate bowls of saline for flushing and wet swabs.

b. A closed system of perfusion.

May also occur when a guide wire is wiped with a dry gauze pad.

5. Artery dissection: Due to entry of the catheter, guide-wire or contrast medium into the subintimal space. It is recognized by resistance to movement of the guide-wire or catheter. increased resistance to injection of contrast medium or subintimal contrast medium. The risk of serious dissection is reduced by:

a. Not using a single-wall needle with a long bevel
b. Using floppy J-shaped guide-wires.
c. Using catheters with multiple side holes.
d. Employing a test injection prior to a pump injection
e. Careful and gentle manipulation of catheters.

6. Catheter knotting. More likely during the investigation of complex congenital heart disease. Non-surgical reduction of catheter knots is discussed by Thomas and Sievers. Surgical removal after withdrawal of the knotted end to the groin may be only solution in some cases.

7. Catheter impaction:

In a coronary artery produces cardiac ischaemic pain,

In a mesenteric artery produces abdominal pain.

There should be rapid wash-out of contrast medium after a selective injection.

8. Guide-wire breakage: More common in the past and tended to occur 5 cm from the rip, where a single central core terminates.

9. Bacteraemia/sepricaemia: Rarely of any clinical significance. ([111])

Transplant Donor Arteriography:

The study is usually limited to an aortogram. If the number of renal arteries is at all in question, a selective arteriogram may be performed to demonstrate in the nephrogram phase whether the entire kidney is opacified by the artery injected. If the potential donor kidney has multiple arteries, selective arteriograms are performed in search of a ureteral artery, the origin of which should be preserved during surgical removal.

Normal Renal Arteriogram:

Serial radiographs after the injection of contrast medium into the renal artery demonstrates three phases: arterial, nephrographic, and venous. The arterial phase lasts about 2 seconds after the end of the injection and shows the vascular tree from the main renal artery to the interlobular arteries. Interlobular arteries usually opacify within 1 to 1.5 seconds after contrast medium is injected. In normal individuals, interlobular arteries are almost immediately obscured by the granular densities of surrounding glomeruli. Contrast medium normally ascends in the interlobular arteries so rapidly that all levels of the cortex are opacified virtually simultaneously.

The nephrographic phase begins about 1.5 seconds after beginning the injection, readies a maximum 2 seconds after the end of injection, and fades gradually. The early nephrogram is largely attributable to opacification of vascular structures smaller than the resolution of the radio-graphic system, whereas the late nephrogram is increasingly attributable to contrast medium within the collecting tubules. The cortex is normally much more densely opacified than the medulla and is sharply demarcated from it. Cortical density reflects the large integrated sum of glomerular capacitance. Cortical thickness is usually approximately equal throughout both kidneys, except for some increase in the subhilar lip. In a series of normal individuals, cortical thickness varied between 4.2 and 12 mm among individuals after correction for magnification([26]). Cortical extension between medullary pyramids (septa of Bertin) are present in most kidneys. Fetal lobation may be quite prominent. Lobation can usually be distinguished from scarring because lobar indentations are located between calyces and overlie the center of a cortical septum.

Renal veins are ordinarily only faintly opacified after arteriography. The renal venous phase may begin as early as 4 seconds after the beginning of selective injection and may persist for 6 -10 seconds. The poor but prolonged venous opacification partially reflects the varying rates of blood flow in the cortex, outer medulla, and inner medulla. Because approximately 20% of the contrast medium is filtered, it is unavailable for venous opacification ([113]).

In addition to branches to the renal parenchyma, the renal artery supplies the inferior adrenal artery, extrarenal capsular arteries, perforating capsular arteries (arising from the arcuates, crossing the cortex, and penetrating the capsule), arteries to the renal pelvis, and ureteral arteries. These arteries may enlarge and become clinically important if they contribute to tumor blood supply or if they become routes of collateral flow around a stenotic renal artery ([114]). Renal pelvic branches course in the renal sinus and may provide collateral flow between segmental branches ([115]). Ureteral arteries may be prominent in ureteral infections, and capsular vessels may provide supplemental flow to perinephric infection and tumors.

Contrast Injection Rates and Pressure Measurements:

Optimal demonstration of renal vascular morphology requires an injection rate that approximates the rate of renal blood flow ([116]) There is little purpose in injecting 8 mL/ second into a diseased kidney that will accept only 1 mL/ second. Injection rates considerably less than the rate of blood flow result in dilution and poor opacification of vessels.

OBJECTIVES

- To evaluate the accuracy of renal angiography in living donor renal transplantation.
- To evaluate whether renal angiography can be used to investigate for the pattern of the renal blood supply.

Chapter Two

PATIENTS & METHODS

PATIENTS & METHODS

Study type:

This is a retrospective hospital data based study.

Study area:

Renal Transplantation Unit - Ahmed Gasim Hospital.

Study period:

December 2000-----December 2004.

Study sample:

All cases done during the study period in Renal Transplant unit in Ahmed Gasim Hospital

Study population:

The study population were the candidates for living donor renal transplantation who did (conduct) renal angiographic study to evaluate the pattern of renal blood supply and conduct a nephrectomy for the purpose of donation and consider as an actual living donor .

Exclusion criteria:

Records that considered to be deficient were excluded from the study.

Data collection techniques:

All the records during the study period (december2000-december2004), had been revised and data were collected manually by the author, excluding those with deficient records (radiological or surgical records) .

The data sheet included:

1/ Personal data.

2/ Radiological findings by means of report of angiographic study.

3/ Surgical findings by means of the post operative sheet.

Statistical Methods:

Data had been analyzed by the computer , used the SPSS program ,bi variants analysis and test of significant by x^2 square test.

Difficulties:

Incomplete records .

Team:

The author.

The statisticians in the renal transplant unit .

More stress to be taken as renal angiography is an essential tool in evaluating the renal arteries in the living donors renal transplantation to select the right kidney for donation.

As renal angiography an invasive procedure and including complication due to catheter technique, compared to MRA study. So MRA advised to be introduced to the renal transplant investigating programs.

Sufficient training programs for the radiologist and radiographer to be organized for MRA issue.

More care need to be added to the operation sheet to any nephrectomy conducted for the purpose of donation.

More stress to governmental support to be conveyed in renal transplantation program from the start of investigations .

Academic seminars to rule out the advantage of renal transplantation over dialysis to encourage the physician and nephrologists in specific to renal transplantation rather than dialysis.

Public presentations for orientation and to rease the awareness toward renal diseases and the safety of the local renal transplantation program.

More studies recommended to shed a light on the health situation concerning the renal diseases in north of Sudan as the predominantly cases originated.

When life depends on medical technology renal arterial study answer the question and resolve the problem to whom are under stress of renal diseases especially end stage renal failure.

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Chapter Three

Results

RESULTS

This study was conducted in the Renal Transplant Unit in Ahmed Gasim Hospital ,Khartoum North, Sudan .

In this study the record of 100 actual living donors who underwent a renal angiography and conduct nephrectomy for the purpose of donation (Actual living donor) were reviewed.

Personal data:

Sex distribution was found to be male 67 (67%) donors while 33 (33%) female donors.**(Fig. 1)**

Age: The age of the donors was found to be ranged between 18—50 years**. (Fig**. **2)**

The higher frequency of donors at the age of 20 years (mode), while the mean age was 29.63± S D 7.59 years.

Geographical distributions:

The higher frequency of cases was found to be from Northern Sudan (50.60%) followed by the Central areas (23.00%), then the West (21.00%), while the least cases from Southern Sudan (1.10%) then East (3.40%)**.(Fig. 3)**

Relationship between Donor and Recipient:

The 1^{st} degree relationship was found to be (91.80%) and the 2^{nd} degree (7.10%), while the non-related was only one case(1.2%)..**(Fig. 4)**

The 1^{st} degree relationship was again was subcategorized , and the result that brothers had the higher cases of the relation between donors and recipients, then between sisters. 44, (56.40%) and 17,(21.80%) respectively **(Fig. 5)**

Radiological finding:

Renal angiography revealed that in this study the single renal artery was the commonest picture in the actual living renal donors. Right renal artery 92, (92%) and left renal 85, (85%) **(table 3).**

Two renal arteries were more in the left 10, (10%) , while in the right were 4, (4%),

Three renal arteries and more also more in the left 5, (5%) ,while in the right was 4 ,(4%).

Regarding the length of the renal arteries ,Renal angiography in this study revealed that almost the renal arteries of the donors are of normal length, as in the right 99, (99%) and 96 (96%) in the left. ,while dictated as short in only one (1%) on the right side and 4, (4%) on the left side. **(table 4)**

Regarding the caliber of the renal arteries of the actual living donors in this study were found of normal caliber on both right an left sides.

Surgical finding:

In this study on the basis of the angiographic finding left kidney was selected for donation in 84 donors (84%), while the right kidney was selected in 16 donors, (16%) only **(Fig. 6).**

After nephrectomy the number of the renal arteries in the donated kidneys ,the single renal arteries was the common finding (93.9%), while double renal arteries were found in (6.10%). **(Fig. 7)**

All the renal arteries of the donated kidneys were found to be of normal length by the transplant surgeons.

Regarding the caliber of the renal arteries of the donated kidneys, they were found of normal caliber .

Accuracy of renal angiography compared to surgical finding

In relation to the number of renal arteries:

In this study renal angiography was accurately identified the number of the right single renal arteries 15 out of 15 compared with the surgical findings , that means it was found 100% accurate.

While in evaluating the left single renal arteries ,renal angiography was found less accurate as it detect 77 out of 79 compared with the surgical findings and consider as 96% accurate.

In detecting multiple renal arteries , renal angiographic study was found more accurate in detecting the right renal arteries (2 out of 2) (100%) than the left renal arteries (3 out of 5) (60%).

Regarding the accuracy of renal angiography in evaluating the number of the renal arteries as a whole without concerning the multiplicity of renal arteries, the accuracy was found to be 94% and 96% in detecting the right and the left renal arteries respectively **(Fig. 7 and Fig. 8) .**

In relation to the length of the renal arteries:

Renal angiography was accurately evaluating the length of the renal arteries in the living renal donors , compared to the surgical findings, that all the renal arteries of the donated kidneys was found - by the transplant surgeons - as of normal length in the right kidneys 18 out of 18 (100%) ,compared to 79 out of 83 normal and 3 cases detected as rather short, in the left kidney ,and this was concordant with the angiographic findings that indicate 100% accuracy of renal angiography.

In relation to the caliber of renal arteries:

Regarding the evaluation of the caliber of the renal arteries , renal angiography was 100% accurately evaluate the caliber that found to be normal and was concordant with the surgical findings.

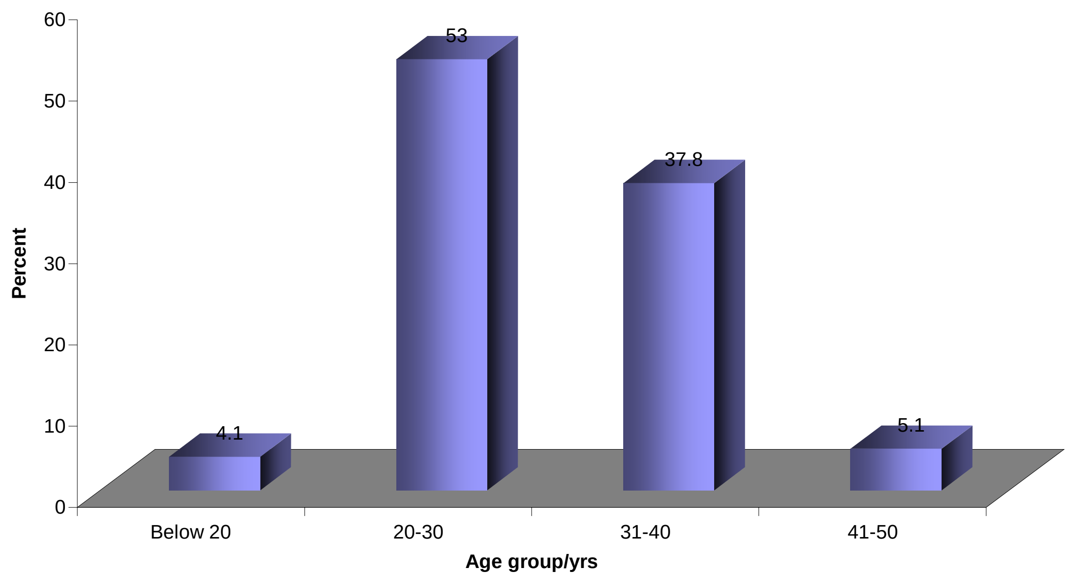

Fig. (2): Age distribution among the actual living renal donors in the study

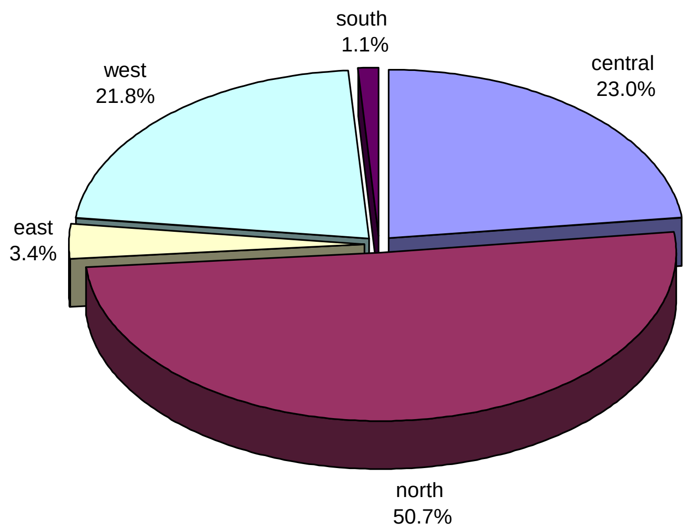

Fig. (3): Geographical distribution of the actual living renal donors in the study

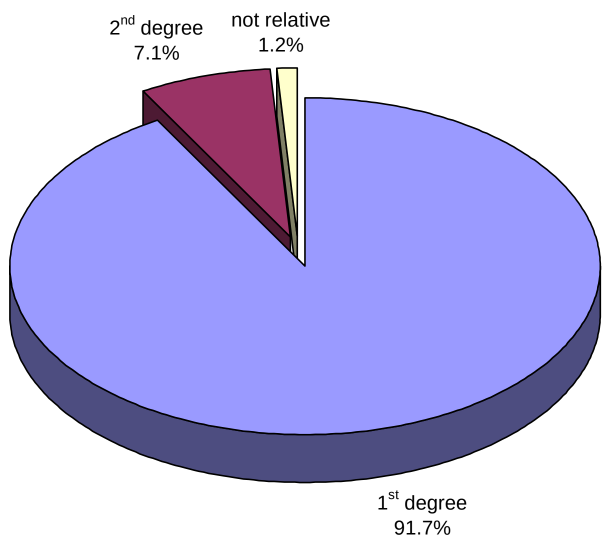

Fig. (4): Degree of relationship between the actual renal donors and the recipients

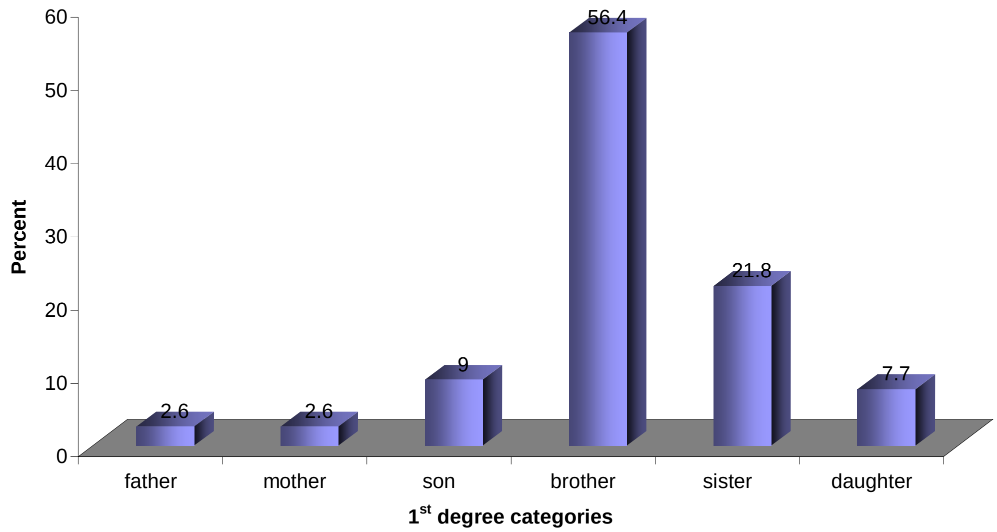

Fig. (5): Subcategorization of the 1st degree relation between the actual renal donors and the recipients

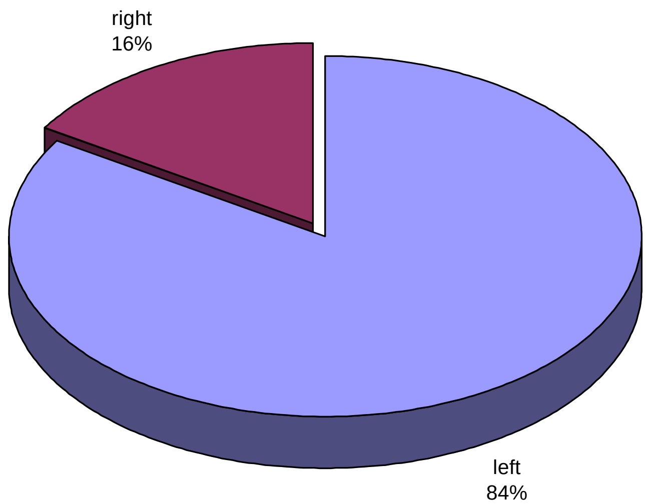

Fig. (6): Anatomical selection of the donated kidneys in the study

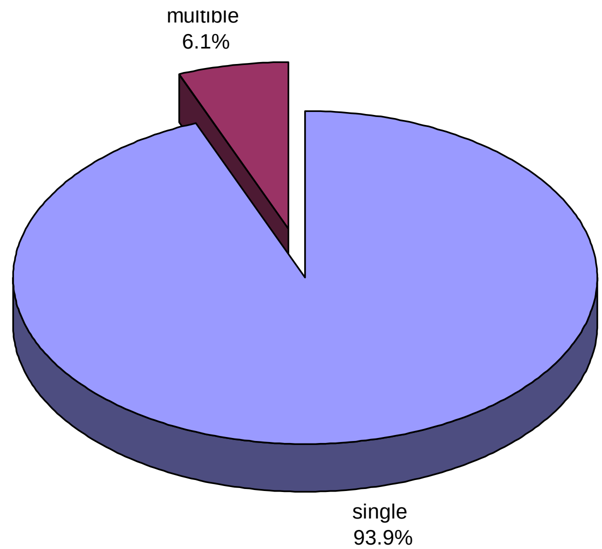

Fig. (7): Number of renal arteries in the selected donated kidneys

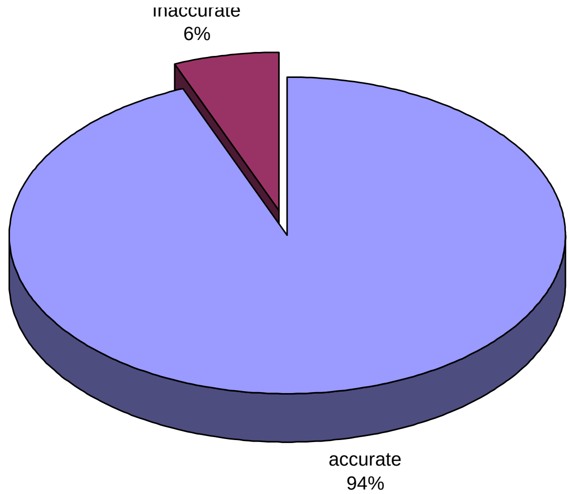

Fig. (8): Accuracy of renal angiography in identifying the number of the right renal arteries compared to surgical findings in actual living renal donors

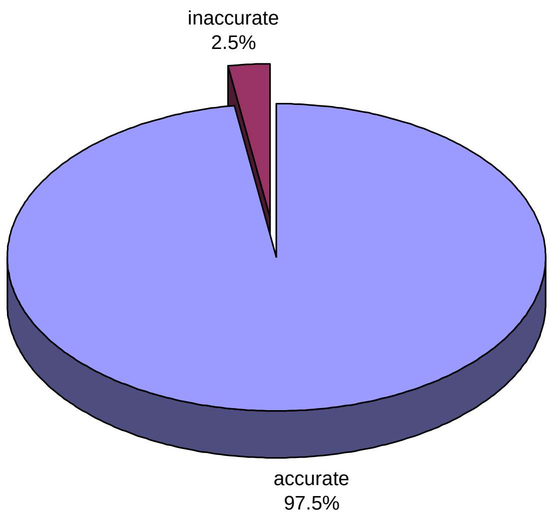

Fig. (9): Accuracy of renal angiography in identifying the number of the left renal arteries compared to surgical findings in actual living renal donors

Year	Number of cases	Deaths
2000	1	0
2001	31	4
2002	27	4
2003	37	6
2004	32	6
Total	**128**	**23**

Table 1: Shows Number of living renal transplant done in Renal Transplant Unit – Ahmed Gasim Hospital in duration between December 2000---December 2004

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Age group	Frequency	Valid percent
Below 20	04	4.10%
20 - 30	52	53.30%
31 – 40	37	37.80%
41 – 50	05	5.10%

Table 2: Age distribution among the actual living Renal donors in the study

Number of renal artery	Right kidney	Left kidney
Single	92	85
Double	4	10
Triple	4	4
Total	100	100

Table 3 : Pattern of renal arterial supply as detected by renal angiography in the study

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Length of renal artery	Right kidney	Left kidney
Normal	99	96
Short	1	4
Total	100	100

Table 4 : Renal angiographic evaluation of the length of the renal artery of the donated kidneys in the study

Chapter Four

Discussion

Discussion

The total number of renal transplantation done in the Renal Transplant Unit in Ahmed Gasim Hospital ,Khartoum North, Sudan in the period of study was 128 with record of 23 deaths. **Table (1).**

Personal data:

Sex:

Although male was outnumbered in this study 67 donors, (67%) ,but the female (33) donors (33%) shared more in the meaning of transplantation ,This reflects the awareness of the public with the seriousness of the renal diseases and the importance of renal transplantation,

Age:

The majority of donors in this study were aged between 20—30 years, And this reflects the age of fitness and productivity.

This match other study and revealed the donors are usually adult between the age of 18 - 60 years (compared to the age of this study range between 18 -50 years) ,although older donors have been used successfully and minors may be used as well.([54])

Geographical distributions:

The predominant number of donors originated from Northern Sudan (50.6%) while the least from Southern Sudan (1.1%) .Although it is stated blacks are more affected by the renal diseases than the white people.([34]) This may be attributed to more health orientation and care in the Northern Sudan. Also there was case noted from other country (Kenya), this may reflect that our renal transplant center had been well recognized to the surround countries.

Relationship between Donors and Recipients:

In this study the majority of the donors were of blood consanguinity (91.80%) and the 1st degree cousin , more brothers and sisters 56.40% and 21.80% respectively, compared to the only one donor who was unrelated to the recipient. This in contradistinction with recent advice that living donors for renal transplant not necessarily be a relative and this reflects only the need. And this match the literature in this issue that most donors have traditionally been blood relatives of the recipient ,substantial unrelated have been noted ,sometimes with no emotional or personal relationship. ([54, 66, 67])

Radiological finding:

In this study single renal artery was the predominant radiological finding in the actual living donors right 92 and 85 in the left .This reflect the importance of the preoperative renal angiography which make it easy for decision taken to the selection of the kidneys with single renal artery that make it easy for surgical grafting, and for the grafted kidney to be sound without affection to its blood supply in the recipient.

In a study done as angiographic study of 444 prospective renal donors revealed multiple renal arteries in 44% of the donors, unilateral in 32% and bilateral in 12% ([8]).The difference in the percentages, can be explained by the fact that a numbers of the prospective living donors were excluded from donation due to their multiple renal arteries .

Other study done on 100 renal donors by DSA reveals that bilateral single renal artery was found 71% and bilateral multiple renal arteries in 2% ,and unilateral multiple renal arteries in 27%([9]) .This study is rather matching with the present study. Although the average percentage of the multiple renal arteries in this study may reflect the higher experience in reconstructing the individual arteries to permit a single vascular anastomosis .

In a study done to see the relation between hypertension and the multiple renal arteries , The study result in the incidence of multiple renal arteries is higher in individuals with hypertension rather than those with normal blood pressure. ([13]) This also strongly support that the main age of donors in present study range between 20 – 30 years reflect the age of fitness and good health and of normal blood pressure.

In a study done Palil UD, Ragavan A, et al, in September 2001 – Helical CT angiography in renal donor vessel evaluation. In 204 renal donors a single renal artery present in (74%) .Multiple renal arteries were more common on the left side (31%) vs. the right side (20%).([117])

The angiographic finding as a radiological tool in evaluating the length of the renal arteries in the actual living renal donors in the present study found that almost all donors of normal renal arteries length, right 99,(99%) , left 96,(96%). Although that detected as short only one .(1%) in the right and 4,(4%) in the left , but this very sound that the donors in this study were actual good health condition.

In study done in Paris , France, Saint – Michel hospital, found that the right renal arteries were longer, with median 53.8 mm (38 – 65 mm) , than the left renal arteries with the median 47.6mm(35 - 63).

In evaluation the caliber of the renal arteries of the donated kidney in this study , all the cases are of normal caliber , that means there were no radiological evidence of Reno vascular diseases, arteriosclerosis or fibro muscular diseases that can cause reno vascular hypertension. ([13, 23])

Surgical Finding:

In the present study the left kidneys were selected for donation by the transplant surgeons in 84 donors,(84%). This proper selection was supported and guided based on the angiographic findings. Although the left kidney is always preferred for donation due to the length of the left renal vein as it is longer than the right renal vein and facilitate subsequent vascular anastomosis by the transplant surgeons ([60])

The single renal artery was the common anatomical and surgical finding in this study for the pattern of renal blood supply of the donated kidneys 94,(94%), this finding was concordant with the radiological finding and confirm the preference of the kidneys with single renal artery for donation by the transplant surgeons.

Regarding the length of the renal artery of the donated kidneys ,surgical finding in all those actual donors in this study was of normal length ,which is concordance with radiological finding by the renal angiographic study. This finding reflect the actual and proper selection of the donors of normal and sound donated kidneys.

Surgical finding of the caliber of the renal arteries of the donated kidneys support the radiological evaluation , as they were found to be of normal caliber and that reflect the health condition of the actual donors in this study in specific to the reno-vascular condition.

Accuracy of renal angiography:

This study reveals that the renal angiography done preoperatively to those actual donors was an important radiological tool for evaluating the donated kidney in different manners.

In evaluating the number of renal arteries ,the accuracy of renal angiography was 97% in evaluating the left renal arteries while less accuracy result in the right side 94%. This can be explained by the fact that the high number of the left donated kidneys 84,(84%) ,compared to the less number of the right donated kidneys,16,(16%). And the inaccuracy in the left was 2 candidates and in the right only one.

In studying the accuracy of the renal angiography in evaluating length of the renal arteries of the donated kidneys in this study, renal angiography was found to 100% accurate in both right and left sides. This reflect high standard of the radiological performance and the quality of the radiological technique in our home country.

In studying the accuracy of the renal angiography in evaluating the caliber of the renal arteries of the donated kidneys ,renal angiography was found 100% accurate and this will help the clinicians to make more use of the help in diagnosing Reno vascular diseases and renal arterial abnormalities by renal angiography in our country. and promote vascular surgery in general and renal in specific.

CONCLUSION

Renal transplantation in Sudan was well established in the last four years, as 140 operations successfully performed between December 2000 – April 2005.

Young age group still the group of donation as their fitness healthy and pronounce the language of love and social links by renal donation.

The social bond in the Sudanese culture have more translation by means of related living renal donors special brother and sisters.

Single renal artery still the most common preferable anatomical base in the actual living donors .

The normal anatomical foundation by means of normal length and normal caliber of the renal arteries in the donated kidney were the most familial recognition .

The left kidney is more preferable for donation compared than the right supported .by normal anatomical foundation for selection.

Evaluation of renal vascular anatomy of the donors in addition to functional assessment is necessary before accepting the donors for renal transplantation.

Renal angiography shows very high accuracy in evaluating renal vascular anatomy as compared to finding seen on the operative table and providing anatomical information.

Renal angiography is very accurate in evaluating the number of the renal artery of the donated kidney.

Renal angiography is very accurate in evaluating the length and caliber of renal artery of the donated kidneys.

RECOMENDATION

More stress to be taken as renal angiography is an essential tool in evaluating the renal arteries in the living donors renal transplantation to select the right kidney for donation.

As renal angiography an invasive procedure and including complication due to catheter technique, compared to MRA study. So MRA advised to be introduced to the renal transplant investigating programs.

Sufficient training programs for the radiologist and radiographer to be organized for MRA issue.

More care need to be added to the operation sheet to any nephrectomy conducted for the purpose of donation.

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