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Original article

Role of Multi Detector Computerized Tomography Angiography (MDCTA) in Evaluation of Renal Vascular Anomalies

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Abstract

Background: Multidetector computed tomographic (MDCT) angiography has become a key imaging investigation for assessment of the renal vasculature challenging conventional angiography. **Objective:** To assess the diagnostic performance and accuracy of multi-detector computed tomography angiography in evaluation of renal vascular abnormalities. **Subjects and Methods:** Prospective study included 95 patients (60 males and 35 females) evaluated by MDCT renal angiography, divided into four groups .First group are renal donors prepared for renal transplant, Second group are patients with history of suspected renal trauma or post percutaneous nephrolithetomy hematuria ,Third group are patients suspected for renovascular hypertension . Fourth group are patients with renal masses assessed for preoperative angio-embolization & surgical guidance. MDCTA findings were correlated with conventional angiography or operative findings. **Results:** MCT angiography results show no significant statistical deference compared with intraoperative findings in first group, as well as compared with conventional angiography regards detection of pseudoaneurysmas in traumatic & post PCNL patients (P value > 0.05) in second group. In patients with suspected renovascular hypertension there was significant difference between renal artery Doppler findings & MDCT angiography as well as conventional angiography (P value <0.05). MDCT Angiography has AUC of 0.973, Sensitivity 93.3% and Specificity 90%. **Conclusion:** We can conclude that, MDCT Renal angiography is an excellent imaging investigation because it is a fast and non-invasive tool that provides detailed evaluation of normal renal vascular anatomy, variants &abnormalities .

Keywords; MDCT; Angiography; renal; vascular; anomalies

Introduction:

The development of multidetector computed tomography (MDCT) technology and helical scanning techniques has radically transformed the role of CT in vascular disease. Modern CT scanners have made CT angiography (CTA) into a clinical reality for diagnostic vascular evaluation (1).

Multislice computed tomographic angiography (CTA) has largely replaced conventional catheter-based diagnostic angiography. New CT technology allows for very short scan times, and scanning at low tube voltage can reduce radiation exposure and/or contrast media (CM) volume. This introduces new challenges in clinical practice (2).

Evaluation of conditions affecting the renal vasculature constitutes a major focus of volume-rendered CT angiography, which has documented utility for demonstrating both arterial and venous disease. Three-dimensional (3D) volume-rendered computed tomographic (CT) angiography provides a fast, noninvasive modality for the evaluation of the renal vascular pedicle (3).

Preoperative evaluation of the vascular anatomy of the donor kidney is the main basis for donor kidney selection and the formulation of the donor nephrectomy scheme (4).

After comparing the advantages and limitations of different imaging methods, and combining with the knowledge of the anatomical characteristics and clinical requirements of blood vessels in the donor kidney, most transplantation centers evaluate the anatomical structure and adjacent relation of the blood vessels in the donor kidney by using MDCT, the outcomes of which have attracted extensive attention and recognition (4).

Computed tomography has become the imaging modality of choice for the assessment of blunt abdominal injuries in major trauma centers. CT can provide precise delineation of a renal laceration, help determine the presence and location of renal hematoma with or without active arterial extravasations, and indicate the presence of urinary extravasations or of devascularized segments of renal parenchyma. Most important, CT can help differentiate trivial injuries from those requiring intervention ,also image reconstruction at 5 mm intervals can be performed when vascular injury is suspected (5).

Almost all renal punctures for PCNL are associated with vascular injury - some trivial and self-resolving; while other injuries can be progressive leading to pseudoaneurysmas or A-V fistulas, which need to be investigated and managed by angioembolization. Type of renovascular injury can be detected either by angiography or multidimensional computerized tomography angiogram with 3-D reconstruction (6).

CT angiography (CTA) is one of the well-established minimally invasive diagnostic procedures for the assessment of suspected renovascular hypertension (7)

Computed tomography angiography is valuable in the detection and characterization of arterio-venous malformation, arterio-venous fistula and renal artery abnormalities. These lesions represent an important group of entities for diagnostic consideration, and understanding the vascular anatomy helps in guiding for proper treatment .It is important to differentiate these vascular anomalies from other renal enhancing lesions before any attempt to perform any percutaneous or surgical intervention (8).

This work aimed to assess the diagnostic performance and accuracy of multi-detector computed tomography angiography in evaluation of different renal vascular anomalies.

Patients and methods

This prospective study included 95 patients (60 males and 35 females), were evaluated with MDCT angiography during the period of 24 months (from May 2019 to May 2021) , at Nephrology and Urology center , Mansoura University . Patients referred from outpatient clinic. The patients are divided into four groups:

- First group are kidney donors prepared for renal transplant as a control group (50 candidate) for detection of vascular variants.
- Second group are patients with history of suspected renal trauma & post percutaneous Nephrolithotomy (PCNL) hematuria (30 patients, 12 traumas, 18 PCNL) searching for pseudoaneurysmas.
- Third group are patients suspected of Reno vascular hypertension searching for renal artery stenosis (10 patients).
- Fourth group are patients with large renal tumour exceeds 10 cm in size for preoperative evaluation of tumour vascularity & guidance angio-embolization if indicated (5patients) .This group will be mentioned as case presentation in our study .

Inclusion criteria:

- Kidney donors.
- Patient with suspected renal trauma & post PCNL.
- Hypertensive middle age patients suspected for renovascular hypertension (persistenthypertension).
- Patients with large renal tumour (size more than 10 cm).

Exclusion criteria:

- Pregnant females or suspected to be pregnant.
- Patient refusing doing the study.
- Patients with renal failure.
- Patients with history of allergy from contrast media.
- Patients with renal tumours with size < 10 cm.

All candidates were subjected to

- Full clinical examination in the form of full history taking and related diseases according to the condition .
- Laboratory investigations including coagulation profile, renal functions (serum creatinine and blood urea).
- Renal ultrasound for patient with renal tumors to interpret size of tumour
- Renal artery Doppler for patients suspected with renovascular hypertension
- Renal CTA .

Serum creatinine and blood urea levels were mandatory before the scan. All donors were below the accepted limit for IV contrast injection (serum creatinine limit was 1.4 mg/dl and blood urea limit was 40 mg/dl).

Each candidate was instructed to fast at least 8 hours before scan in non-emergency patients .No oral contrast material was administered .Each non-emergency patient had to wait about 30 minutes after examination in CT lobby in case that any contrast allergy or adverse effects occurred.

Multidetector CT Protocol:

The study was performed by 64-multisclice helical CT scanner (Brilliance Philips, The Netherlands).CT Scan was performed in cranio-caudal direction. Unenhanced CT of abdomen and pelvis was performed from the vertebral body of T12 to the sacro-iliac joint by 5-mm sections thickness and table speed of 5 mm per-rotation, collimation = 4x1 &rotation time = 0.5 second.Subsequently, all candidates received a dose of (1 ml/kg) with maximum 120 ml, intravenous non-ionic iodinated contrast material (Omnipaque™ 350 mg/ml).

Contrastenhanced CT was initiated, the arterial phase was adjusted according to bolus tracking method from diaphragm till iliac crests , then cortico-medullary and excretory phases were adjusted at 55 seconds and 10 minutes after injectionr espectively taken from diaphragm till symphysis pubis.

Post CTA procedure workup:

One- and 5-mm axial images and 5-mm coronal images routinely were reviewed by two the specialist and consultant for all phases.Images were transferred to a Advantage workstation volume share 2 (GE Healthcare) and Multi-planner reformatted images were obtained in coronal and sagittal planes with a section thickness of (1.25 mm) forallcases:

- Sagittal reformation of each kidney to measure kidney length.
- Axial thin-section maximum intensity projection (MIP) images of the renal arteries and veins.
- Curved coronal reformation across the renal arteries and veins.
- Thin-section coronal–maximum intesnsity projection (MIP) : volume rendering (VR)images obtained on the basis of previous curved coronal reformations.
- Three-dimensional (3D) volume-rendered images for evaluation of arteries and veins.

Image interpretation:

After post-processing workup is finished, CT study is reported. The report includes

A. Non-vascular findings:

- Site, shape and diameter of each kidney
- Parenchymal thickness and pattern of enhancement.
- Presence or absence of cysts, hyperdense stones, parenchymal masses or hydronephrosis .Pattern of calyceal opacification, presence or absence of filling defects.
- Presence or absence of congenital renal anomalies
- Excretory function.
- Ureter: caliber, presence or absence of dilatation, obstruction, stones.

B. CT angiographic findings

➢ In renal donor pateints:

- Renal artery number & caliber (in MIP images) and pattern of opacification & presence or absence of stenotic segments.

- Distance between right first arterial segmentary bifurcation and right margin of aorta and right margin of IVC
- Distance between left first arterial segmentary bifurcation and left margin of aorta
- Renal veins number.
- Presence or absence of intra-luminal venoust hrombi.

➢ In patients with suspected renal trauma & post PCNLbleeding :

Presence of pseudoaneurusmas formation.

➢ In patients with suspected renal hypertension

Presence of stenotic segments in renal artery.

➢ In patients with renal tumors > 10 cm in size

Number of feeding vessels of the tumour for preparing of angioembolization.

Gold standard:

The gold standard for CTA results in our study is intraoperative findings by renal surgeon in control group& conventional angiography findings in other groups.

Ethical considerations

A written informed consent was taken from all participants; each participant was given a code number to facilitate registration and to keep privacy. The study protocol was discussed by selected staff members of the Radiology department, Mansoura urology and nephrology center, was approved from the IRB "institutional review board" of the same faculty.

An informed written consent was obtained from every patient before filling the participation. They were reassured about the strict confidentiality of any obtained information, and that the study results would be used only for the purpose of research. They had the choice to refuse without any change in their management plan.

Statistical analysis:

All data were collected, tabulated and statistically analyzed using SPSS 20.0 for windows (SPSS Inc., Chicago, IL, USA). Quantitative data were displayed in the form of mean ± standard deviation (SD). Qualitative data were demonstrated through figures of frequency and percentage. Charts of different types were used to illustrate data and relations where appropriate.Significance between groups of qualitative data, chi-squared-test ($\chi 2$) was used. For significance in between more than 2 groups for a quantitative variable, independent t-test was used .

Results

This study included 61 men and 34 women with mean age at time of evaluation in group A, B, C and D was 39.47, 42.48, 45.21 and 42.91 years, respectively without statistical significant difference between groups regarding age and sex.**(Table 1& Fig 1) .**

-In control group A (renal donor individuals) (50 individuals) :-

* Regards renal artery evaluation :43 person (86%) shows single renal artery , however there are 2 (4%) have pre-hilar branching, 4 (8%) accessory arteries, , one patient (2%) with multiple renal arteries **(table 2).**

* Regards renal vein evaluation: 46 person (92%) show single renal vein, however there

is one patient with multiple renal veins (2%) , one patient (2%) Circum-aortic renal vein and two patients (4%) with Retro-aortic renal vein **(table 2).**

-There is no statistically significant difference between MDCT Angiography and surgical operative finding regarding detection of vascular variants (arteries & veins) in group A **(Table 2 , Fig 2 &3).**

-In group B (Patients with suspected renal trauma & post PCNL bleeding) (30 patients) :Pseudoaneurysmas were detected in 2patients (16.7%) with renal trauma and 3 patients (16.7%) with Post PCNL bleeding .

-There is no statistically significant difference between MDCT Angiography and Conventional angiography results regarding detection of pseudoaneurysm in traumatic and Post PCNL bleeding patients **(Table 3 & Fig 4)**

-In group C (Patients with suspected renovascular hypertension) (10 patients) : Renal artery stenosis was diagnosed in 3 (30%) patients by Doppler .However one patient only diagnosed by both MDCT Angiography and Conventional angiography with significant statistical difference between renal artery Doppler result sand both MDCT Angiography and Conventional angiography ($p < 0.001$)**.(Table 4 –Fig 5)**

-Collectively previous results suggests that MDCT Angiography has sensitivity of 93.3% and specificity 90.0% and AUC was 0.973.**(Table 5 & Fig 6)**.

ILLUSTRATIVE CASES :

Figure 7: CT Angiography of kidney transplant donor; (a) Coronal reformatted images in non-contrast phase. **(b & c)** Coronal reformatted images in arterial phase showing bilateral single renal arteries. **(d)** Axial reformatted images in arterial phase confirming the number of the renal arteries. **(e & f)** Coronal reformatted images in venous phase showing bilateral single renal veins.

Operative date: Left kidney donor nephrectomy with single renal artery and vein.

Figure 8: CT Angiography of post-PCNL patient with hematuria;(a & b) post-contrast coronal CT showed lower polar renal laceration with pseudoaneurysm **(c)** MIP angiography in the arterial phase showed the pseudoaneurysm with its feeding artery **(d & e)** Super selective angiography of the left kidney before and after coil insertion.

Figure 9: CT Angiography of the left kidney;(a) Axial CT scan in the arterial phase showed lower polar large enhanced mass with evidence of arterial aneurysm inside. **(b)** MIP at the same level well delineating the aneurysm. **(c & d)** Coronal images for more delineation of the mass showed the high vascularity of it. **(e)** Another MIP image showed the feeding artery of the aneurysm. **(f)** 3D image showed the aneurysm and its feeding artery. **(g)** Selective conventional angiography of the left renal artery showed the kidney vasculature, the mass vasculature and the aneurysm with its feeding artery. **(h)** Super-selective conventional angiography through the feeding artery showed the mass vasculature and the aneurysm. **(I)** Selective conventional angiography of the left renal artery after coil insertion in the feeding

artery, no opacification of the mass and the aneurysm.

Table 1: Comparison between studied groups regarding age and sex

	Group A (n=50)	Group B (n=30)	Group C (n=10)	Group D (n=5)	P value
Age (year) Mean +SD	39.47 +3.55	42.48 +5.20	45.21 +2.48	42.91 +5.82	0.236 (NS)
Sex No (%)					0.473 (NS)
– **Male**	34 (68%)	19 (63.3%)	5 (50%)	3 (60%)	
– **Female**	16 (32%)	11 (36.6%)	5 (50%)	2 (40%)	

Table 2: Comparison between of MDCT Angiography and operative finding regarding vascular variants in control group

	Group A (n=50)		
	MDCTAngiography	**Operative finding**	**P value**
Arterial			
Single renal artery	42 (86%)	41(84%)	0.435 (NS)
Pre-hilar branching	2 (4%)	2 (4%)	1 (NS)
Accessory arteries	4 (8%)	5 (10%)	0.327 (NS)
Multiple renal arteries	1(2%)	1 (2%)	1(NS)
Venous			
Single renal vein	45 (92%)	45 (92%)	1(NS)
Multiple renal veins	1 (2%)	1 (2%)	1(NS)
Circum-aortic renal vein	1 (2%)	1 (2%)	1 (NS)
Retro-aortic renal vein	2 (4%)	2 (4%)	1 (NS)

***A** donor case is not presented in table 2 , as there is no operative data available because of arterial multiplicity in CTA and availability of another matching one (included in case presentation).

Table 3: Comparison between MDCT Angiography and conventional angiography regarding detection of pseudoaneurysm in traumatic and Post PCNL patients

		Group (B) (n=30)		
		MDCT Angiography	**Conventional angiography finding**	**P value**
Trauma (N=12)	Yes	2 (6.7%)	2 (6.7%)	1 (NS)
	No	10 (33.3%)	10 (33.Y%)	
Post PCNL (N=18)	Yes	3 (10%)	2 (6.7%)	0.492 (NS)
	No	15 (50%)	16 (53.3%)	

Table 4 : Comparison between doppler and MDCT Angiography and conventional angiography regarding renal artery stenosis in group C

		Group (C) (n=10)			
		Doppler	**MDCT Angiography**	**Conventional angiography**	**P value**
Renal artery stenosis	Yes	3 (30%)	1 (10%)	1 (10%)	**<0.001* (S)**
	No	7 (70%)	9 (90%)	9 (90%)	

Table 5: Diagnostic accuracy of MDCT Angiography

AUC	**P-value**	**95% C. I.**		**Sensitivity**	**Specificity**
0.973	0.000	0.938	1.00	93.3%	90.0%

AUC: Area Under a Curve p value: Probability value CI: Confidence Intervals

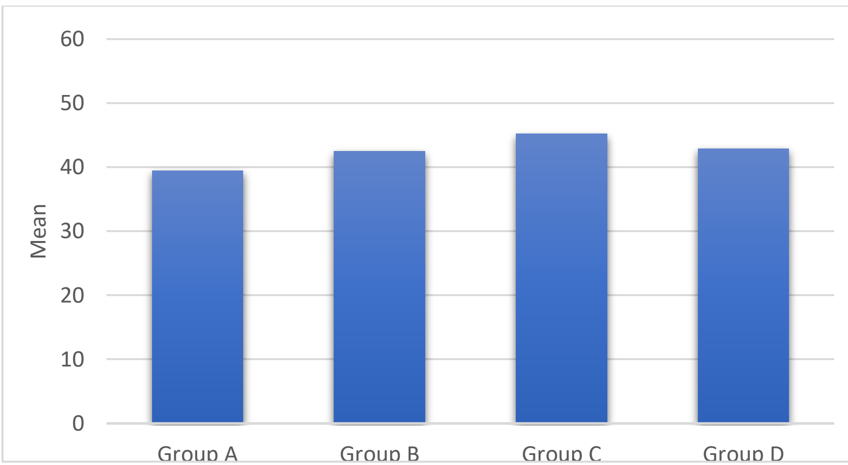


Figure (1): Comparison between studied groups regarding age

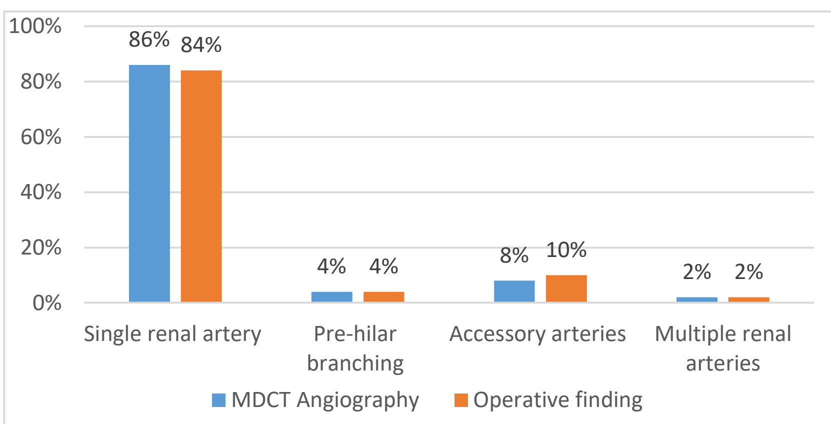


Figure (2): Distribution of arterial variants in control group regarding MDCT angiography & operative findings

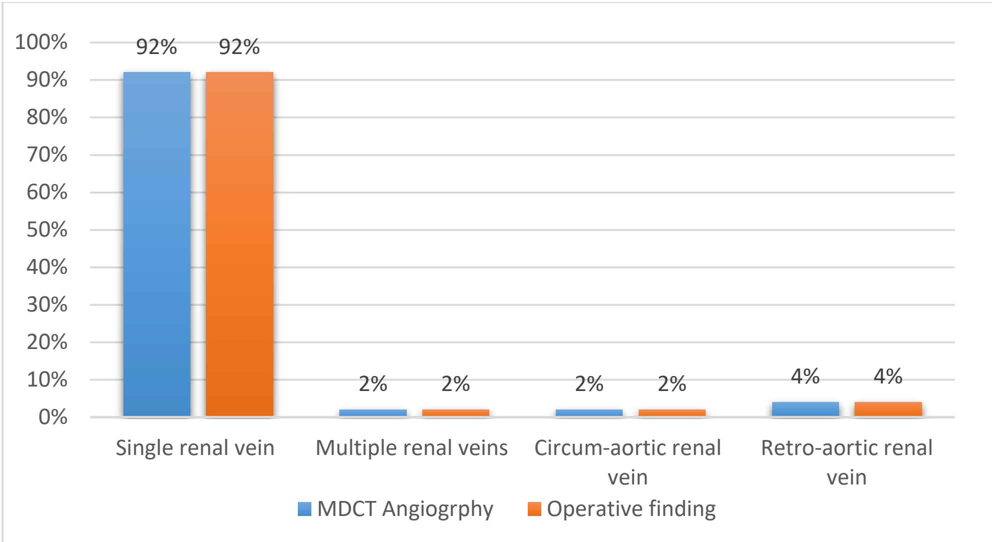


Figure (3): Distribution of venous variants in control group regarding MDCT angiography & operative findings

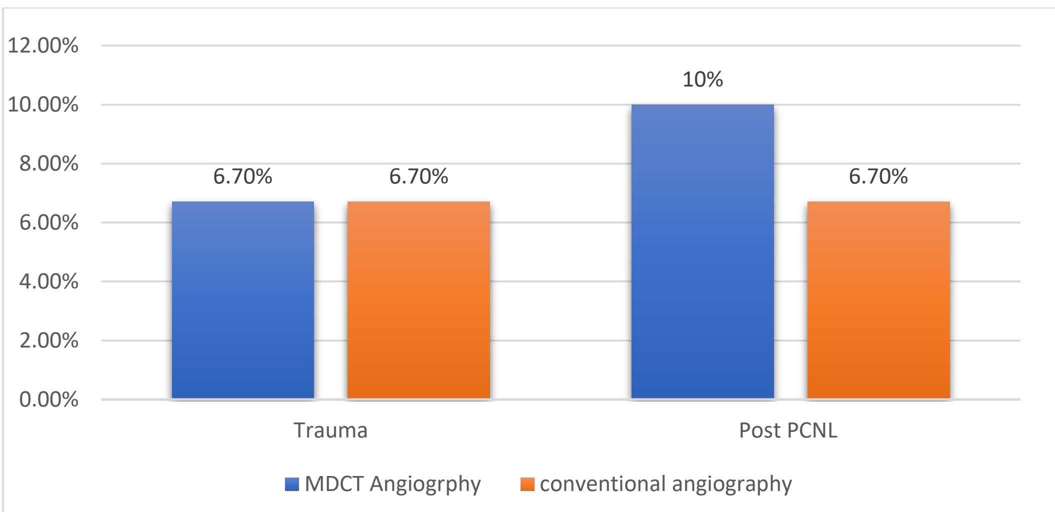
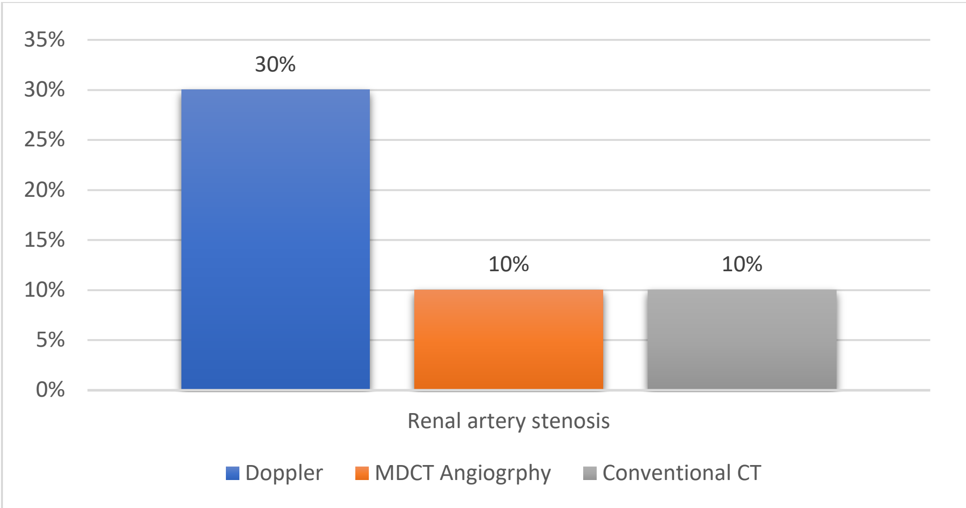


Figure (4): Comparison between MDCT Angiography and conventional angiography finding regarding pseudoaneurysm in traumatic and Post PCNL patients



Figure(5): Comparison between doppler and MDCT Angiography regarding renal artery stenosisin group C

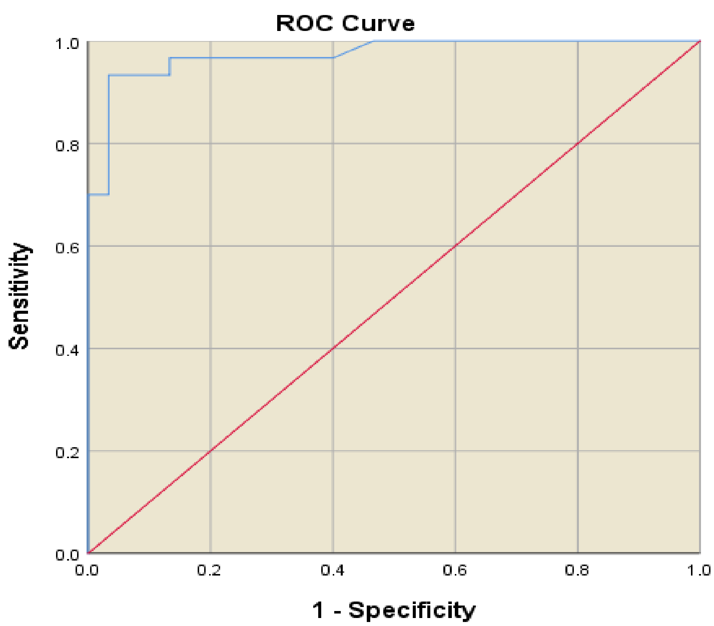


Figure (6): ROC curve of MDCT Angiography

ILLUSTRATIVE CASES :

Figure 7:

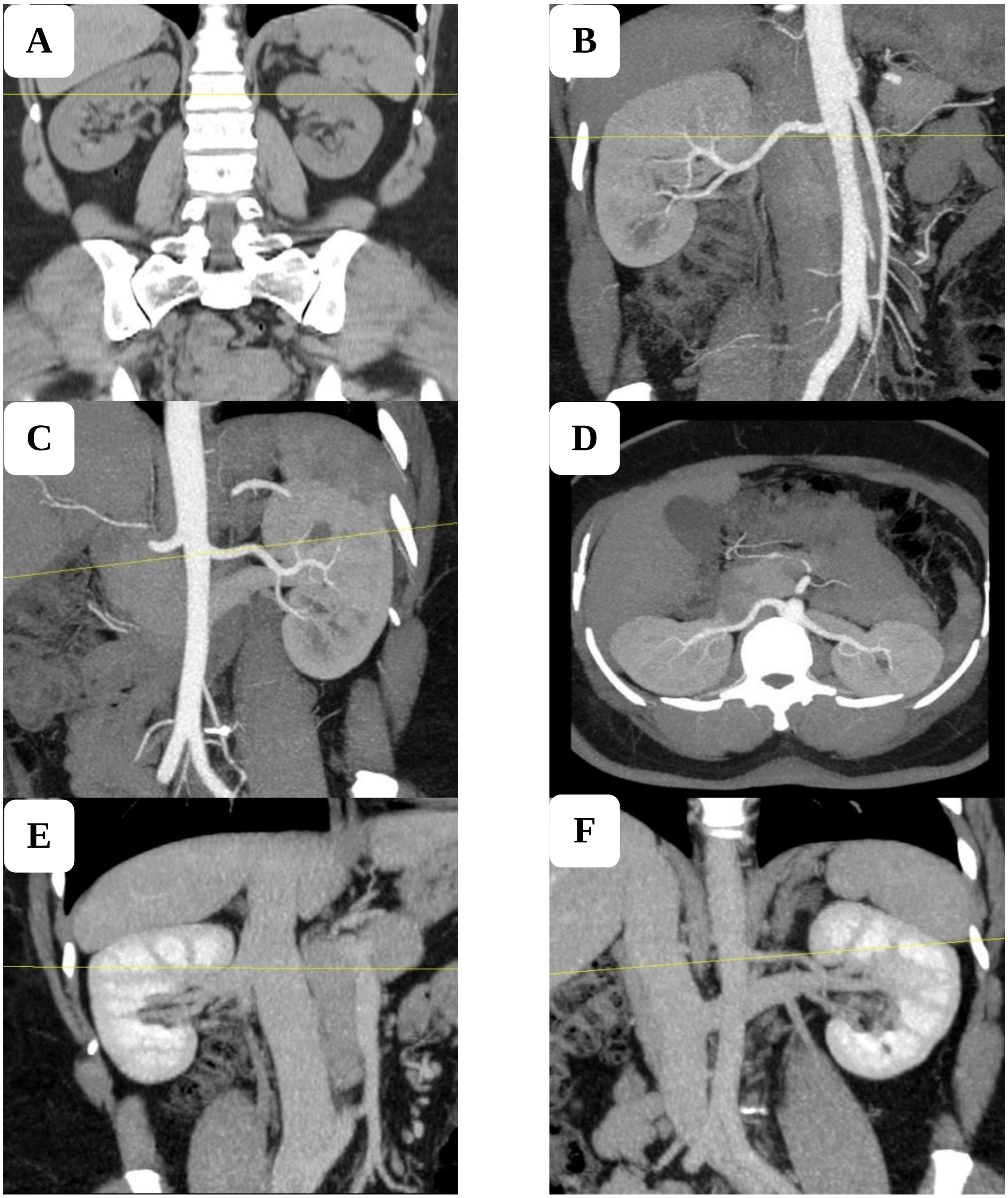


Figure 8:

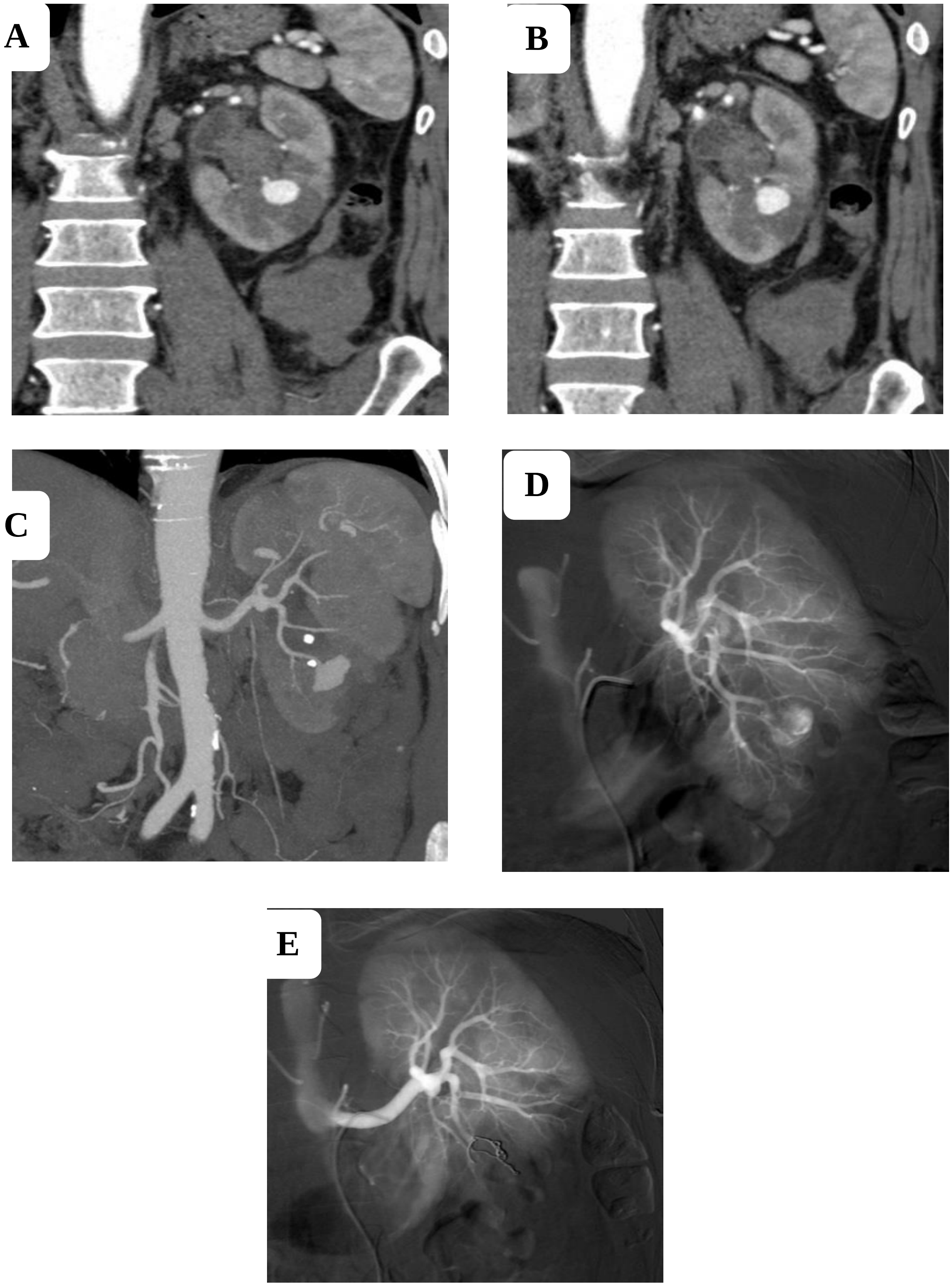
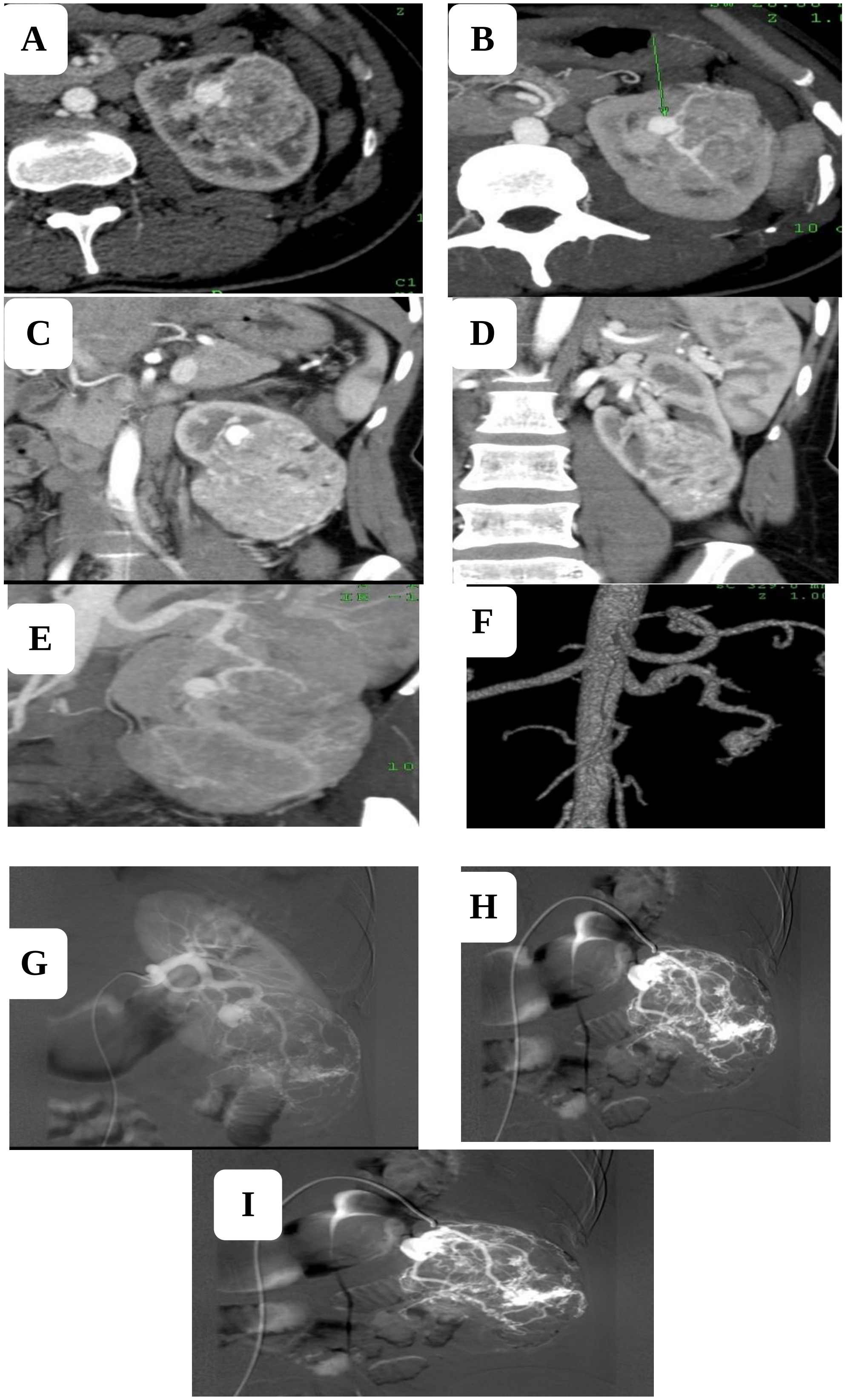


Figure 9:



Discussion

Recently, multidetector computed tomographic (MDCT) angiography has become a key imaging investigation for assessment of the renal vasculature and has challenged the role of conventional angiography (**9**).

In our study, as regard comparison between of MDCT Angiography and operative finding regarding vascular variants in control group, there was non-significant difference between MDCT Angiography and operative finding regarding arterial and venous variants.

Similar results were reported where comparison of the MDCTA and postoperative findings revealed that the MDCTA anatomy of the renal vasculature matched the surgical findings for the 22 donors for 100% of arteries and 95.5% of veins, as one very small accessory vein was missed on MDCTA and detected during surgery. The sensitivity was 100% and 95.5% for arteries and veins, respectively, and the specificity was 100% for both arteries and veins. The accuracy rate was 100% for arteries and 95.5% for veins **(9).**

Also, in another study (**10**), total number of 60 living kidney donors who underwent open surgical approach for transplantation were selected: Kidney anatomy of donors evaluated by CT angiography (group 1) or traditional angiographic examination (group 2). Renal vessels anatomy was compared with surgical findings in both groups. The accuracy for detecting number of main renal arteries were not different in both groups which were 96.7% in CT angiography group and 90% in traditional angiography group (P = 0.15). The accuracy for detection of main renal veins were 100% in group 1 and 96.7% in group 2 (P = 0.31). Finally, they concluded that MDCT has the same accuracy as traditional angiography to detect renal abnormalities in living kidney donors.

In our study, regarding diagnostic accuracy of MDCT Angiography. MDCT Angiography has AUC of 0.973, Sensitivity 93.3% and Specificity 90% for diagnosis of renal vascular abnormalities.

Higher percentage of accuracy was reported (**11),** all anatomical findings reported by MDCT in early arterial phase were confirmed by intraoperative findings with sensitivity of 100%. Right renal vein was supernumerary in 17 cases and left renal vein was circumaortic in 3 and retroaortic in 5 cases. Renal arteries had early branching in 13, two arteries in 12 and accessory in 8 cases. They concluded that Early arterial phase & venous phase has similar accuracy in preoperative evaluation compared with intraoperative findings.

Multidetector computerized tomography (MDCT) is currently being used prior to endourologic intervention. There is a paucity of literature describing its utility in post PCNL bleeding. A MDCT would potentially help in assessing the vascular anatomy, the site of bleeding and hence subsequently aid intervention. They accuracy of findings of multidetector computerized tomography (MDCT) angiography in patients with post PCNL bleeding were comparable to the findings seen using conventional angiography as described by study (**12)**.

In **(13**), a retrospective analysis of patients undergoing transarterial embolization (TAE) for the treatment of hemorrhagic complications after percutaneous nephrolithetomy. All patients underwent computed tomography angiography (CTA) ,& concluded that CTA has high diagnostic accuracy, CTA provides the interventional radiologist with valuable data for individualized therapeutic planning. This result approaches our results regarding CTA in group of patients with post PCNL hematuria.

In our study, as regarding comparison between Doppler and MDCT Angiography regarding renal artery stenosis in group C. There was significant difference between MDCT Angiography and Doppler regarding renal artery stenosis ($p < 0.001$). MDCT was more accurate than Doppler in detecting stenosis. This is consistent with results of study **(14).**

In a study done in 2021 (**15),** the sensitivity and specificity of CT angiography for renal artery stenosis (RAS) diagnosis were 90.0% and 89.7%, respectively. CT angiography identified all cases of main RAS .the study done on patients 0–18 years of age who underwent CT angiography for evaluation of RAS as a cause of hypertension compared with digital subtraction angiography (DSA) study .These results shows relative lower sensitivity &approaches specificity of our study .

MDCT was proved to be rapid, reproducible and noninvasive. MDCT angiography performed in the setting of post PCNL bleeding provides an accurate assessment of the site and nature of bleeding. The MDCT angiography matched the CA findings in all patients in the present study (16).

It was stated that MDCT renal angiography has a sensitivity ranging from 62% to 100% and specificity ranging from 56% to 99% in assessment of anatomical eligibility for renal sympathetic denervation, since 3-D datasets are acquired, it is possible to view the anatomy from any angle similar to that of MR angiography (17).

Our study results were comparable to another study which stated that Multi detector C.T renal angiography has a priority in detecting renal vascular anomalies rather than other diagnostic procedures (**18)**.

Conclusion:

We can conclude that, MDCT angiography is an excellent imaging investigation because it is a fast and non-invasive tool that provides highly accurate and detailed evaluation of normal renal vascular anatomy and variants in various renal disease or before renal transplantation. The number, size and course of the renal arteries and veins are easily identified by MDCT angiography. No significant differences were noted between MDCT and intraoperative results in transplant donors. Also MDCT has a good rule detection of the cause of post traumatic & post PCNL vascular abnormalities as pseudoaneurysmas well as detection of renal artery stenosis in patients with suspected renovascular hypertension. Multidetector computed tomographic (MDCT) angiography has become a key imaging investigations for assessment of the renal vasculature and has challenged the role of conventional angiography.

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