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## ORIGINAL ARTICLE

# Role of multi-slice CT angiography versus Doppler ultrasonography and conventional angiography in assessment of aorto-iliac arterial disease

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### KEYWORDS

Aorto-iliac arterial disease;  
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**Abstract** The new clinical entity, known as aorto-iliac atherosclerosis obliterans or aorto-iliac occlusive disease (AIOD), is one of the most frequent clinical problems confronted by vascular surgeons today. Digital subtraction angiography is considered the gold standard technique in assessment of these arteries. However, the invasiveness of the procedure, and radiation exposure led to the need for less and non-invasive imaging techniques.

**Objective:** The aim of this study is to evaluate the MDCT angiography as a recent non invasive technique for investigating aorto-iliac arterial disease as compared to CCD and DSA.

**Materials and methods:** This study included 16 patients (12 males & 4 females) with an age range of 33–75 years. All of these patients underwent MDCT angiography and CCD. Only 13 patients underwent DSA. The arterial tree of the lower limbs was divided into 31 arterial segments. Each segment was evaluated and given a grade from 0 to 4 according to its appearance in the three modalities.

**Results:** There was a 98.7% agreement between the findings of DSA and MDCT angiography. While agreement between DSA and CCD was 96.1%.

**Conclusion:** Considering conventional angiography as the gold standard, MDCT angiography shows higher sensitivity (98.7%) than color coded Doppler ultrasonography (96.2%) in the assessment of aorto-iliac arterial disease.

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## 1. Introduction

The abdominal aorta and iliac arteries are amongst the arterial segments most commonly affected by atherosclerosis. The resulting clinical entity, known as aorto-iliac atherosclerosis obliterans or aorto-iliac occlusive disease (AIOD), is one of the most frequent clinical problems confronted by vascular surgeons (1).

Until as recently as 10 years ago, catheter-directed conventional angiography and digital subtraction angiography were the only angiographic techniques that provided sufficient anatomical details to allow surgical planning for patients with peripheral vascular disease. However the complications and patient discomfort associated with these techniques have prompted the need of less invasive means of assessing the lower extremity arterial system. Doppler ultrasonography has shown to be non invasive but shown some limitation as it is personal dependant. CT angiography has been shown to be accurate in the investigation of a number of diseases, but long gantry rotation periods and slow table speed limited the performance of CT angiography with single-detector scanners to relatively small anatomical areas. Multi-detector row CT scanners allow imaging over cranio-caudal lengths exceeding 1.5 m. Imaging of the entire arterial supply of the lower extremities in a single helical acquisition is now possible (2).

## 2. Materials and methods

This study included 16 patients who were referred to the radiology department from the surgery department with suspected aorto-iliac arterial disease. They underwent multi-detector row CT angiography of the aorto-iliac arteries. All of these patients also underwent color Doppler sonography. Of these patients, 13 patients were studied by conventional angiography as well and consequently were available for comparison with multi-detector row CT angiography and color Doppler sonography.

Conventional angiography had not been performed in 2 patients with aneurysmal disease. It was not done due to their critical condition and for fear of complications as they were on high dose of anticoagulants that could not be stopped. The third patient had been complaining of Le Riche syndrome. She had no palpable femoral pulsations. Trans-axillary approach was tried, but failed due to difficult cannulation of both axillary arteries.

The radiological work up of these patients was done within a period of 3 days.

The patient population consists of 12 males and 4 females with age ranging from 33 to 75 years with a mean of 54 years. Ten patients were chronic heavy smokers (smoking more than 20 cigarettes per day for 20 years or more). Four patients were diabetics. Eight patients were hypertensive and on regular anti-hypertensive drugs.

Eight patients had intermittent claudication. Four patients had rest pain. No patients with previous amputation surgery. Two patients had underwent vascular operations. One had aorto-bifemoral by-pass graft, the other had left ilio-femoral by-pass graft.

### 2.1. Multi-detector row CT Angiography

CT scans were acquired with a four channel multi-detector row CT scanner (LightSpeed Plus; GE medical systems, Milwaukee, Wis).

Patients' laboratory data were initially revised with particular interest in the results of the renal function tests.

All patients were instructed to stop solid fluid intake for 6–8 h prior to examination. They were asked to continue adequate simple fluid intake up to 3 h prior to examination to ensure adequate hydration.

Patients were taught how to hold breath during examination when requested, to ensure their cooperation.

Patients were positioned supine on the CT table in the "foot first" position with his arms resting comfortably above the head.

A 18–20 gauge catheter was placed into a superficial vein within the antecubital fossa, forearm, or dorsum of the hand.

Before the contrast material was administered by the injector, saline injections were manually administered at a high rate of flow, with the patient's arms in the scanning position. This was done to ensure the successful cannulation of the vein.

Two scouts were acquired, antero-posterior and lateral. The examination was planned on these scouts from the level of D12 till the mid thigh.

Smart prep software from GE medical systems was used to determine the delay time between the time of injection to the start of acquisition. A localizer section was chosen at the level of the D10. A region of interest (ROI) was applied on the descending aorta at this level. Acquisition is started manually when a threshold of 150 HU is reached.

CT angiography was performed following target injection of 120–150 ml of contrast medium at a flow rate of 3–4 ml/s. The contrast medium used was low osmolar non-ionic contrast medium (Omnipaque 300 mg I/ml; Nycomed Amersham, Princeton, NJ).

Helical CT was performed by using a 2.5 mm nominal section thickness, a slice pitch of 6, a gantry rotation period of 0.8–0.5 s, and a table speed of 15 ml per rotation. X-ray tube voltage was 120 KV, and the current was 300–350 mA.

Patients were requested to hold their breath during the first 20 s of the acquisition and were allowed to breath quietly after that.

Sections were reconstructed at 1.25 mm which is half the nominal section thickness. The whole examination took 10–20 min depending on the venous access while actual time of scanning ranged from 20 to 30 s.

All images were transferred to the workstation (Advantage Windows 4.0, GE medical systems) for post processing.

An image containing only the bones was created by using the appropriate threshold level while trying to keep all the data from the vascular structures out of the image. Subtraction was then done by this image from the source images to get a set of images with no bones within.

Some views were taken before bone subtraction and others were taken afterward. Three dimensional maximum intensity projections (MIP), volume rendering (VR), and curved planer reformations were created at different angles of views, mostly antero-posterior, both obliques, and lateral with zooming on areas of abnormal findings. Further usage of advanced vessel analysis software was done according to the radiological findings.

No complications what so ever occurred during the multi-detector row CT angiography examination including contrast extravasation or reaction.

### 2.2. Color Doppler sonography

Color Doppler sonography examinations were done using Phillips-ATL; HDI 5000, which can combine a real time B-mode imaging system with pulsed and continuous wave Doppler facilities together with the availability of color coding of signals.

Patients were instructed to fast for 6 h prior to examination and avoid eating colonic gas forming food eg milk products, to facilitate examination of the aorto-iliac vessels.

Patients were examined in the supine position.

Beginning at the aortic bifurcation, a 3.5 MHz probe was used to examine the aorta, common, and external iliac arteries. A 7.5 MHz probe was sometimes used in well prepared 4 thin patients.

Both common femoral arteries were examined using a 7.5 MHz probe with the limb under examination slightly abducted and externally rotated for better scanning of the femoral artery.

Each segment was examined first by B-mode for detection of atheromatous plaques and wall calcifications then by color flow imaging transversely and longitudinally to size the colored flow in the lumen with respect to the arterial wall and to detect areas of flow disturbance, increased velocity, and jets. The transducer was transverse to the arterial segment with 30° angulation to the vertical plane to encode the arterial color signal. Then longitudinal scanning was performed by placing the Doppler sample gate in the lumen and correcting the angle cursor parallel to the flow in the lumen to obtain the Doppler spectrum and calculation of peak systolic velocity (PSV).

The color scale was set for about 30 cm/s maximal mean velocity. The overall gain was increased until color noise appeared in the static tissues adjacent to the arterial wall then the gain was gradually decreased until tissue noise just disappeared.

The Doppler angle formed by the pulsed Doppler beam and the angle cursor, was kept below 60°. The angle cursor was adjusted to follow the axis of the blood flow visualized by color Doppler flow imaging. The smallest available sample volume was placed in the midstream of the visualized flow.

The peak systolic velocity (PSV) was recorded from all the examined segments and in any area of suspected stenosis, values were recorded immediately before, within, and just distal to the stenosis.

Occlusions were diagnosed when no color flow or Doppler spectral signal was detected in the segment inspite of the attempts to maximize the sensitivity for slow flow detection by increasing Doppler gain, decreasing the scale, and increasing the sample volume size.

### 2.3. Conventional angiography

All angiographic examinations were performed using digital subtraction technique using a Philips Diagnost 94 apparatus with digital imaging facilities.

Modified Seidenger's technique was used to cannulate the common femoral artery. A 5F or 6F pig tail catheter was placed in the abdominal aorta above the renal arteries, then it was withdrawn to a position just above the aortic bifurcation.

In three patients transaxillary approach was performed due to failure of cannulation of both common femoral arteries.

Water soluble iodinated ionic or non-ionic contrast media (Urografin or Omnipaque) were used according to the age of the patient and the results of the kidney function tests. Doses of contrast media and rate of injection varied according to the situation. Arteriography was performed in the frontal plane.

### 3. Results

This study included 16 patients (12 males & 4 females) with an age range of 33–75 years (mean age 54 years), as shown in [Table 1](#).

Four of these patients were diabetic, 8 were hypertensive and 10 were chronic heavy smokers. Three patients were both diabetic and hypertensive.

Eight patients complained of intermittent claudication, 4 of them had associated rest pain, and only 2 of them had lower limb gangrene. The duration of the patients' complaints ranged from 15 days to 10 years (mean duration 48 months). Two patients underwent ilio-femoral graft operation.

Two of our patients had aneurysms at different sites [one had two infrarenal saccular aortic aneurysms, and the other had two saccular infrarenal and one left ileal mycotic aneurysm. These patients were sent for the assessment of the aneurysm and the arterial tree distal to the aneurysm. None of them performed conventional angiography.

One patient had acute left iliac block which proved to be embolic as the patient had history of rheumatic heart disease and atrial fibrillation.

All of the 16 patients were examined by multi-detector row CT angiography and by color coded Doppler. Only 13 of them underwent DSA examination, and 3 patients did not perform this examination. They were complaining of aneurysmal disease. Conventional angiography was not performed for fear of complications as they were on high dose of anticoagulants that could not be stopped. The third case had Le Riche syndrome with non-palpable both femoral pulsations. The third one trans-axillary approach was tried, but failed due to difficult cannulation of both axillary arteries.

#### Data analysis:

- The aortoiliac arterial system was divided into 18 anatomical segments as follows:

Supra-renal aorta, infra-renal aorta, renal arteries (proximal, middle and distal thirds), common iliac arteries, external iliac arteries (proximal and distal portion), internal iliac arteries and common femoral arteries and their bifurcation (considered one segment).

**Table 1** Sites of patients' complaint.

Site of patient's complaint	Number of patients
Right lower limb	4
Left lower limb	7
Bilateral lower limb (more on the right)	1
Bilateral lower limb (more on the left)	2
Abdominal pain	2

- Each and every anatomical segment of the arterial tree was assigned a grade for the disease extent using a five point ordinal scale:

- 0 = Normal.
- 1 = Mild stenosis (1–49% diameter reduction).
- 2 = Moderate stenosis (50–74% diameter reduction).
- 3 = Severe stenosis (75–99% diameter reduction).
- 4 = Occlusion.

- These grades were given for all arterial segments as evaluated in the three techniques; multi-detector row CT angiography, color Doppler ultrasonography, and conventional angiography. For all arterial segments the degree of stenosis was measured by dividing the minimal vessel luminal diameter with in this segment by the maximal observed luminal diameter.
- The conventional angiography was considered the gold standard technique. Multi-detector row CT angiography and Doppler findings were compared with digital subtraction angiography findings for each arterial segment.

The results of the 13 patients who underwent DSA, multi-detector row CT angiography and color coded Doppler examinations will be reviewed first:

### 3.1. Supra-and infra-renal aorta

Six patients (46.1%) had atheromatous changes in all the three examinations. Calcification could be detected in all the 6 patients by multi-detector row CT angiography and color coded Doppler. These calcifications were reported in only one patient by DSA.

One patient (7.6%) had an ectatic aorta in the three performed examinations.

One patient (7.6%) had a stenotic segment grade I at the infra-renal aorta that could be detected in all the three examinations. Another patient (7.6%) displayed complete occlusion of the distal infra-renal aorta.

### 3.2. Renal arteries

No abnormalities were detected in any segment of the examined renal arteries apart from calcific plaque depicted at the middle third of one of the renal arteries examined. This calcification was detected in multi-detector row CT angiography and color coded Doppler but not in DSA.

### 3.3. Common iliac arteries

The results of common iliac arteries are shown in Table 2 and Fig. 1. Three of the patients examined by angiography showed irregularity of the wall of the arteries on both sides, which appeared as calcifications upon CT angiography (sensitivity 100%) while only 2 of them appeared on color coded Doppler examination (sensitivity 75%).

In one case of stenosis of the left CIA, DSA showed it to be 88% (grade III) while multidetector CT angiography and Doppler showed it to be 67% and 69%, respectively ie (grade II) stenosis. In another case DSA displayed complete occlusion of the CIA due to embolism while multidetector CT angiography and Doppler proved it to be severe stenosis (grade III).

**Table 2** The results of the different modalities on the common iliac arteries.

	Angiography (N = 26)	CT angiography (N = 26)	Doppler (N = 26)
Normal	17 (65.3%)	17 (65.3%)	17 (65.3%)
Mild stenosis	0	0	0
Moderate stenosis	0	1 (0.04%)	1 (0.04%)
Severe stenosis	1 (0.04%)	1 (0.04%)	1 (0.04%)
Occluded	8 (30.7%)	7 (26.9%)	7 (26.9%)

The discrepancy between multidetector CT angiography and Doppler compared to DSA is 22% with sensitivity being 88%.

### 3.4. External Iliac arteries

#### 3.4.1. Proximal

The results of proximal external iliac arteries are shown in Table 3 and Fig. 2. Four of the patients examined by angiography showed irregularity of the wall of the arteries on both sides, which appeared as calcifications upon CT angiography and color coded Doppler examination (sensitivity 100%).

In one case DSA demonstrated (grade III) stenosis while multidetector CT angiography and Doppler demonstrated (grade II) stenosis resulting in 7% discrepancy.

Doppler failed to detect stenosis in one patient due to patient obesity resulting in 91.6% sensitivity compared to 100% sensitivity in multidetector CT angiography.

#### 3.4.2. Distal

The results of distal external iliac arteries are shown in Table 4 and Fig. 3. Four of the cases examined by angiography showed irregularity of the wall of the arteries on both sides, which appeared as calcifications upon CT angiography and color coded Doppler examination (sensitivity 100%).

No discrepancy was detected between the three modalities.

### 3.5. Internal iliac arteries

The results of internal iliac arteries are shown in Table 5 and Fig. 4.

Internal iliac arteries could not be assessed by Doppler in four patients due to obscuration by abdominal gases resulting in 25% discrepancy with 57% sensitivity.

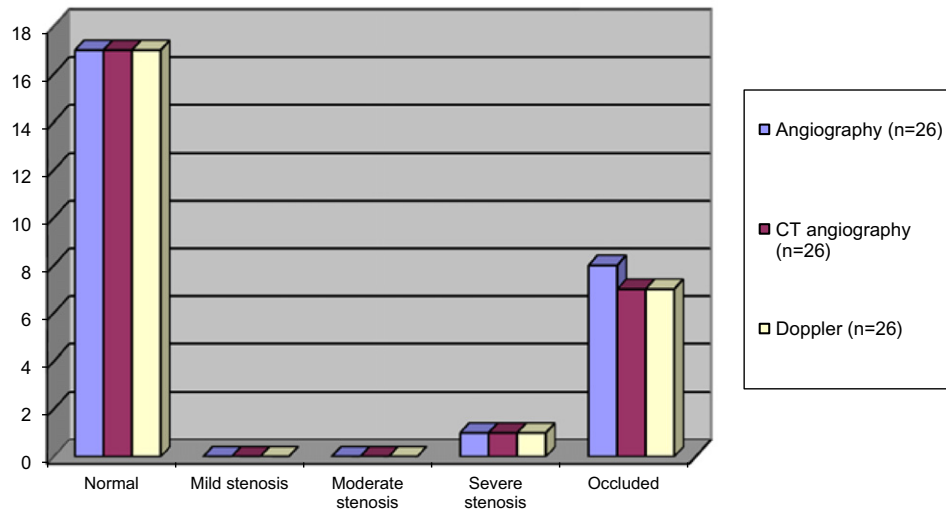
No discrepancy was detected between multidetector CT angiography and DSA with 100% sensitivity.

Four internal iliac arteries showed calcifications by multi-detector row CT angiography, which were not detected by any of the other modalities.

### 3.6. Common femoral arteries

The results of common femoral arteries are shown in Table 6 and Fig. 5.

A left common femoral artery pseudoaneurysm resulting from leakage at the site of ilio-femoral graft insert was detected by multidetector CT angiography and Doppler that was not visible in DSA. The graft was also noted to be occluded only by Doppler study.



**Fig. 1** Bar chart shows the different pathologies seen in the common iliac arteries by the different modalities.

**Table 3** The results of the different modalities on the proximal portion of the external iliac arteries.

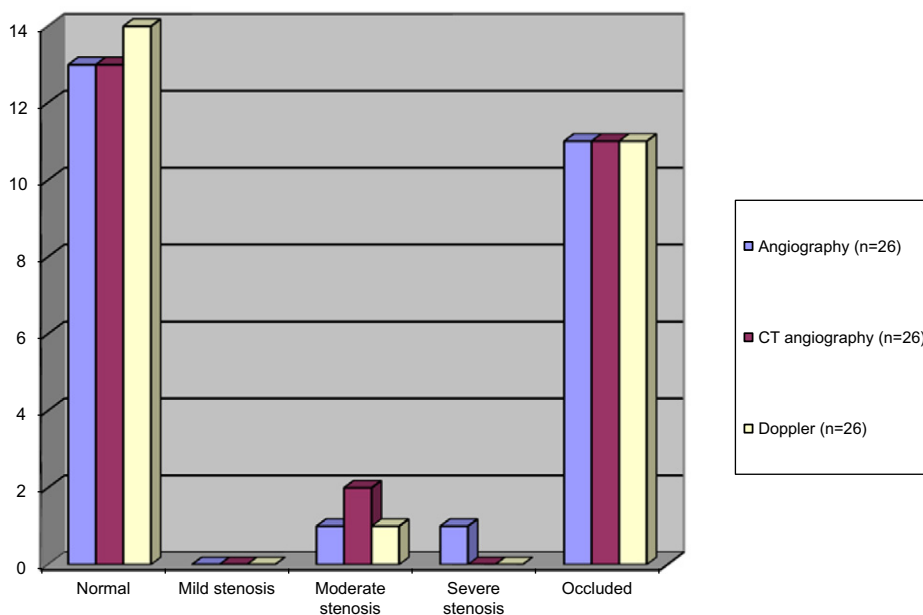
	Angiography (N = 26)	CT angiography (N = 26)	Doppler (N = 26)
Normal	13 (50%)	13 (50%)	14 (50%)
Mild stenosis	0	0	0
Moderate stenosis	1 (3.8%)	2 (7.6%)	1 (3.8%)
Severe stenosis	1 (3.8%)	0	0
Occluded	11 (46%)	11 (46%)	11 (46%)

The results of the 3 patients that did not perform DSA and underwent only multi-detector row CT angiography and color coded Doppler examinations came as follows:

Two of these patients had aneurysmal disease. DSA was not performed for fear of complications as they were on high dose of anticoagulants that could not be stopped.

One of these patients had infra-renal saccular partially thrombosed aortic aneurysms, yet it did not involve any of the major vessels. This aneurysm had two components on both sides of the aorta. Color coded Doppler confirmed the diagnosis.

The other case had two infrarenal aneurysms and a third left common iliac aneurysm. Peri-aneurysmal leakage and haematoma formation were depicted on the right side of the lower infra-renal aneurysm which also caused erosion of the underlying vertebral body. This patient then experienced thrombosis of the aneurysm with consequent aortoiliac block. This patient underwent successful aorto-bifemoral graft. There



**Fig. 2** Bar chart shows the different pathologies seen in the proximal portions of the external iliac arteries by the different modalities.



**Table 4** The results of the different modalities on the distal portion of the external iliac arteries.

	Angiography (N = 26)	CT angiography (N = 26)	Doppler (N = 26)
Normal	15 (57.6%)	15 (57.6%)	15 (57.6%)
Mild stenosis	0	0	0
Moderate stenosis	0	0	0
Severe stenosis	0	0	0
Occluded	11 (42.3%)	11 (42.3%)	11 (42.3%)

multi-detector CT angiography and the color coded Doppler findings were compatible.

The third case was a female patient complaining of Leriche syndrome. Multi-detector row CT angiography revealed an occlusion of the aorta at the level of L3 down to the bifurcation. The left CIA and EIA were seen also occluded with collateral refilling of the left CFA from the left inferior epigastric and a hypertrophied inferior mesenteric artery. The right CIA was seen also occluded with collateral refilling at its distal segment. CCD revealed an occlusion at the aortic bifurcation with the same distribution. There was no discrepancy between MDCT angiography and CCD in this case. This patient underwent successful aorto-bifemoral graft after which the dorsalis pedis pulse could felt on both sides.

#### 4. Final results

The final results are shown in Figs. 6(A–E), 7(A–G) and 8(A–F). Multi-detector row CT angiography was used to examine a total of 288 arterial segments in 16 patients. Color coded Doppler was used to examine 284 arterial segments (the internal iliac arteries of 3 patients could not be assessed by CCD due to marked gaseous distension). Only 234 arterial segments were also examined by digital subtraction angiography.

If we consider only the 13 patients who underwent the 3 examinations, this will make a total of 234 arterial segments. The number of lesions in these segments was 48 lesions as detected by DSA. Out of these lesions, 10 lesions were involving

**Table 5** The results of the different modalities on the internal iliac arteries.

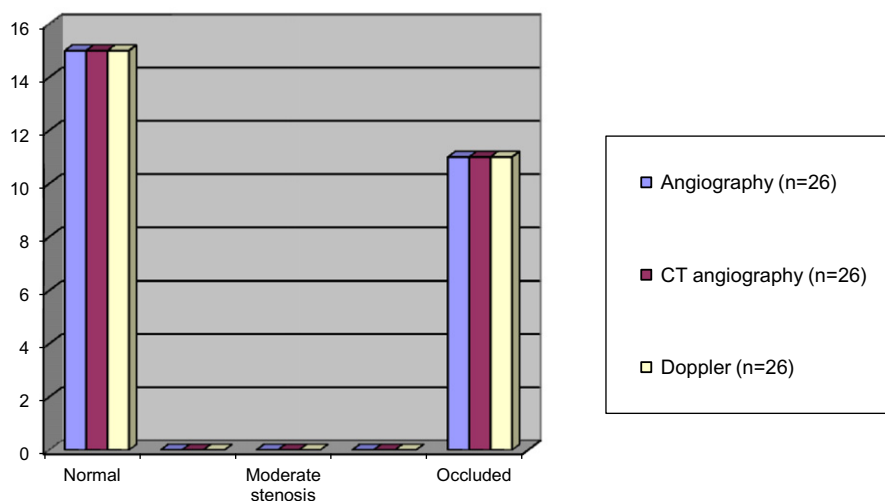
	Angiography (N = 26)	CT angiography (N = 26)	Doppler (N = 26)
Normal	22 (84.6%)	22 (84.6%)	25 (96.1%)
Mild stenosis	0	0	0
Moderate stenosis	0	0	0
Severe stenosis	0	0	0
Occluded	4 (15.3%)	4 (15.3%)	1 (3.9%)

the aorta, while 38 lesions were detected in the iliac arterial system.

As regards the degree of stenosis there was agreement between DSA and multi-detector row CT angiography in 9 lesions (82%), with discrepancy in two lesions (18%). The agreement between DSA and color coded Doppler occurred in 8 lesions (73%), while discrepancy occurred in three lesions (27%). This discrepancy was mainly due to the ability of multidetector CT angiography to detect small amount of contrast in the stenotic segment and the ability of color coded Doppler to detect weak flow within a stenotic artery compared to digital subtraction angiography.

Agreement occurs in 231 arterial segments between the findings of DSA and multi-detector row CT angiography (98.7%). Only 3 segments showed a discrepancy (3.2%). These were arterial segments seen occluded by DSA and were seen opacified but attenuated by MDCT angiography. Agreement occurs in 225 arterial segments between the findings of DSA and color coded Doppler (96.1%). The discrepancy between the DSA and color coded Doppler examinations was seen in 9 arterial segments (3.9%) due to patient obesity and obscuration by gaseous distension.

The sensitivity of MDCT angiography in this study was almost near the gold standard angiography being 98.7% denoting its high sensitivity with nil difference from the conventional angiography as the gold standard, yet the sensitivity of the color coded Doppler was 96.2% which is considered mildly low compared to the CT angiography. However, this

**Fig. 3** Bar chart shows the different pathologies seen in the distal portions of the external iliac arteries by the different modalities.

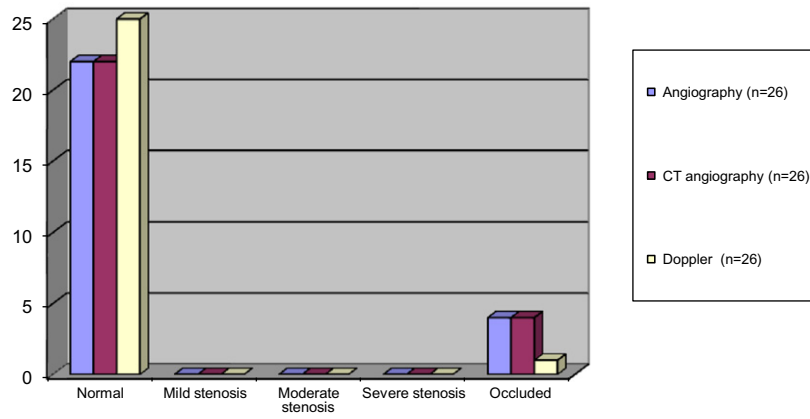


Fig. 4 Bar chart shows the different pathologies seen in the internal iliac arteries by the different modalities.

**Table 6** The results of the different modalities on the common femoral arteries.

	Angiography (N = 26)	CT angiography (N = 26)	Doppler (N = 26)
Normal	21 (80.7%)	21 (80.7%)	21 (80.7%)
Mild stenosis	2 (7.6%)	2 (7.6%)	2 (7.6%)
Moderate stenosis	0	0	0
Severe stenosis	2 (7.6%)	2 (7.6%)	2 (7.6%)
Occluded	1 (3.8%)	1 (3.8%)	1 (3.8%)

difference is statistically insignificant. The overall results highlight that the CT conventional angiography is still the gold standard and the CT angiography is mildly just one step behind then comes the color Doppler.

**5. Discussion**

Digital subtraction angiography is considered the gold standard technique in assessment of the aortoiliac arteries. The major advantages of DSA are high spatial resolution images and temporal information regarding delayed filling of the vasculature of interest. The invasiveness of the procedure, and radiation exposure, however, led to the development of noninvasive imaging techniques (3).

CT angiography has the advantages of being minimally invasive, requiring only an intravenous injection of contrast medium and imaging surrounding soft tissues. Multiplanar reconstruction aids the visualization of asymmetrical stenoses, and collateral blood supply is readily appreciated (4).

Single-detector row helical CT has been used for evaluation of the aortoiliac arteries. The trade-off between scan volume and spatial resolution along the z axis of single-detector row helical CT was a substantial limitation (5).

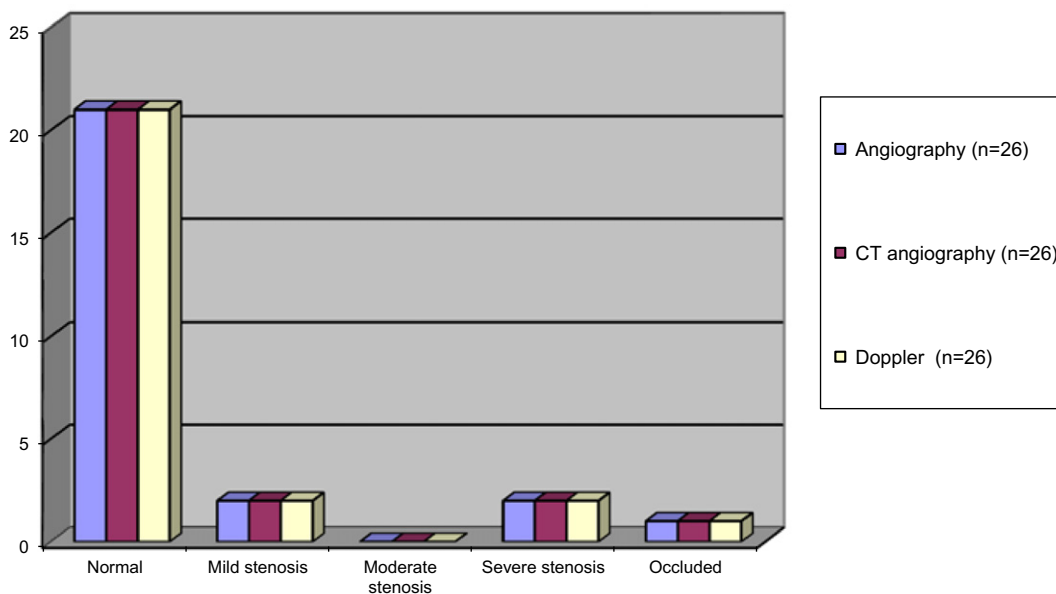
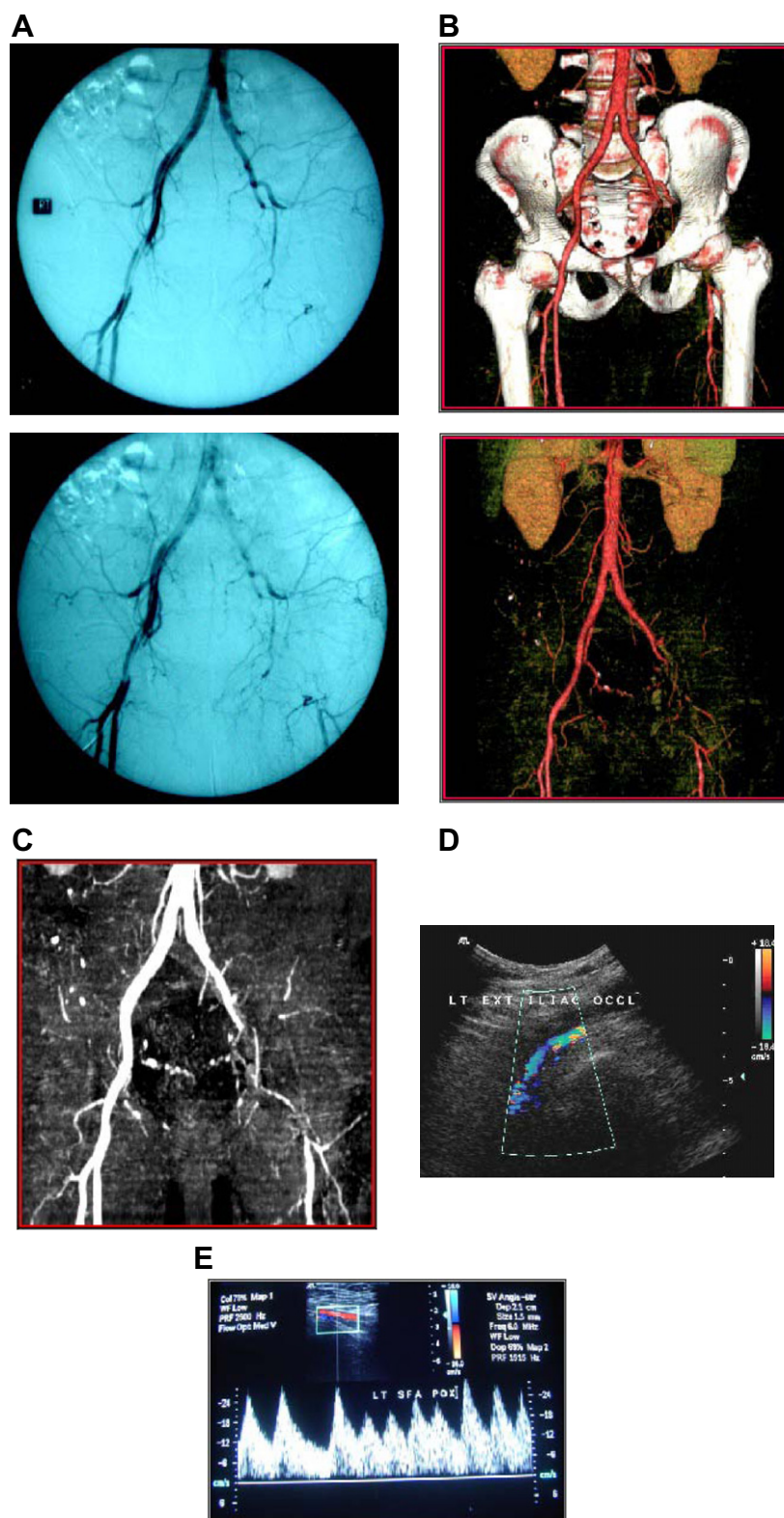


Fig. 5 Bar chart shows the different pathologies seen in the common femoral arteries by the different modalities.



**Fig. 6** (A–E): A 46-year old male, smoker, hypertensive and on regular anti-hypertensive drugs. He had history of chronic left lower limb pain since 2 years. The patient experienced intermittent claudication in the left thigh and buttock. On clinical examination, no pulsations could be felt on left lower limb. Mild atrophic skin and color changes were noted at left foot. (A) DSA in AP projection of the aortoiliac vessels shows complete occlusion of the left EIA at its origin with few collaterals refilling the left SFA. (B) MSCT 3D volume rendering images, before (above) and after (below) subtraction of the bone demonstrating the left EIA complete occlusion and consequent collaterals refilling the left SFA. (C): MSCT MIP images in AP projections show findings comparative with those of the DSA. (D) CCDS revealed flow within the left external iliac vein but no flow in the adjacent left EIA. (E) CCDS revealed patent left SFA but with damped monophasic flow due to the proximal obstruction.



Olaf et al. (6) performed a study using single slice CT angiography to evaluate the aortoiliac arteries using 4.0 mm collimation, 8 mm/s table speed and 150 ml of iodinated contrast media. The study included 30 patients with a sensitivity of 100% for iliac occlusion and 93% for stenosis. In the same year Raptopoulos et al. (7) proposed CT angiography technique using two sequential helical scans to image the aortoiliac segment only using two successive bolus injections of IV contrast material and two breath-holds and thereby expanding the craniocaudal span of the CTA.

Until the recent introduction of MDCT, CT angiography was limited to a short cranio-caudal distance during a single IV contrast material injection. While being sufficient for imaging the majority of systemic arteries, it was insufficient for studying the arterial inflow and runoff of the lower extremities. MDCT with four channels of simultaneous acquisition has eliminated this limitation. MDCT has had a substantial effect on CT angiography, offering shorter acquisition times, lower doses of contrast medium, and improved spatial resolution. (8)

In 2001, Rubin et al. (8) described the imaging of the entire arterial supply of the lower extremities using four-channel multi-detector row CT in a single helical acquisition using a 2.5 mm nominal section thickness, 1.25 mm reconstruction intervals, and 180 ml of iodinated contrast media. This study focused on the ability of multi-detector row CT angiography to reveal all arterial segments with sufficient opacification and without venous contamination. Of the 24 subjects, 18 also underwent conventional angiography. Mean arterial attenuation in the mid-abdominal aorta was 253 HU. For arterial segments identified with conventional angiography, they found 100% concordance with CT angiography. Furthermore, CT depicted 26 additional segments that were seen occluded with conventional angiography because of improved arterial opacification distal to the occluded segments. They concluded that the arteries of the lower extremity inflow and runoff can be reliably depicted with minimal venous enhancement by using multi-detector row CT angiography.

Our study was much like this study. We used a lower amount of contrast material (120–150 ml) as we had a faster scanner. Our gantry rotation period was 0.5 s, while his was 0.8 s. The examinations were started at the level of the celiac artery.

In 2001, a study was made to compare single versus four-channel MDCT angiography on the aorta and iliac arteries by Rubin et al. (8) using nominal section thickness and pitch of 3.0 mm and 2.0, respectively for one-channel CT and 2.5 mm and 6.0 for the four-channel CT. At four versus single-channel CT, CT angiography was 2.6 times faster, scanning efficiency was 4.1 times greater, contrast efficiency was 2.5 times greater, dose of contrast media was reduced by mean of 57% (97 vs 232 ml) without significant change in aortic enhancement, and sections were thinner by mean of 40% (3.2 vs 5.3 mm) despite a 59% shorter scanning duration (22 vs 56 s). No advantages of single-channel CT angiography were demonstrated.

In 2003, two studies were published on multi-detector row CT angiography of peripheral vascular disease making a double blinded prospective comparison with digital subtraction angiography. Ofer et al. (9) performed four-channel multi-detector row CT angiography for 18 patients with peripheral vascular disease from the level of the superior mesenteric artery to the level of the pedal arteries. The study revealed an

agreement with digital subtraction angiography in 91.95% of cases that needed treatment. Compared with digital subtraction angiography, CT angiography yielded a sensitivity of 90.9% and a specificity of 92.4% for lesions that needed treatment.

Martin et al. (10) study in 2003 included 41 patients with ischemic legs and suspected aortoiliac occlusive disease. They performed four-channel multi-detector row CT angiography and digital subtraction angiography. The sensitivity and specificity of multi-detector row CT angiography for depicting arterial occlusion were 88.6% and 97.7%. While sensitivity and specificity for stenosis more than 75% were 92.2% and 96.8%, respectively. Substantial inter-technique agreement was present in 97.7%.

Our study was performed in a similar fashion and showed the following results. In arterial occlusion there was a 98.7% agreement between the findings of DSA and MDCT. In stenotic lesions there was 82% agreement between the findings of DSA and MDCT. The sensitivity of MDCT angiography in this study was 98.7% when considering the conventional angiography as the gold standard. In multi-detector row CT angiography we are dealing with a huge number of axial images (800–1000 image). In two studies, one by Rubin et al. (11) in 1999 and the other by Rubin (12) in 2000, stated that this “data explosion” was considered to be the greatest challenge of the new multi-detector row CT scanners. Using 3D techniques might help to solve this problem. Yet, reviewing the axial images by the radiologist is mandatory. Watching axial images in cine mode is proposed as a fast and reliable method for reviewing a large number of images (13).

If we consider CT angiography as an alternative to conventional angiography, we must generate CT angiograms in a presentation format similar to those of conventional angiography with which referring surgeons are accustomed. It is not possible for clinicians to view more than 800 axial slices containing much irrelevant, nonvascular information (9).

Many display formats may be used, including multiplanar reformation, maximum intensity projection, surface shaded display, and, most recently, volume rendering has been developed (14).

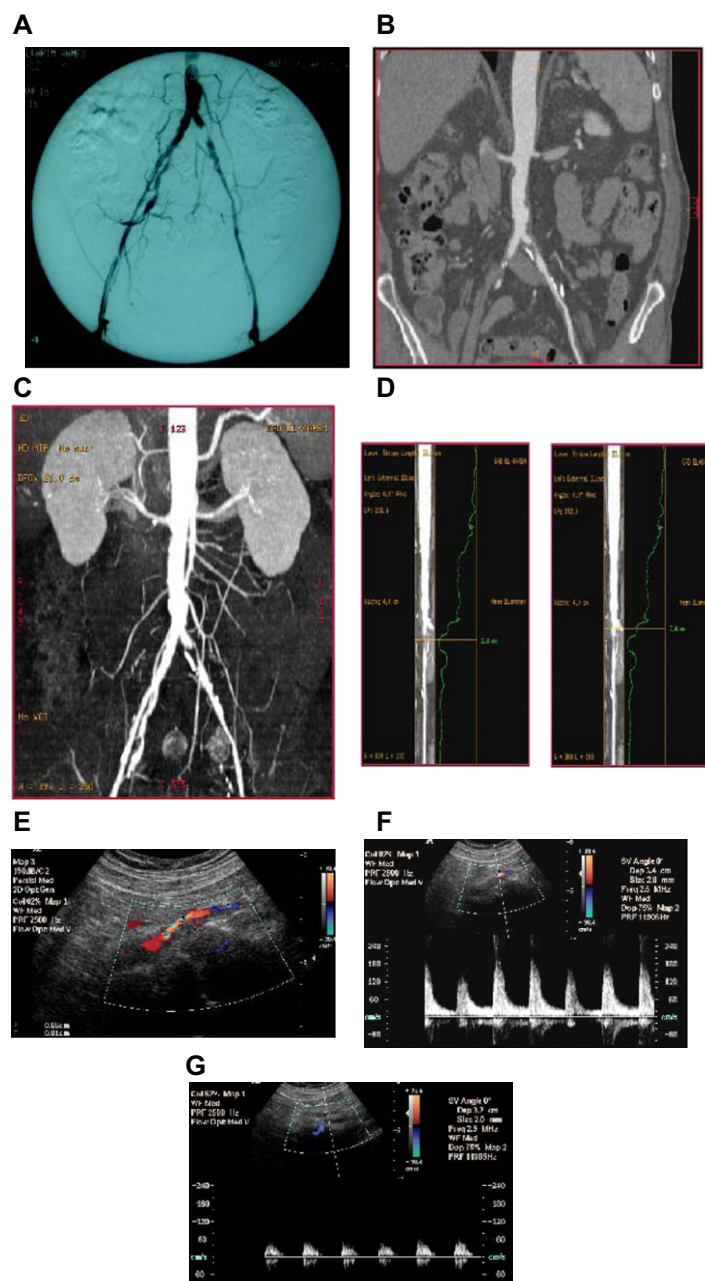
Bones and dense calcifications obscure the true lumen of the arteries and must be erased from the projections produced. In the presence of dense calcified plaques, especially in the distal arteries, it is difficult to produce MIP images with a good diagnostic value. Continuous calcification of the wall of an artery may cause a false diagnosis of patency, whereas the process of erasing these calcifications may result in a false diagnosis of high-grade stenosis or occlusion (9).

In 2003 Willman et al. (5) concluded that underestimation or overestimation of arterial stenosis due to vessel wall calcifications on CT angiograms is most frequently encountered at the renal and internal iliac arteries of patients with suspected occlusive disease.

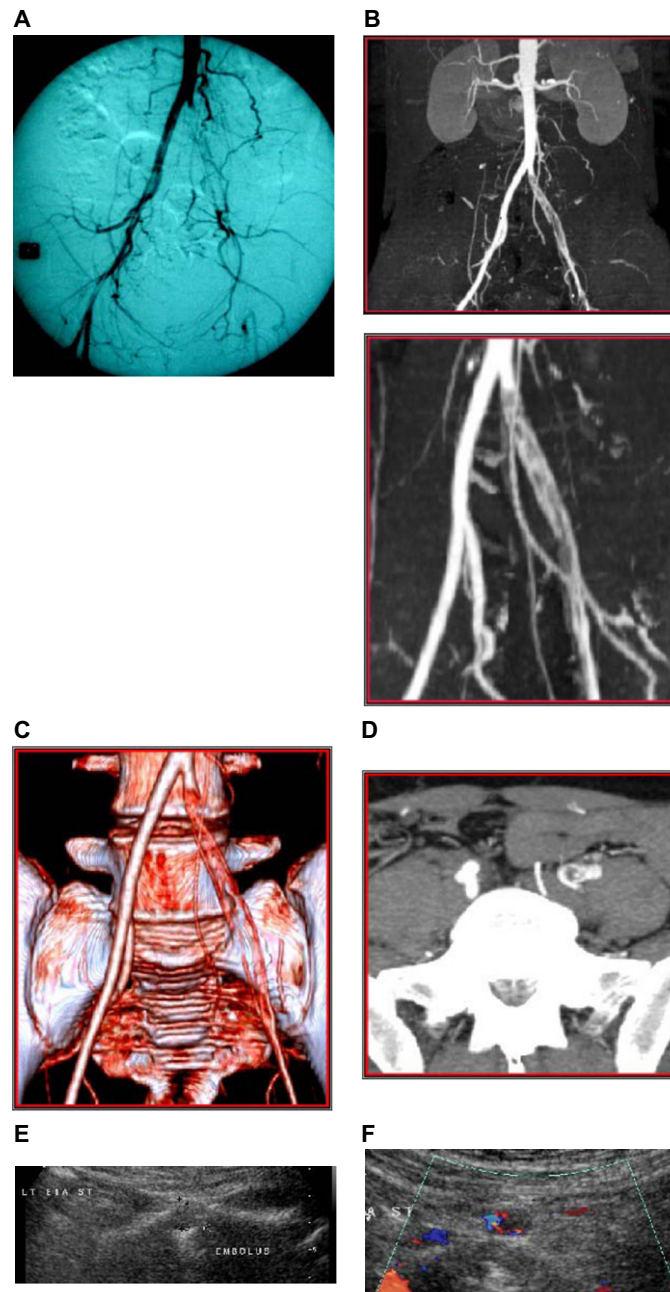
In our study, we did not use any technique to remove arterial wall calcifications. The problem was satisfactorily solved in the large iliac arteries by viewing the related axial images.

Axial images should be viewed as well with the MIP images in cases of stent placement and dense calcifications to delineate the lumen from the stent or from calcified plaques (15).

In 2003, Visser et al. (16) made a study on the cost-effectiveness targets for MDCT angiography in the work-up of patients with intermittent claudication in USA. The purpose of their



**Fig. 7** (A–G): A 65-year old male, chronic heavy smoker, hypertensive and on regular anti-hypertensive treatment. Not diabetic. He has history of chronic ischemic heart disease. He has history of chronic left lower limb ischemic pain since 5 years. Two months ago he developed gradual increase in pain in the left thigh. A source of emboli was excluded by echocardiography and bilateral lower limb venous Doppler. On clinical examination, the femoral pulse could be felt on both sides with normal right lower limb pulsations. No trophic changes or gangrene were noted. (A) DSA shows atherosclerotic mural irregularities with severe grade III stenosis of the left CIA. (B) Multiplanar coronal reconstruction showing mural atheroma encroaching on and attenuating the lumen of the left CIA with adjacent mural calcific plaque. (C) MSCT MIP image IN AP projection of the aortoiliac arteries revealed atheromatous calcifications and mural irregularities of the aortoiliac arteries with the left CIA stenosis. (D) Advanced vessel analysis using the work station enabled us to calculate the degree of stenosis. The figure to the left illustrates the pre stenotic lumen diameter while the figure to the right demonstrates the diameter of the stenotic segment. It was calculated to be 67.5% stenosis grade II. (E) CCD shows left CIA stenosis by a hypochoic atheroma. The reduction in diameter was calculated to be 69% indicating moderate grade II stenosis. (F) CCD spectral wave analysis revealed high PSV at the stenotic segment. (G) CCD spectral wave analysis shows dampened monophasic wave in the post stenotic segment.



**Fig. 8** (A–F): A 40-year old female, with history of rheumatic heart disease, namely mitral stenosis and mitral regurge as well as the presence of atrial fibrillation. She is a non smoker and does not suffer from diabetes or hypertension. The patient experienced sudden severe cramping pain in the left lower limb especially in the thigh region after which she was referred to the vascular department and then to us. On clinical examination the left CFA could not be felt. (A) DSA in AP projection shows abrupt cut off of the left CIA with faint tram line appearance outlining the left CIA. (B) MSCT MIP images in AP projection with special magnification on the left CIA demonstrating the hypodense tubular shaped embolus filling and mildly dilating the left CIA. (C) MSCT volume rendering images with close up on the left CIA showing defect at the site of the embolus yet with continuity of the wall of the left CIA. (D) Axial MSCT image at the level of the left CIA shows the hypodense embolus with contrast seen at its periphery. (E) B mode ultrasonography shows echogenic embolus within the left CIA. (F) CCDS shows the embolus with color flow seen at its periphery.

study was to determine the target values for diagnostic accuracy that would make MDCT angiography, as compared with gadolinium-enhanced MR angiography cost-effective in terms of the following parameters: the sensitivity for detection of significant stenosis, the proportion of cases requiring additional work-up with digital subtraction angiography because of

equivocal results, and the costs of MDCT angiography in the work-up of patients with intermittent claudication. They concluded that MDCT angiography, as compared with currently used imaging modalities in USA as MR angiography, has the potential to be cost-effective in the evaluation of these patients.

As for evaluating abdominal aortic aneurysms, MDCT angiography has the potential to replace conventional angiography in the evaluation of the aorta and its branches, but few prospective comparative studies have been performed. Spiral CT already holds an important role in the evaluation of aortic aneurysmal disease. MDCT angiography adds further to this by helping define the relationship of the aneurysm to both the mesenteric vessels and the renal arteries, which is critical for preoperative planning. With scanners now allowing examination of the entire aorta and both lower limbs with a single injection of contrast material, the relationship of the aortic dissections to branch vessels is clearly depicted (17).

In the 2001, Rubin et al. (8) performed a study on the radiation dose that the patient is exposed to during multi-detector row CT angiography. They stated that the radiation dose in MSCT is higher than the dose he gets during routine CT scan of the abdomen, but it is much less than the dose he gets during conventional angiography. Thus, the radiation exposure with conventional angiography was 3.9 times greater than that with MDCT angiography.

The most common indication for Doppler is the assessment of patients with ischemic symptoms of the lower limb in order to determine if they are likely to benefit from angioplasty or a bypass graft. The ultrasound findings provide information on the extent and severity of the disease, allowing any subsequent arteriogram to be scheduled as either a straightforward mapping examination prior to bypass grafting, or as a more time-consuming angioplasty procedure (18).

For optimal Doppler ultrasonographic scanning of the aortoiliac vessels the patient should fast for at least 8 h prior to the examination for two reasons; first, fasting will improve visualization of the aorta and its branches and secondly the splanchnic blood flow will be in the basal fasting state, rather than the dynamic post prandial state (19).

De Smet et al. performed a study on the different duplex velocity characteristics in aortoiliac stenoses. Together with other published data, the following criteria for aortoiliac stenoses were proposed:

- PSV ratio  $< 1.5$ , reverse flow, and a clear systolic window indicate  $< 20\%$  stenoses.
- PSV  $< 200$  cm/s and/or a PSV ratio  $< 2.5$  indicate  $< 50\%$  stenoses.
- PSV ratio  $\geq 2.5$  indicates  $\geq 50\%$  stenoses.
- PSV ratio  $\geq 5.0$  and an EDV  $> 40$  cm/s indicate  $\geq 75\%$  stenoses.
- EDV  $> 0$  cm/s indicates stenoses of hemodynamic importance.

In 2003 Shaalan et al. (20) investigated the utility of color duplex ultrasound (CDU) derived common femoral artery (CFA) hemodynamics for detecting significant aortoiliac occlusive disease and predicting its severity. They concluded that CFA PSV 45 cm/s or less combined with a monophasic waveform is highly predictive of ipsilateral iliac occlusion. CFA color duplex US scanning may be considered an alternative technique to direct duplex scanning of the aortoiliac segment in patients being evaluated for endoluminal procedures. In our study, the agreement between DSA and CCD was 96.2% in arterial occlusions while it was only 73% in stenotic

lesions. The sensitivity of CCD when considering conventional angiography as the gold standard was 96.2%.

A comparative study between CCD and conventional angiography was made and concluded that Duplex scanning with spectral waveform analysis has excellent resolution allowing the visualization of the arteries of the lower limb, and providing unique modality for displaying normal and abnormal hemodynamics. In contrast, conventional angiography which is the accepted gold standard of investigating the arterial system has important limitations even with biplaner views. It can overestimate or underestimate the hemodynamic significance of eccentric lesions.

In 2003, Willmann et al. (5) made a prospective blinded comparative study between MDCT angiography, DSA and CCD in evaluation of peripheral arterial bypass grafts. There were no significant differences in sensitivity and specificity between MDCT angiography and CCD in detection of hemodynamically significant lesions. They concluded that MDCT angiography is feasible, accurate, and reliable in the assessment of peripheral arterial bypass grafts and detection of graft-related complications, including stenosis, aneurysmal changes, and arteriovenous fistulas.

William et al. (5) made a study in 2003 to compare contrast-enhanced MRA and MDCT angiography. They found no statistically significant difference between 3D contrast-enhanced MR angiography and MDCT angiography in the detection of hemodynamically significant arterial stenosis of the aortoiliac and renal arteries. Yet, the patients' acceptance was better for MDCT angiography. It took shorter time and caused less noise.

The lack of ionizing radiation is an advantage of MR angiography compared with CT angiography. Advantages of CT angiography include the visualization of calcified plaques and insusceptibility to metallic vascular clips. Iodinated contrast material for CT angiography is less expensive than the dose of gadolinium required for MR angiography (19).

Mulligan et al. (20) compared color Duplex and MR angiography in the evaluation of lower limb arterial disease. Color duplex US was limited in the evaluation of iliac segments because of non-visualization. The iliac region was visualized in more patients with MR angiography than with color duplex US, but image quality with MR angiography was inconsistent.

## 6. Conclusion

Considering conventional angiography as the gold standard, MDCT angiography shows higher sensitivity (98.7%) than color coded Doppler ultrasonography (96.2%) in the assessment of aorto-iliac arterial disease.

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