Original Research Article

Colour Doppler Ultrasound Versus CT Angiography or MR Angiography in Diagnosis of Lower Limb Ischaemia

Abstract:

Background: Limb Ischemia is an obstruction of the arteries which reduces blood flow to the extremities (hands, feet and legs) and has progressed to the point of severe pain and even skin ulcers, sores, or gangrene. The pain caused by ischaemia can -wake up an individual at night. This pain is often in the leg and can be relieved temporarily by hanging the leg over the bed or getting up to walk. The complications of diabetic vasculopathy commonly include two categories: microvascular and macro-vascular complications. Macro vascular disease is the most common reason of mortality and morbidity in diabetes and is responsible for high incidence of vascular diseases such as stroke, myocardial infarction, and peripheral vascular diseases (PAD). EEpidemiological evidence has confirmed an association between diabetes and increased prevalence of PAD. The duration and severity of diabetes correlate with incidence and extent of PAD. Diabetes changes the nature of PAD.

Aim of the Work: The aim of this present study is to evaluate the role of colour Doppler Ultrasound (US) in the diagnosis of lower limb ischaemia.

Patients and Methods: In this study, 40 diabetic patients with ischemic limb underwent arterial reconstruction or intervention bypass surgery at Department of Diagnostic Radiology, Tanta University Hospitals. The age of our selected patients ranged from 40-80 years showing that about 2/3 patients in this study were above the age of 60 years and this was found in 24 patients (60%) this is due to high incidence of ischemia and prevalence of atherosclerosis in old age.

Results: There are variable risk factors were present. DM was present in 100% of patients followed by hypertension was found in 30 patients (75%) coronary heart disease was found in 9 patients (22.5%) and at least cigarettes smoking was found in 12 patients (30%). Regarding the clinical presentation, intermittent claudication pain was the most frequent symptoms and was present in 26 patients (65%), followed by persistent pain and delayed healing foot ulcer was present in 9 patients (22.5%), followed by rest pain was present in 4 patients (10%) at least amputated leg was present in one patient (2.5%). Colour Doppler US has some limitation eg. In ability to see particular vessels wall due to wall calcification, gases and vessels tortuously. Colour Doppler US sometimes failed to differentiate between tight stenosis and total occlusion. CTA still had an important role especially in the infra-popliteat region and peri-vascualr masses.

Conclusion: Our study suggested that computed tomography angiography can be used to assess the entirety of lower extremity arterial inflow and runoff, with volumetric data that demonstrate robust arterial enhancement and minimal venous opacification. Nevertheless, computed tomography angiography cannot be considered a viable clinical alternative to colour Doppler US until its diagnostic accuracy and effectiveness are determined.

Key Words: Colour Doppler Ultrasound, CT Angiography, MR Angiography, Lower Limb Ischaemia

Introduction:

Limb Ischemia is an obstruction of the arteries which reduces blood flow to the extremities and has progressed to the point of severe pain and even skin ulcers, sores, or gangrene. The pain caused by ischaemia can -wake up an individual at night[(1)].

The complications of diabetic vasculopathy commonly include two categories: microvascular and macro-vascular complications. Macro vascular disease is the most common reason of mortality and morbidity in diabetes and is responsible for high incidence of vascular diseases such as stroke, myocardial infarction, and peripheral vascular diseases (PAD)[(2)].

There is an association between diabetes and increased prevalence of PAD. The duration and severity of diabetes correlate with incidence and extent of PAD[(3)].

Diabetic; patients more commonly have infrapopliteal arterial occlusive disease and vascular calcification than nondiabetic cohorts [(4)].

Pathological changes of major blood vessels lead to functional and structural abnormalities in diabetic vessels including endothelial dysfunction, reduced vascular compliance, and atherosclerosis[(5)].

Diabetic lower extremity arterial disease is the main cause of non traumatic amputation[(6)].

The affected limbs of diabetic patients were examined with coloured Doppler in the following order: iliac artery, femoral artery, popliteal artery, and pedal artery. The location of the lesion may be iliac: (common iliac artery and external iliac artery), femoral (common femoral artery, superficial femoral artery, and profunda femoris), popliteal, anterior tibial, posterior tibial and peroneal [7].

Doppler ultrasonography (US) has become the first line in the evaluation of lower-extremity arterial disease. Doppler US findings provide good information about the anatomy and physiology of the vessels. Spectral Doppler ultrasonography and color-flow vascular imaging supplement gray-scale US in identifying blood vessels, confirming the direction of blood flow, and detecting 'vascular stenosis or occlusion [8,9].

CT angiography (CTA) and MRA are quite comparable in visualizing vessels and can provide much of the diagnostic; information of the lower extremity arteries that can be obtained with conventional angiography. A prospective study comparing CTA, MRA, and digital subtraction angiography (DSA) showed similar diagnostic accuracy [10,11].

CTA provides higher resolution and can scan the entire volume quickly. It allows evaluation of arterial calcium, vascular stents, volume rendering, and imaging unstable patients. MRA is a fast procedure, providing much of the diagnostic information that can also be derived from catheter angiography with less risk. MRA is generally used in young patients and in patients with contrast allergy or renal insufficiency. MRA should not be used in patients with pacemaker and other implants. MRA is not effective in unstable and uncooperative patients. Generally, CTA is the preferred imaging modality for planning endovascular interventions for abdominal and thoracic; aortic aneurysms and lower-extremity arteries [12-14].

Patients & Methods:

In this study, 40 diabetic patients with ischemic limb underwent arterial reconstruction or intervention bypass surgery at Department of Diagnostic Radiology, Tanta University Hospitals.

Inclusion criteria:

1. Patients have lower extremity ischemia due to advanced peripheral arterial disease.
2. Patients undergoing arterial reconstruction or intervention bypass surgery.

Exclusion criteria:

1. Major tissue loss.
2. Patients with Rutherford stage I ischemia (non-capacitated claudication).
3. Patients contraindicated for contrast media in CT and MRI like allergy to IV contrast media used in CT or cases with renal failure with raised Glomerular Filtration Rate (GFR) in MRI.

Computed tomography angiography:

Computed Tomography with angiographic technique was performed using Toshiba Asteon2 C.T. scanner and 128 Philips.

After explanation of the procedure to the patients, examinations were done in the supine, feet first position and scout views in the antero posterior and lateral planes were taken.

Scanning is planned from the level of renal arteries down to the forefoot. Both lower limbs were examined even in cases with unilateral ischemia. Non enhanced scans were first performed to assess calcification which can affect the interpretation of volume rendering and reformatted images. Then, contrast enhanced images were obtained. The following parameters were used: helical high speed scan with rotation time of 0.6 seconds, table speed of 22.5 mm per rotation and collimation thickness of 5 mm, large FOV, X-ray tube voltage of 120 KV and current of 320-350 MA.

Contrast administration was performed using power injector (Vistron CT injector). Nonionic water soluble contrast (Ultra vest) was used in all patients using wide bore canula (18-20 G)

inserted in a big vein. The injected amount ranged from 100-140 ml at rate of 3-3.5 cc/sec. delay time after start of injection was 25 seconds. The total acquisition time ranged from 35-45 seconds. Transverse sections were reconstructed at 1-2.5 mm interval (at least equal to the half of the collimation. All the volumetric data were analyzed using volume rendering (VR) and multiplanner curved reformation in maximum intensity projection (MIP).This volume analysis was done using a software program of lower extremity vessels.

The CT table and any other unwanted data were cut from the images to maximize vascular visualization. All images including the axial, VR, and MIP reformation images were reviewed as regards popliteal artery patency or occlusion and its degree (complete or partial), degree of stenosis: less than 50 % in diameter or more than 50 % in diameter, state of collaterals and looking for associated pathologies e.g. pseuo-aneurysm were assessed in each case.

Magnetic resonance angiography:

At time of this study there is no cases of MRA of lower limb ischemia can be detected at Tanta University Hospital.

After final diagnosis of 40 diabetic patients (25) patients treated conservative (15) patients underwent arterial reconstruction or intervention bypass surgery.

Results:

On clinical examination of 40 patients with ischaemic lower limb 13 patients (32.5%) showed biolateral lower limb ischaemia and 27 patients (67.5%) showed unilateral lower limb ischaemia (right or left leg).

Each limb was examined with duplex sonography prior to CTA, 9 segments in each limb were evaluated namely (CIA, EIA, CFA, profunda femoris artery, SFA (proximal, middle, distal), popliteal A, ant tibial A, post tibial A and peroneal A) and classified into the ilio-femoro-popliteal arterial segments (CIA, EIA, CFA, PFA, SFA and popliteal A) and infrapopliteal arterial segments (ATA, PTA and peroneal A) divided the finding of CTA and duplex sonography in to 3 groups for grading of PAD.

a) Total occlusion (100% diameter reduction) character by no flow is detected in the vessels.
b) Significant stenosis (50-99% diameter reduction) character by >100% increase PSV, absent of reverse flow component and marked spectral broadening.
c) Non significant stenosis (<50% diameter reduction) character by 30-100% increase PSV with preserved the reverse flow component (triphasic wave) and filling of spectral window.

The most frequent finding is total occlusion and was presented in 14 patients (35%) affecting SFA and followed by affection popliteal artery and posterior tibial artery in 9 patients (22.5%) (table 1).

Table (1): Frequency of affected arteries in studied patients by colour Doppler US

Affected arteries	Patient no. (n=40)		Segment affection		
	n	%	Total occlusion	Significant stenosis >50%	Non-significant stenosis
Common iliac artery	4	10.0	3	1	0
External iliac artery	5	12.5	2	3	0
Common femoral artery	6	15.0	6	0	0
Profunda femoris artery	1	2.5	0	0	1
Superficial femoral artery	14	35	9	3	2
Popliteal artery	9	22.5	3	4	2
Anterior tibial artery	8	20.0	4	3	1
Posterior tibial artery	9	22.5	4	3	2
Peroneal artery	2	5.0	0	1	1

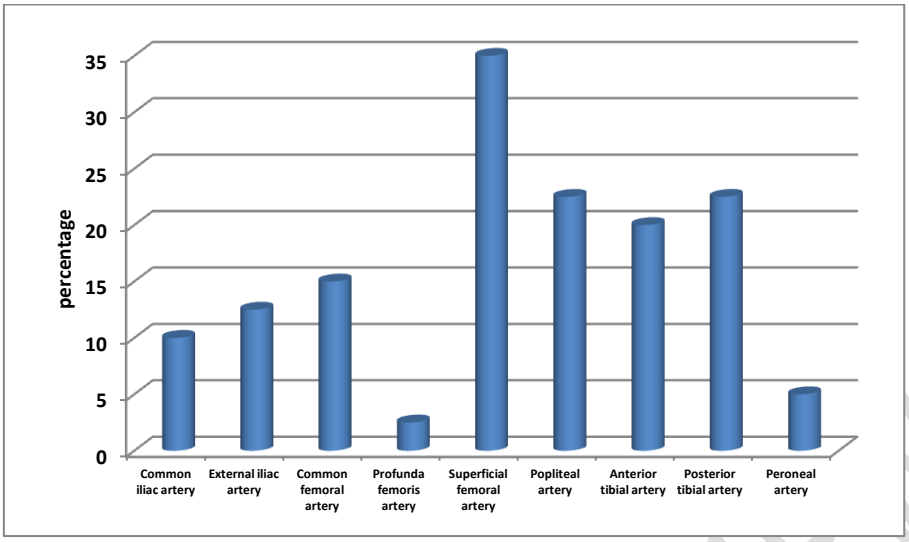

Fig. (1): Frequency of affected arteries in studied patients

In all arterial segments (ilio-femoro-popliteal and infra popliteal segment) calculated true positive, true- negative, false positive and false negative results are shown for detection accuracy, specificity and sensitivity of Doppler US compared to CTA (gold standard) and differentiate between significant and non significant stenosis.

Regarding ilio-femoro-popliteal A segment the high sensitivity of Doppler US was present in SFA (100%) and less sensitivity of Doppler US was present in PFA (0%).

Regarding infrapopliteal arterial segment the high sensitivity of Doppler US was present in ant tibial A (100%) and less sensitivity of Doppler US was present in peroneal artery (50%).

The number of false negative cases by Doppler US are less than by CTA both iliofemero popliteal and infra popliteal arterial segment.

Colour Doppler US sensitivity is 57.1%, specificity 0% and accuracy is 50% compared to CTA.

So that colour Doppler US has some limitation eg. In ability to see particular vessels wall due to wall calcification, gases and vessels tortuously.

Colour Doppler US sometimes failed to differentiate between tight stenosis and total occlusion.

CTA still had an important role especially in the infra-popliteat region and peri-vascualr masses.

Color Doppler US have an important role in examining superficial vessels of the lower before by pass graft operations to detect its suability as a graft (Table 2,3,4,5).

Table (2): Cross tabulation of affected arteries and affected legs in studied patients

Affected arteries	Patient no. (n=40)		Affected leg			Segments affected (n=78)
	n	%	Right leg	Left leg	Bilateral	
Common iliac artery	4	10.0	1	1	2	6
External iliac artery	5	12.5	1	2	2	7
Common femoral artery	6	15.0	1	3	2	8
Profunda femoris artery	1	2.5	0	1	0	1
Superficial femoral artery	14	35	5	4	5	19
Popliteal artery	9	22.5	7	1	1	10
Anterior tibial artery	8	20.0	2	2	4	12
Posterior tibial artery	9	22.5	1	4	4	13
Peroneal artery	2	5.0	0	2	0	2

Table (3): Accuracy of Doppler compared to CT in diagnosis of stenotic lesions in ilio-femoro-popliteal arteries in studied patients

Artery	Doppler	CTA		Total	Sensitivity	Specificity	Accuracy
		Positive	Negative				
Common iliac artery	Positive	1	0	1	33.3%	100%	50%
	Negative	2	1	3			
	Total	3	1	4			
External iliac artery	Positive	2	0	2	40%	0%	40%
	Negative	3	0	3			
	Total	5	0	5			
Common femoral artery	Positive	3	1	4	75 %	50%	66.6 %
	Negative	1	1	2			
	Total	4	2	6			
Profunda femoris artery	Positive	0	0	0	0%	0%	0%
	Negative	1	0	1			
	Total	1	0	1			
Superficial femoral artery	Positive	9	5	14	100 %	0%	64.3 %
	Negative	0	0	0			
	Total	9	5	14			
Popliteal artery	Positive	6	0	6	85.7 %	100%	88.8 %
	Negative	1	2	3			
	Total	7	2	9			

Table (4): Accuracy of Doppler compared to CTA in diagnosis of stenotic lesions in infra-popliteal arteries in studied patients

Artery	Doppler	CTA		Total	Sensitivity	Specificity	Accuracy
		Positive	Negative				
Anterior tibial artery	Positive	7	0	7	100 %	100 %	100 %
	Negative	0	1	1			
	Total	7	1	8			
Posterior tibial artery	Positive	6	1	7	85.7 %	50 %	77.7 %
	Negative	1	1	2			
	Total	7	2	9			
Peroneal artery	Positive	1	0	1	50 %	0 %	50 %
	Negative	1	0	1			
	Total	2	0	2			

Table (5): Accuracy of Doppler compared to CTA in diagnosis of lower limb ischemia in studied patients

Doppler	CTA		Total	Sensitivity	Specificity	Accuracy
	Positive	Negative				
Positive	20	5	25	57.1%	0 %	50 %
Negative	15	0	15			
Total	35	5	40			

Discussion:

Forty patients were examined with duplex sonography prior to CTA, this is synchronous with **(Kerr and Bandy, 1993)** [15] who stated that duplex scanning showed became standard screening method before CTA to do any operation.

Jagar et al., (1985) [16] out lined the major criteria for classification the arterial diseases by duplex US, the three major stated by them were derived from Doppler spectrum and included overall wave form contour, PSV (peak systolic velocity) and spectral width (spectral broadening).

Jagar et al., (1985) [16] classified PAD into five categories: A) Normal, B) 1-19% diameter reduction, C) 20-49% diameter reduction, D) 50-99% diameter reduction, E) total occlusion,

on the other hand, **(Hatsukami et al., 1992)** [17] classified peripheral arterial disease into four groups only as follow: A) normal, B) <50% DR, C) 50-99% DR, D) total occlusion.
Elsman et al., (1995) [18] stated that whether the arterial lesion is proximal or distal to the inguinal ligament is a key question for the management of patients with lower extremely arterial disease, so in our study we divided the lower limb arterial tree into 2 main anatomical portion iliofemoropopliteal and infrapopliteal arterial segments.
Moneta et al., (1992) [19] in study done by them, twenty out of 524 aortoiliac segments couldn't be visualized while in study done by **(Kohler et al., 1987)** [20] one out of 135 aortoiliac segment couldn't be visualized by sonography.
In our study 6 patients out of 9 patients in the aortoiliac region couldn't be seen by duplex as, three of them were due to marked obesity while the other 3 patients were due to marked tortuosity of the iliac segments.
In our study we used PSV ratio in diagnosis of hemodynamic significant stenosis, it was obtained by comparing PSV in the stenotic zone with that in a normal portion of the same or another vessels we considered ration of 2 or more for diagnosis of heamodynamicaly significant stenosis as stated by **(Cossman et al., 1989)** [21].
Our result showed that duplex US sensitivity 55.9 specificity 0% and accuracy 48.7% compared to CTA these results are nearly agreement with **(Koelemay et al., 1996)** [22] who reported sensitivity 73% also our results are near to results of **(Polak et al., 1990)** [23] who reported sensitivity 88% in diagnosis of thermodynamically significant stenosis.
Regarding CFA and for diagnosis of heamodynamically significant stenotic lesion, our results showed sensitivity 75%, specificity 50% and accuracy 60% these the sensitivity in our study was higher than that reported by **(Kohler, 1987)**[20] who reported sensitivity 67% and this higher results noted are due to superficial location of common femoral artery and more advanced technology of machine.
The sensitivity in our study was superior to that reported by **(Jagar et al., 1985 and Polak et al., 1990)** [16,23] which were 72.3% and 76% respectively.
Our study reported one false negative results were present in the studied CFA these segment were diagnosed by colour Duplex as non significant stenosis <50% DR but by CTA as significant stenosis >50% DR. this is due to proximal stenosis of iliac arteries in these patients so PSV tend to decrease in stead of increase.
Polak et al., (1990)[23] reported similar results and stated that in long irregular stenotic segment velocity tend to decrease in stead of increase.
SFA was divided into 3 arterial segment (proximal, middle, distal) as done by **(Jenkins et al., 1998)**[24] examination of SFA by colour duplex US in our study revealed sensitivity 100%, specificity 0% and accuracy 64.3%.
Our results were near to that of both **(Polak et al., 1990)** [23] who reported sensitivity 88% and **(Meissner et al., 2004)** [25] who reported sensitivity 89% in detection of significant lesion >50% DR in SFA.
This is away from that of **(Sacks et al., 1992)**[26] who reported sensitivity 98%, specificity 96% for diagnosis lesion of PFA.
The false negative result in our study was over estimated by colour duplex as significant stenosis >50% DR while by CTA is totally occluded this was due to proximal occlusion of CFA. So the velocity in this segment tend to decrease markedly below sensitivity of machine. Similar finding were reported by **(Polak et al., 1990)**[23].
This false negative results was graded by colour duplex as non significant stenosis (<50% DR) but by CTA graded as significant stenosis >50% DR. this was due to proximal significant arterial stenosis with subsequent decreased velocity of pop artery **(Zenchner et al., 2001)**[27] reported similar results by colour duplex missed one heamodynamic significant stenosis in patients with multisegmented arterial stenosis.

Also, **Molligan et al., (1991)**[28] compared CTA and duplex US in the evaluation of 32 patients with lower limb arterial disease. Color Duplex US performed well in the assessment of infrainguinal disease but was limited in the evaluation of iliac segments because of non-visualization. The iliac region was visualized in more patients with duplex US than with CTA, but image quality with CTA was inconsistent. Strategies to improve CT Angiography of the lower extremities arterial system merit further study.

Moneta et al., (1992) [19] made a comparative study between CCD and conventional angiography 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 haemodynamics, this conclusion is coinciding with the results obtained in our study.

Ouwendijk et al., (2008)[29] compared the costs and effects of three noninvasive imaging tests as the initial imaging test in the diagnostic work up of patients with peripheral arterial disease. They suggested that both MRA and CTA are clinically more useful than duplex sonography, and that CTA leads to cost savings compared with both MRA and duplex sonography in the initial imaging evaluation of patients with PAD.

CTA showing superiority in assessment of aorto-iliac regions due to the presence of intra-abdominal structures, colonic gases and obesity in addition to the unique characteristics of tortuous and deeply located iliac vessels in the retroperitoneal cavity which create a challenge in the visualization of iliac arteries and iliac stents by duplex ultrasonography. However, we were able to assess aorto-iliac region by using duplex ultrasonography indirectly by detecting the distal effect of arterial stenosis/occlusion in the form of dampened monophasic waveform in the arterial segment distal to the occlusion/significant stenosis.

Our study is limited by its relatively small number of patients, but excellent overall follow up was achieved.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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