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Correlation of Multidetector Computed Tomography Peripheral Angiography with Color Duplex Sonography in Peripheral Arterial Disease

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ABSTRACT

Background: With aging of the global population peripheral arterial disease is increasingly common. Arteriography, computed tomography angiography and magnetic resonance angiography are common modalities used for evaluation of peripheral arterial disease. However, they have limitations of being invasive, costly, limited availability or contraindicated in patients with renal impairment or contrast allergy. Duplex imaging, a method of evaluation of peripheral arterial disease is cost effective, widely available and safe even in patients with renal impairment and contrast allergy.

Methods: A prospective cross sectional descriptive study involving 114 patients was conducted from November 2015 to October 2016. The patients were evaluated by Doppler ultrasound following multi-detector computed angiography in Department of Radiology, Tribhuvan University Teaching Hospital. The lower limb arteries were divided into 10 segments and stenosis or occlusion of each segment in Computed Tomography angiography were compared with findings in Doppler, Computed Tomography angiography being considered the gold standard. Data was collected in predesigned proforma in Microsoft Excel spread sheet.

Results: Duplex imaging showed sensitivity 94.94%, specificity 98.54%, accuracy 97.54%, positive predictive value 96.15 % and negative predictive value 98.06 %. In assessment of 22 segments, partial stenosis seen in Computed Tomography angiography was overestimated as complete stenosis in Doppler. There was significant positive correlation of velocity ratio with degree of partial occlusion ($r=0.918$ for right lower limb and $r=0.895$ for left lower limb, $p<0.01$).

Conclusions: Duplex imaging is safe cost effective and reliable method of evaluation of patients with peripheral arterial diseases.

Keywords: Computed tomography; doppler ultrasound; peripheral arterial disease.

INTRODUCTION

More than 10% of the patients in their 60s and 70s have peripheral arterial diseases (PAD).[1] It is strongly associated with concomitant coronary and cerebrovascular diseases.[1] In the developed world, it affects about 5.3% of 45 to 50 years old and 18.6% of 85 to 90 years old. In the developing world, it affects 4.6% of people between the ages of 45 to 50 and 15% of people between the ages of 85 to 90.[2,3]

CT angiography being gold standard for the assessment of limb ischemia, it cannot be used for evaluation of patients with renal impairment. Ultrasound imaging provides a measurement of blood velocity through a vessel and color Doppler imaging enables the rapid localization of arterial stenosis and occlusions.[4] This study aims to make a comparison between CT angiography and Duplex

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imaging to evaluate the reliability of Duplex imaging in assessment of patients with PAD in lower limb.

METHODS

The patients who were referred to Department of Radiology and Imaging of Tribhuvan University Teaching Hospital (TUTH) by clinicians from TUTH or other hospitals/clinics for obtaining CT angiography of lower limb were selected in the study. The CT angiography was performed using 128 slice MDCT Siemens of Department of Radiodiagnosis and Imaging. The patients who had undergone surgical recanalization were excluded from the study. Duplex imaging of these patients were done with USG machines Philips iU22, Philips HD11XE, and Samsung Medison H60NF40/WR in Department of Radiology.

Sampling technique used was non probability sampling. Sample size included all patients referred for MD-CTA of lower limb in Department of Radiology of TUTH in a period of one year (November 2015-October 2016). Ethical approval was taken from Institutional Review Board, Research Department, Institute of Medicine. Data was collected in predesigned proforma. Informed written consent was taken from patients.

Patients were scanned in supine position in cranio-caudal direction from renal arteries to toe using 110 Kv and 150 mAs with modulation pitch of 1-1.5. Slice collimation of 0.6x128 mm was used. Volume of contrast media used was around 120-150mL with control flow rate of 4 ml/s, scan delay of 6-20 seconds or bolus tracking. Tracker was placed at infra-renal abdominal aorta. The CT angiography performed was evaluated. The criteria of analysis were opacification or non-opacification of the studied segment, absence or presence of significant stenosis (more than 50%) and absence or presence of an occlusion assessed in predefined 10 arterial segments in each leg. The arteries of lower limb were divided into following 10 arterial segments: common femoral artery (CFA), profunda femoris artery (PFA), proximal superficial femoral artery (SFA), mid SFA, distal SFA, popliteal artery, proximal ATA, distal ATA, proximal PTA and distal PTA.

Each lower extremity was scanned with the radiologist/resident blinded to the type and location of symptoms as well as to the results of MD-CTA. In Duplex imaging arteries of lower limb were also divided into 10 segments as in CT angiography. Scanning was performed from the groin crease to the level of ankle. Arterial segments were scanned contiguously in the transverse plane for assessment of lumen diameter. Once the vessels were mapped in the transverse plane, color imaging parallel to the vessel was used to place the Doppler sampling gate in the lumen and angle indicator line was placed parallel to the flow in the lumen. A Doppler spectrum was then obtained and the PSV calculated from it. The ratio between PSV in narrowed segment and PSV in normal proximal segment was calculated. PSV ratio was used as the criterion for calculating degree of stenosis.

After both extremities were scanned arterial map was drawn summarizing the location and degree of stenosis i.e. non-significant stenosis (0-49%), significant stenosis (50-99%), and occlusions (100%).

The findings in MD-CTA was compared with findings in Duplex imaging. Sensitivity, specificity, accuracy, positive predictive value and negative predictive value of Duplex imaging was calculated. The correlation between degree of stenosis and PSV ratio was also calculated.

RESULTS

Of the 114 patients who underwent MD-CTA of lower limb for PAD, three patients had normal CT angiography. 70 patients (70.3%) were male and 33 (29.7%) were females. 73 patients (65.7%) were above 50 years. Highest prevalence of PAD was seen in 60-70 years age group (Figure1). Nearly 50% of the patients with PAD (47.4%) had underlying medical diseases like hypertension (Table1). 45 patients (40.5%) with PAD had increased BMI. 74 (73%) of the patients had borderline to high LDL level (greater than 130mg/dl) and 98 patients (88.3%) were smokers.

Table 1. Associated medical diseases with PAD

Medical disease	Number	Percentage
None	22	19.3%
Diabetes	14	12.3%
Hypertension	54	47.4%
Diabetes + Hypertension	22	19.3%
Others (Vasculitis)	2	1.7%

Among the total segments evaluated, there were 600 True Positive (TP), 1624 True Negative (TN), 24 False Positive (FP) and 32 False Negative (FN) segments with(Table 2), Sensitivity and Specificity of 94.94% and 98.54% respectively. Likewise Accuracy was 97.54% and Positive Predictive Value (PPV) and Negative Predictive Value (NPV) were 96.15 % and 98.06 % respectively.

Table 2. Comparison between Findings of MD-CTA and Doppler (n=114).

	Segments showing abnormality in MD-CTA	Segments showing normal findings in MD-CTA
Doppler showing abnormality in segments	600	24
Doppler showing normal segments	32	1624

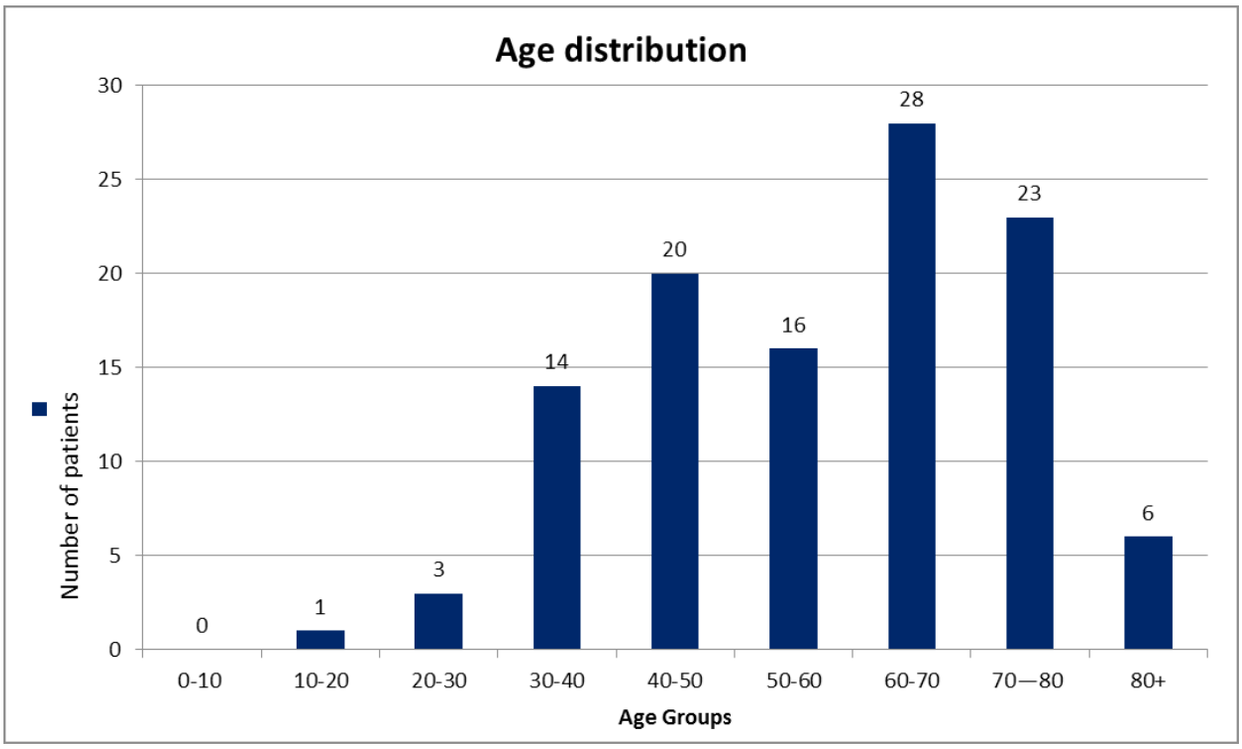

Figure 1. Age distribution of PAD

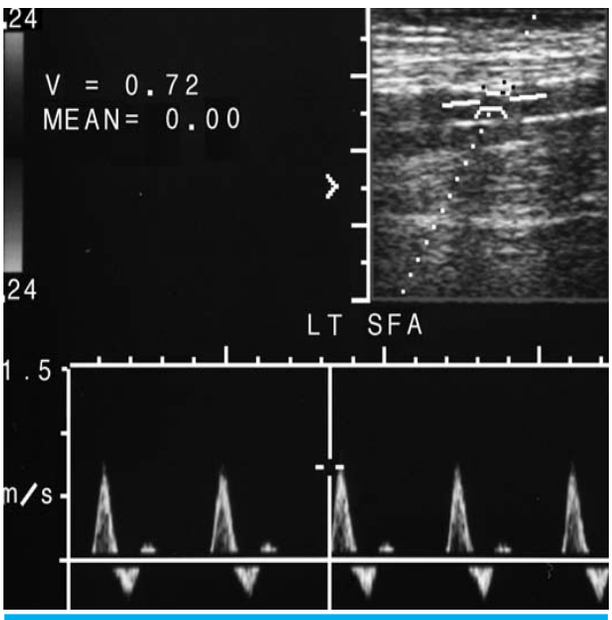

Figure 2. 2A Normal superficial femoral artery spectral Doppler waveform

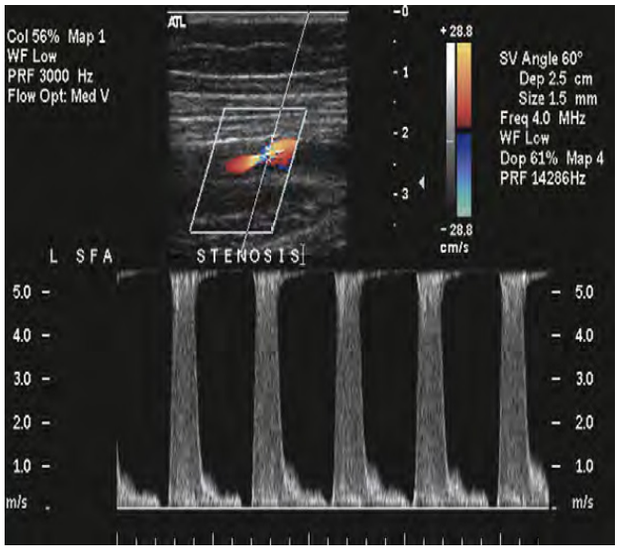

Figure 2B. Duplex scan of a severe SFA stenosis. Color flow image showed a localized, high velocity jet. Spectral waveforms obtained at the site of stenosis indicate PSV>500 cm/sec.

The normal and completely occluded segments were excluded from the analysis. Pearson's correlation coefficient (r) for velocity ratios and degree of stenosis was found to be 0.918 (p <0.01) which showed significant positive correlation between degree of stenosis and velocity ratio in right side (Table 3).

Table 3. Correlation between velocity ratios and degrees of stenosis in right lower limb.

Pearson Correlation	Parameters
	Velocity ratio and Percent stenosis
Correlation Coefficient (r)	0.918
Sig (2-tailed)	0.000

The normal and completely occluded segments were excluded from the analysis. Pearson's correlation coefficient (r) for velocity ratios and degree of stenosis was found to be 0.895 (p <0.01) which showed significant positive correlation between degree of stenosis and velocity ratio in left lower limb (Table 4).

Table 4. Correlation between velocity ratios and degrees of stenosis in left lower limb.

Pearson Correlation	Parameters
	Velocity ratio and Percent stenosis
Correlation Coefficient (r)	0.895
Sig (2-tailed)	0.000

DISCUSSION

Arteriosclerosis is becoming a major health problem. Many studies have concentrated on the coronary and cerebral form of the disease, PAD has received little attention.[3] Although multiple noninvasive and invasive imaging modalities like Ankle brachial index, Digital subtraction angiography (DSA), Multi-detector Computed Tomogram Angiography (MD-CTA), Magnetic Resonance Angiography (MRA), contrast enhanced MRA and Duplex imaging are available, but these modalities of evaluation have their own limitations. ABI though simple method of evaluation of PAD is limited by its inability to provide the location and extent of PAD. Invasive modalities like DSA besides being invasive is not readily available. CTA and contrast enhanced MRA are useful imaging modalities but they may not also be widely available. Moreover, they are not suitable in patients with renal impairment or contrast allergy. MRA may not be also suitable for claustrophobic patients.[4]

Nearly two thirds of the patients in our study aged more than 50 years. Statistical significance was not achieved probably because patients were recommended for MD-CTA by referring physicians based on clinical and Doppler findings. Hence, only patients who had very high suspicion of disease were only included. Prevalence of the PAD increases with age. A study by Diehm et al found that most of the cases of PAD were older population, maximum number being older than 40 years.[5] In our study male had higher prevalence i.e. 70.3% and female had lower prevalence of 29.7% respectively. Similar gender distribution (male 70.2% and female 29.8%) was seen in a study by Diehm et al.[5]

The percentage of smoker was higher than nonsmoker in patients with PAD (88.3% smoker Vs 11.7% non-smoker) in this study. Nearly half of the patients with PAD (47.4%) had underlying medical diseases like hypertension and nearly half of the patients had borderline high or higher LDL levels. Smoking, diabetes mellitus and advancing age were regarded as the cardinal risk factor.[5] PAD is associated with various medical diseases like diabetes, HTN, dyslipidemia and vasculitis.[6] In patients with peripheral arterial disease, diabetic patients have worse arterial disease and a poorer outcome than non-diabetic patients.[7] In a study by Ridker et al, found that maximum number of patient having PAD were suffering from hyperlipidemia. About 58.7 % of patient had borderline high LDL and 6.1 % had high LDL.[8]

In this study the sensitivity of Doppler imaging was 94.94% and specificity was 98.5% and accuracy of 97.5%. There was progressive increase in velocity ratio with degree of stenosis in our study. In a meta-analysis of studies comparing Doppler Vs DSA by Koelemay et al, sensitivity was found to be 86% (74%-91%) and specificity to be 97% (94%-99%).[9] In another study (n=61) done by Legemate et al to validate the use of duplex scanning in the detection of lesions in the aorto-iliac and femoro-popliteal arteries, duplex scanning was prospectively compared to DSA in patients with peripheral atherosclerotic disease. Based on a peak systolic velocity ratio ≥2.5 or the absence of a Doppler signal, the overall sensitivity and specificity to detect lesions of ≥ 50% diameter reduction was 84% and 96%.[10] The study done by Shirol et al, comparing color Doppler USG with MD-CTA, there was significant agreement on detection of stenosis (k=0.783, p< 0.001). Color Doppler was able to detect 86% of stenosis detected in MD-CTA.[3]

In our study 22 segments with partial stenosis were overestimated as complete stenosis in Doppler imaging. Most of the overestimation was seen in distal arteries. In the study done by Chidambaram et al, 619 arterial segments were studied with CT angiography and Doppler ultrasound. Doppler overestimated stenosis grade

predominantly in distal runoff arteries of lower limbs. Doppler USG and CTA findings showed good correlation (74%) in most of the vessels.[11] Similar results were also seen in the study done by Joseph F. Polak et.al, which showed duplex sonography coupled with color flow sonography had a sensitivity of 88% for detecting significant stenosis or occluded segments with specificity was 95% and accuracy was 93%.[12] The sensitivity, specificity and accuracy of Doppler USG compared with CT angiography was 93.36%, 82.44%, and 86.42%.[11] Our study also showed similar findings that Duplex imaging was slightly less accurate for distal arteries compared to more proximal ilio-femoral vessels.

In a multicenter study by Ouwendijk et al, 514 of 984 PAD patients who met the inclusion criteria were randomized to MRA or duplex and MRA or CT angiography in Diagnostic Imaging of Peripheral Arterial Disease (DIPAD) trial. The outcome measures included the clinical utility, functional patient outcomes, quality of life, and costs during 6 months of follow-up. The recommendations for additional imaging performed during 6 months of follow-up were collected. Costs concerning all relevant items of medical care (i.e. diagnostic and therapeutic) used by each patient during the entire trial were recorded. Patient's functional status was determined using resting and post exercise ABIs. The response rate improvement in all quality-of-life measures from baseline to 2 weeks, 3 months, and 6 months of follow-up was not statistically significant among the groups. However, the total diagnostic costs per patient were significantly higher in the MRA group than in the duplex sonography group ($p = 0.01$) and CTA group ($p < 0.001$). This increase in diagnostic costs was not caused by more costs for additional imaging but by the higher unit costs of the initial imaging test in the MRA group. The total costs, including diagnostic, therapeutic, and outpatient visit costs, were significantly lower in the CTA group than in the MRA group ($p< 0.001$) and compared with the duplex sonography group ($p = 0.01$). The therapeutic confidence was significantly higher for MRA than for duplex sonography (difference 0.8, $p < 0.001$) and for CTA compared with duplex sonography (difference 1.0, $p < 0.001$). More additional vascular imaging tests per patient were performed in the duplex sonography group compared with MRA (0.42 Vs 0.23, $p = 0.001$) and 0.22 for duplex sonography compared with CTA (0.42 Vs 0.20, $p = 0.03$).The difference in functional status from baseline to 6 months follow-up was not statistically significant among the groups.[13]

In the systematic review by Collins et al, evaluation of 113 studies (including six economic evaluations) was done to determine the diagnostic accuracy and cost-effectiveness of duplex ultrasound, MRA and CT angiography for the detection of stenosis greater than 50% in the whole leg. Contrast enhanced MRA had the highest diagnostic accuracy with sensitivity ranging from 92 to 99.5% and specificity from 64 to 99%. Two-dimensional time-of-flight MRA was less accurate, with sensitivity ranging from 79 to 94% and specificity from 74 to 92%. 2D phase-contrast MRA had a sensitivity of 98% and specificity of 74%. CT angiography also appeared slightly inferior to contrast enhanced MRA, with a sensitivity ranging from 89 to 99% and specificity from 83 to 97%, but better than Duplex ultrasound which had a sensitivity ranging from 80 to 98% and specificity from 89 to 99%. The study showed that contrast enhanced MRA and Duplex ultrasound were more accurate for detecting stenosis /occlusions of the arteries above the knee than below the knee. The economic evaluation showed Duplex ultrasound dominated the other alternatives when the whole leg was assessed, by presenting higher effectiveness at a lower cost per quality-adjusted life-year. The results of the economic modeling suggested that for the PAD patients as evaluated by a preoperative diagnostic test, Duplex ultrasound dominated the other alternatives by presenting higher effectiveness at a lower cost per quality adjusted life year. The study showed that Duplex imaging may be cost effective method in initial evaluation of PAD. However, less accurate sensitivity and specificity may necessitate use of other imaging modalities of evaluation of PAD which may add to the overall cost.[14]

CONCLUSIONS

PAD is common disease with significant morbidity and mortality which is in increasing trend with rise in comorbities like hypertension and diabetes mellitus. There was significant association of PAD with smoking. Many imaging techniques are available for evaluation of PAD. Of these, Doppler is cost effective, widely available and safe modality of evaluation which can provide assessment of PAD with comparable diagnostic efficacy. In our study, the sensitivity of Doppler imaging was 94.94%, specificity was 98.5% and accuracy of 97.5%.

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CONFLICT OF INTEREST

None

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