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Diagnosis of peripheral artery disease in Saudi Population - CTA and MRA Based Study

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Abstract : *The current study highlight the main findings in lower limb arteries diagnosed by Computerized Tomography Angiography(CTA) and Magnetic Resonance Angiography (MRA) done for Saudi Arabia population whom were smokers, hypertensive and diabetic. As well to evaluate which arteries were better to be diagnosed by CTA and which was better be diagnosed by MRA. Next, to review the properties of different visualization techniques for extracting the relevant findings finally, discuss the practical application of CT and MR angiography within the context of various conditions.*

100 consecutive patients in both genders were enrolled. Their main pertinent medical history included smokers (n = 30), diabetics (n = 45) and hypertensive (n = 25). The main symptoms of the patients were limb pain and claudication, with an average duration of 11.5 months. All were underwent MRA and CTA under the standard protocol of examinations. For the whole sample ,arteries above the femur were evaluated by CTA and the results showed that stenosis was found in common iliac, external iliac, internal iliac, femoral, and femoral profound artery, MRA found the total occlusion in common iliac,external iliac,femoral , femoral profound artery which were not detected in CTA. Aneurysm was detected similarly in both imaging methods. Arteries below the femur were well diagnosed as stenosis and total occlusion by MRA for anterior tibial, posterior tibial, and peroneal artery, however 6 cases gives negative results in popliteal artery CTA.

CTA is limited in the evaluation of calcified lesions, where the high attenuation induces artifact that results in an overestimation of stenosis that reflect the false positive results. This effect becomes more relevant vessels below the femur, leading to a lower diagnostic performance of CTA. Our results indicate that MRA can overcome some limitations of CTA and result in improving the diagnostic confidence for evaluating lower extremity arteries. This make MRA a first-line diagnostic test for evaluation of lower extremity vessels, particularly in patients with known or suspected calcification or abnormal or asymmetric inflow patterns. The comparison done between the CTA technique are found to be interesting and MRA techniques help to reduce the limitations to CTA imposed by calcification.

Keywords - Peripheral arterial disease; Computed tomographic angiography; MRA

I. INTRODUCTION

Magnetic resonance angiography (MRA) and CT angiography (CTA) are proposed as non-invasive methods of vascular imaging that can be performed on patients with peripheral artery diseases (PAD)[1]

Significant CT scanning technique relies upon achieving images with thin slice thickness that will give a best spatial resolution along the z-axis within the time that the vasculature is maximally opacified by contrast medium. With 64-detector row scanners, data acquisition is normally either 0.625 or 0.5 mm slice thickness. However, with fast rotation times it can be important to intentionally slow the acquisition speed of these scanners, particularly in patients with aneurysmal disease and/or poor cardiac output, to prevent ‘‘bolus out-run’’, which has been reported to occur [2]

At present, high performance MR scanners provide remarkable angiographic images without patient exposure to radiation or the difficulty of removing overlying bone from 3D reconstructed images. MRA can be performed using contrast-enhanced (MRA) approach or non-contrast enhanced.[3]

The disease prevalence increases with age and 12% to 20% of Americans age 65 have PAD. Studies showed that the prevalence could be increased more by 2050.[4] Although PAD affects both genders equally, worse outcomes have been observed in females. Studies have suggested a unreasonably higher PAD prevalence among African Americans compared with non-Hispanic whites [5]This ethnic tendency is independent of susceptibility to known cardiovascular risk factors such as diabetes, hypertension, and obesity. [6,7]The major obstacle to improve the care of patients with PAD are related to the lack of disease recognition, poor

understanding of its impact on the patient, and the gross underuse of safe, effective, and widely available therapies. PAD is common in high-risk individuals, older ages, or with a history of cigarette smoking or diabetes. [8, 9]

Practice that may give rise to lower limb arterial disease include thromboangiitis obliterans arterial aneurysms, vascular malformations, cystic adventitial disease and the various popliteal entrapment syndromes that are due either to popliteal artery compression by various congenital musculotendinous variations or to functional entrapment without abnormal anatomy .[10,11]

For the vascular, interventional radiologist, vascular surgeon and cardiovascular specialist, it is increasingly important to be familiar with this latest vascular imaging technique, to know its strengths and limitations, and, most importantly, to learn how to read and interpret the large CT angiographic data sets and their reformatted images for treatment planning.[12]

The current study highlight the main findings in lower limb arteries diagnosed by CTA and MRA done for Saudi Arabia population whom were affected with diabetes ,smokers and hypertension and what is the cases which were diagnosed better by CTA and which was better diagnosed by MRA. Next, to review the properties of different visualization techniques for extracting the relevant findings and explain how they are interpreted. Finally, discuss the practical application of CT and MR angiography within the context of various conditions.

II. MATERIALS AND METHODS

In this study, cases were maintained at King Fahad Hospital regarding the diagnostic of MRA magnetic resonance angiography for lower extremity peripheral arterial disease, in comparison to CT angiography.The purpose of the current study is to compare the diagnostic performance Magnetic Resonance Angiography at 1.5 T versus CT angiography for evaluation of lower extremity Peripheral Arterial Disease (PAD).100 consecutive patients (52 males, 48 were females, age range 34–83 years, average age 62.3 years) with clinically suspected lower extremity PAD underwent MRA and CTA. The diagnosis was compared in both modalities by two radiologists with 10 and 8 years' experience.

Main symptoms of the patients were limb pain and claudication, with an average duration of 11.5 months. Mean Creatinine level was from 41 to 228 μmol/ with an average of 76.3 μmol/L. Main pertinent medical history was smoking ($n = 30$), diabetes ($n = 45$), hypertension ($n = 25$). Permission was obtained from all patients before the examinations. MRA and CTA examinations were performed on the same day. MRA was performed prior to CTA in 70 cases and after CTA in 30 cases.

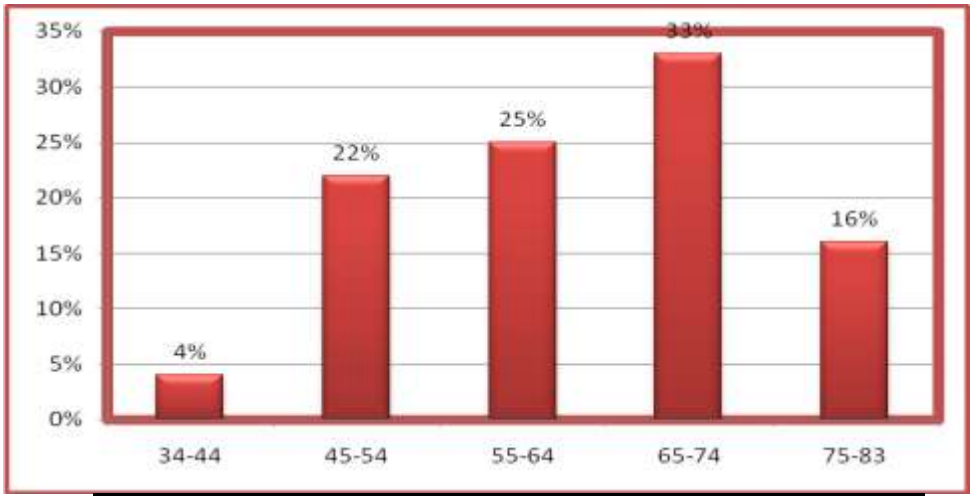
Magnetic Resonance Angiography-(MRA)-:

All MRA examinations were performed on a 1.5 T whole-body MR system GE. Patients were placed on the scanner in feet-first supine position. A dedicated peripheral coil and two eight-element body array coils were used to cover the lower extremity and lower abdomen, and were combined with the posterior integrated multi-channel spine coil. Electrocardiographic triggering was used to ensure proper synchronization between the arterial inflow events and data sampling. Initially a scout image was performed of the whole lower extremity and abdomen for localization purposes using the following parameters: TR/TE, 2.56/1.44 ms; FOV, 48 cm × 149 cm; slice thickness, 5 mm. MRA was performed in the transverse plane with the following parameters: TR = 1 heart beat; TE = 1.68 ms; flip angle, 90, or reduced according to SAR limitation; bandwidth, 700Hz; FOV, 400 mm × 260 mm; matrix, 400 × 261; number of slices, 40; slice thickness, 3 mm. The data acquisition was performed in approximately 6.5 min, given an average heart rate of 80/min. Coronal Maximum Intensity Projection (MIP) images of each station were generated by the scanner software, and all the MIP images were automatically spliced into a composite image including the entire region of interest.

Computerized Angiography- (CTA)-:

All CTA examinations were performed at a 128-row CT scanner (Discovery HD 750, GE medical, America), with the following parameters: tube voltage, 100 Kv; tube current, 150 mA; pitch, 0.984:1; table speed, 55 mm/s; slice thickness, 0.625 mm; FOV, 50 cm. Iodinated contrast agent (Ultravist, Bayer, Germany, 1.2 ml/kg body weight) was administered via an electronic power injector (Stellant, MEDRAD, America) through an 18 gauge intravenous line placed in the right cubital vein, at a rate of 3 ml/s. The bolus-tracking technique was used whereby a region of interest (ROI) was positioned at the aortic bifurcation. Image acquisition automatically started 5.5 s after the attenuation in the ROI reached the predefined threshold of 120 Hounsfield Units (HU).Post-processing procedures and measurement were performed on a dedicated General Electric MRI machine. CTA MIP images were reconstructed with a window setting of 600/300 (window width/window level).

III. RESULTS



Mean Age	62.30±11.34 years

Figure No (1) Distribution of study sample according to Participant's age

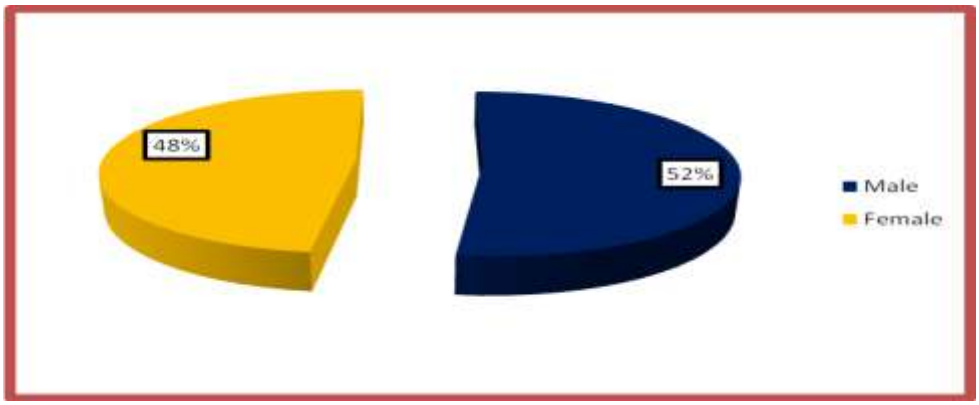


Figure No (2) Distribution of study sample according to Participant's Gender

Table No (2): Arteries above the femur diagnosed by 2 modalities for the whole sample

	CTA-Common iliac artery	**MRA -Common iliac artery**
	Frequency (%)	Frequency (%)
Normal	96(96)	96(96)
Aneurysm	2(2)	2(2)
Stenosis	2(2)	1(1)
Blockage	0(0)	1(1)
	CTA-Distal abdominal aorta	**MRA -Distal abdominal aorta**
Normal	100(100)	100(100)
Aneurysm	0(0)	0(0)
Stenosis	0(0)	0(0)
Blockage	0(0)	0(0)
	CTA-External iliac artery	**MRA -External iliac artery**

Normal	95(95)	95(95)
Aneurysm	2(2)	2(2)
Stenosis	3(3)	1(1)
Blockage	0(0)	2(1)
	CTA-Internal iliac artery	**MRA -Internal iliac artery**
Normal	94(94)	94(94)
Aneurysm	4(4)	4(4)
Stenosis	2(2)	2(2)
Blockage	0(0)	0(0)
	CTA-Femoral artery	**MRA -Femoral artery**
Normal	89(89)	89(89)
Aneurysm	5(5)	5(5)
Stenosis	6(6)	3(3)
Blockage	0(0)	3(3)
	CTA-Femoral profound artery	**MRA -Femoral profound artery**
Normal	90(90)	90(90)
Aneurysm	2(2)	2(2)
Stenosis	8(8)	3(3)
Blockage	0(0)	5(5)

Table No (3): Arteries below the femur diagnosed by 2 modalities for the whole sample

	CTA-Popliteal artery	**MRA -Popliteal artery**
	Frequency (%)	Frequency (%)
Normal	86(86)	86(86)
Aneurysm	3(3)	3(3)
Stenosis	11(11)	5(5)
Blockage	0(0)	6()
	CTA-Anterior tibial artery	**MRA -Anterior tibial artery**
Normal	96(96)	84(84)
Aneurysm	4(4)	3(3)
Stenosis	0(0)	10(10)
Blockage	0(0)	3(3)
	CTA-Posterior tibial artery	**MRA -Posterior tibial artery**
Normal	97(97)	82(82)
Aneurysm	3(3)	4(4)
Stenosis	0(0)	10(10)
Blockage	0(0)	4(4)

	CTA-Peroneal artery	MRA -Peroneal artery
Normal	92(92)	79(79)
Aneurysm	8(8)	3(3)
Stenosis	0(0)	10(10)
Blockage	0(0)	8(8)

Table No (4a): Arteries diagnosed by the two modalities and classification of the findings in Diabetic patients

Diabetic patients	Common iliac		External iliac		Internal iliac		Femoral		Femoral profound		Popliteal	
	N	AB	N	AB	N	AB	N	AB	N	AB	N	AB
MRI	43 (95.6)	2 (4.4)	44 (97.8)	1 (2.2)	43 (43)	2 (2)	40 (40)	5 (5)	41 (41)	4 (4)	40 (40)	5 (5)
CT	43 (95.6)	2 (4.4)	44 (97.8)	1 (2.2)	43 (43)	2 (2)	40 (40)	5 (5)	41 (41)	4 (4)	40 (40)	5 (5)
	Anterior tibial		Posterior tibial		Peroneal		Distal abdominal aorta					
	N	AB	N	AB	N	AB	N	AB	-	-	-	-
MRI	38 (38)	7 (7)	35 (35)	10 (10)	31 (31)	14 (14)	45 (45)	0	-	-	-	-
CT	45 (45)	0	44 (44)	1 (1)	38 (38)	7 (7)	45 (45)	0	-	-	-	-

N=Normal AB=Abnormal

Table No (4b): Arteries diagnosed by the two modalities and classification of the findings in Smokers

Smokers	Common iliac		External iliac		Internal iliac		Femoral		Femoral profound		Popliteal	
	N	AB	N	AB	N	AB	N	AB	N	AB	N	AB
MRI	29(100.0)	0	27(93.1)	2(6.9)	27(27)	2(2)	27(27)	2(2)	24(24)	5(5)	21(21)	8(8)
CT	29(100.0)	0	27(93.1)	2(6.9)	27(27)	2(2)	27(27)	2(2)	24(24)	5(5)	21(21)	8(8)
	Anterior tibial		Posterior tibial		Peroneal		Distal abdominal aorta					
	N	AB	N	AB	N	AB	N	AB	-	-	-	-
MRI	26(26)	3(3)	25(25)	4(4)	.26(26)	3(3)	29(29)	0	-	-	-	-
CT	27(27)	2(2)	27(27)	2(2)	29(29)	0(0)	29(29)	0	-	-	-	-

Table No (4c): Arteries diagnosed by the two modalities and classification of the findings in Hypertensive

Hypertension	Common iliac		External iliac		Internal iliac		Femoral		Femoral profound		Popliteal artery	
	N	AB	N	AB	N	AB	N	AB	N	AB	N	AB
MRI	24 (92.3)	2 (7.7)	24 (92.3)	2 (7.7)	24 (24)	2 (2)	22 (22)	4 (4)	25 (25)	1 (1)	25 (25)	1 (1)
CT	24 (92.3)	2 (7.7)	24 (92.3)	2 (7.7)	24 (24)	2 (2)	22 (22)	4 (4)	25 (25)	1 (1)	25 (25)	1(1)
	Anterior tibial		Posterior tibial		Peroneal		Distal abdominal aorta					
	N	AB	N	AB	N	AB	N	AB				
MRI	20 (20)	6 (6)	22 (2)	4 (4)	22 (2)	4(4)	26 (26)	0				
CT	24 (24)	2 (2)	26 (26)	0	25 (25)	1 (1)	26 (26)	0				

IV. DISCUSSION

Peripheral arterial disease (PAD) is a major cause of morbidity and mortality. It affects mainly the lower limbs, reducing blood flow to the legs causing symptoms such as pain; intermittent claudication. Non invasive imaging techniques are increasingly used for diagnosis of patients with suspected arterial occlusive disease. The progression of PAD is highly associated with risk factors such as smoking, diabetes, and hypertension.[13]

Therefore, it is important to interpret the images regarding the findings. Our results demonstrate the interpretation of MRA and CTA findings for peripheral arterial disease. Figure (1) showed the distribution of study sample according to participant's age. (100 patients) with main pertinent medical history including smoking ($n = 30$), diabetes ($n = 45$), hypertension ($n = 25$) . Main symptoms of the patients were limb pain and claudication, with an average duration of 11.5 months .The highest frequency; is age group 65-74 years old constituting 33% of the sample, the mean age was 62.30±11.34 years. Similarly studies showed that the three risk factors most strongly associated with PAD are advanced age (older than 60 years), cigarette smoking, and diabetes mellitus (DM) [14-19] PAD is more frequent in older adults. Figure (2) showed the distribution of study sample according to participant's gender, it showed that the Saudi males were affected more than females, however studies have mentioned that PAD affects men and women equally.[20]

Radiographic features are usually symmetrical and commonly affects arterial bifurcations, its location of involvement: superficial femoral artery > iliac artery > tibial artery > popliteal artery. Suspect diabetes if tibioperoneal disease > femoral arteries; profunda femoris > Superficial Femoral Artery. Assess significance of stenosis when >50% narrowing of luminal diameter is present. Role of MRA is still in evolution.[21]This is the criteria which the current study depends on .

Literature about agreement of MRA and CTA results in patients with peripheral arterial disease is scarce. Most articles only describe agreement between two different techniques however it is difficult to compare with our results because they used different method of analyses [22]

When comparing the two modalities; both CTA and MRA allow obtaining high-resolution multiplanar and three-dimensional images of the peripheral arteries in a noninvasive approach. Similarly studies have mentioned that both are accurate techniques for evaluating PAD [23,24]Accordingly, we suggested using any of each modality depending on its local availability, medical expertise, and patient's characteristics as diabetes, renal insufficiency, implanted metal devices, prior bypass grafts, or others, as well costs and information required. We facilitate a brief outline of the current state of both techniques from a clinical point of view, highlighting the diagnosis results at each modality.

The evaluated arteries were classified into arteries above the femur and arteries below the femur, as presented in table (2) and (3).Both CTA and MRA were similar in diagnosis of 96/100cases to be as normal in common iliac artery, however one negative result was detected in diagnosis this artery as stenosis and occlusion .In distal abdominal aorta, they all have similar results to be as normal, without presence of aneurysm, stenosis and blockage. External iliac artery were diagnosed as normal and the results were consigned with MRA to be 95/100 cases .2 cases were found to have negative results in MRA ,as it was diagnosed as stenosis in CTA ,but MRA found negative results ,2 cases were diagnosed as normal in CTA however it was found to be blocked in MRA. Both CTA and MRA give similar results in the diagnosis of internal iliac arteries.

In 3 cases the femoral artery were negatively diagnosed as stenosis but they were normal in MRA as well 5 cases were diagnosed as stenosis in CTA, this were not consigned with MRA results .For arteries below the femur: table (3) in 6 cases, the popliteal artery found to have negative results in MRA as well 16 cases for anterior tibial artery and 18 cases for posterior tibial artery and 21 case for peroneal artery. It was noticed that there are increasing in the number of disagreement between the 2 modalities at the arteries below the femur. Our justification is due to the fact that the CTA is limited in the evaluation of severely calcified lesions, where the high attenuation induces blooming artifact that results in an overestimation of stenosis. This effect becomes more relevant in small vessels such as the infrapopliteal vessels, leading to a lower diagnostic performance of CTA in tibial disease than in aortailiac and femoral levels.[23,24,25]

The lack of radiation exposure is clearly one of the main advantages of MRA. MRA requires more time to acquire and is more operator-dependent when compared with CTA, but the post processing reconstructions are more automated and faster. MRA subtracts the background structures only highlighting the enhanced vascular structures, thereby avoiding the CTA complexity of removing overlying bone from 3-D reconstructed images. Interestingly, unlike CTA, the presence of calcium in vessels does not cause artefacts on MRA that is of great importance when examining diffusely calcified vessels, which often occurs in patients with PDA specially in the diabetics.[26].For lower limb arteries, the majority of the literature has focused on occlusive disease. MRA also performs well for popliteal aneurysms [27]

Recent review of the diagnostic performance of CTA showed sensitivity for stenosis >50%, occlusion was 95%, regardless of the location, excellent test characteristics were seen in the aorto-iliac (sensitivity 96% and specificity 98%), femoropopliteal (sensitivity 97% and specificity 94%) and tibial arteries (sensitivity 95%

and specificity 91%). Traditionally, the diagnostic performance of CTA in tibial disease is lower compared to the aorta-iliac and femoral levels, particularly in the setting of heavily calcified vessels.[3]

As well a review for MRA [28] found a sensitivity of 93% and a specificity of 94% for contrast-enhanced MRA in detecting arterial stenosis or occlusion in patients with claudication. The abdominal aorta and the superficial femoral arteries are imaged reliably with MRA. However, problems still arise with imaging of the infrapopliteal arteries , where there is a smaller time difference between arterial and venous enhancement, and venous contamination may obscure arteries below the knee and can cause non-diagnostic images in a substantial number of patients [25].MRA enable scanning of the entire vascular tree in a limited period with a decreasing amount of contrast medium and radiation burden [3].CTA does not only evaluate the vessel lumen but also assesses the vessel wall. Thus, plaque morphology, calcifications, and partially thrombosed aneurysms [25]

The pathophysiology of PAD in the diabetic population is similar to that in the non-diabetic population. However, the distribution of peripheral atherosclerosis in patients with PAD and diabetes is often more distal than in patients without diabetes, and commonly involves the tibial vessels [29]. Our results showed that most common affected artery in diabetics is peroneal artery followed by posterior tibial artery and anterior tibial arteries and all were diagnosed well by MRA Table 4(a). The early diagnosis of PAD in patients with diabetes is critically important in order to reduce the risk of cardiovascular events, minimize the risk and improve quality of life. The diagnosis of PAD in patients with diabetes gives a multi-faceted treatment approach, CTA and MRA showed excellent value in the diagnosis of PDA .The American Diabetes Association recently issued the importance of diagnosis of PAD in patients with diabetes [30]. The abnormal metabolic state that accompanies diabetes directly contributes to the development of atherosclerosis; proatherogenic changes include increases in vascular inflammation and alterations in multiple cell types [31].This was found in our sample that the patients were affected with stenosis and occlusion.

The duration of diabetes correlates with PAD [32]. In a prospective cohort study, Al-Delaimy et al. [33] found a strong positive association between the duration of diabetes and the risk of developing PAD. However our study didn't consider the diabetic duration. We justified the findings as stenosis and occlusion in the lower limb vessels is that the alterations in metabolism in diabetes adversely affect multiple cell types within the vascular wall and thus increased the tendency towards coagulation, coupled with impaired fibrinolysis and contributes to the enhanced thrombotic potential characteristic of diabetes.[30]

Tables 4(b) showed that the most common affected arteries in smokers are popliteal, femoral profound and posterior tibial artery and were diagnosed well by MRA. Most articles provided cross-sectional data [34], with respect to assessment of tobacco exposure. However, if the number of cigarettes smoked per day was substantially underestimated, this would imply that the actual dose-response relationship was more distinct. In our study we did not consider the number or duration of cigarette smoking, which may consider an important limitation in our study. Tobacco use is considered the most important preventable vascular risk factor for peripheral arterial disease (PAD).[35]Literature have mentioned that the association between smoking and PAD is strong.[36]The relationship between smoking and PAD has been recognized previously, when Erb reported that intermittent claudication was 3 times more common in smokers and 6 times more common in heavy smokers, compared with nonsmokers.[37]Since then numerous studies have been performed on the relationship between smoking and the incidence and prevalence of PAD. We performed a study to show the so far the most affected artery and the best modality used to detect the vascular abnormality.

Table 4 (c)most common affected artery in hypertensive patients is the anterior tibial artery , and they are equally affected in posterior tibial, femoral and peroneal artery and were also diagnosed well by MRA .The association with PAD was particularly strong with hypertension and who were current smokers. [30]

The TASC II guidelines [38] and ESC [39] recommend obtaining either a MRA, CTA for imaging of vessel disease depending upon local availability, cost and experience. American Heart Association (AHA)/American College of Cardiology (ACC) [40] guidelines support the use of CTA and MRA in the diagnosis of the anatomic location and presence of significant stenosis in patients with lower extremity PAD. Imaging with either CTA or MRA is well suited for the diagnosis of patients with lower extremity PAD who have suspected aortic aneurysm and other vascular disease.

V. CONCLUSION

CTA is limited in the evaluation of calcified lesions, where the high attenuation induces artifact that results in an overestimation of stenosis that reflect the false positive results. This effect becomes more relevant vessels below the femur, leading to a lower diagnostic performance of CTA. Our results indicate that MRA can overcome some limitations of CTA and result in improved diagnostic confidence for evaluating lower extremity arteries. This make MRA a first-line diagnostic test for evaluation of lower extremity vessels, particularly in patients with known or suspected calcification or abnormal or asymmetric inflow patterns. The comparison done

between the CTA technique are found to be interesting .MRA techniques help to reduce the limitations to CTA imposed by calcification.

Acknowledgements

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