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Original Article

Radiology Section

Symmetry-Based Scoring of Atherosclerotic Plaques in Peripheral Artery Disease: A Retrospective Observational Study

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ABSTRACT

Introduction: Mirror imaging refers to the tendency of atherosclerotic plaques to show a symmetric distribution and comparable severity in anatomically corresponding arteries of both lower limbs. Recognising this pattern is clinically important, as identifying disease on one side may predict occult or future disease in the contralateral limb, thereby aiding comprehensive vascular assessment and management. There is minimal literature available that substantiates that a symmetric pattern exists in the grade of atherosclerotic plaques of the lower limb.

Aim: To assess the presence and extent of bilateral symmetry (mirror imaging) of atherosclerotic plaque burden in lower limb arterial vessels using contrast-enhanced multidetector Computed Tomography (CT) angiography.

Materials and Methods: A retrospective observational study was conducted over one year at a tertiary care hospital in North India from January to December 2024, on 25 (21 male and 4 female) patients with peripheral artery disease. Multi-detector Contrast-enhanced Computed Tomography (CECT) of the lower limbs was done in all patients and graded the atherosclerosis depending upon the percentage of blockage, i.e., 0 to 24%, 25 to 49%, 50 to 74% and 75 to 100% as grade I, II, III and IV, respectively. The primary outcome measured was the degree of bilateral symmetry in atherosclerotic burden across ten predefined lower limb arteries. The cumulative symmetry score reflected the extent to which corresponding arteries in both limbs exhibited similar grades of luminal stenosis. The appropriate statistical tests of significance were applied One-way Analysis of Variance (ANOVA) with post-hoc Tukey test, t-test, and correlation) to determine the relationship between the symmetry score and patients' variables.

Results: The mean age of the study population was 63.2±9.4. Symmetry scores differed significantly across age groups (One-way ANOVA: F=5.118, p=0.015), with a higher mean score in patients aged 71-90 years compared with those aged 51-70 years (Tukey post-hoc p=0.011). Symmetry scoring was performed at the patient level, based on concordance across ten paired arteries, while artery-wise righta-left correlations were analysed independently for each vessel". The distribution of the Symmetry score of nine was seen in 10 patients, i.e., 40%.

Conclusion: The patient's Peripheral Arterial Disease (PAD) must be evaluated for symmetric lesions of atherosclerosis in the contralateral limb, and a symmetric score may be done, thus helping vascular surgeons in management.

Keywords: Atherosclerosis, Luminal stenosis, Multidetector computed tomography, Peripheral

INTRODUCTION

The Peripheral Artery Disease (PAD) is a progressive and gradual narrowing of the arterial lumen by atherosclerosis, which increases with age [1,2]. Most of the patients are asymptomatic; however, approximately 30-35% develops symptoms, which include intermittent claudication and critical limb ischaemia [2]. There was a limitation in diagnosing PAD clinically, so a more objective method like Computed Tomographic Angiography (CTA) proved to be useful in the diagnosis of PAD and can grade it according to the severity of the lumen narrowing by the atherosclerotic plaque [3]. In cases of diffuse severe calcification, CTA may overestimate stenosis due to blooming artefacts; hence, catheter angiography remains preferable. However, the scoring system is intended primarily for non-heavily calcified vessels, where CTA reliably reflects luminal narrowing [1,3,4]. There is a description of the distribution pattern of artery stenosis in the lower extremity. A study conducted by DeBakey ME et al., in their analysis of over 14,000 patients demonstrated that atherosclerosis in the lower extremities follows a predictable distribution pattern. Approximately, 40% of cases showed predominant involvement of the terminal aorta and its major branches, as well as the distal superficial femoral and popliteal arteries, highlighting their surgical significance [5]. Symmetrical distribution of atherosclerotic plaques in PAD has been described in the literature and is thought to reflect the inherent anatomical symmetry of the human vascular system [6-10]. This study aimed to evaluate patients for a symmetric pattern or mirror imaging of atherosclerotic plaques in both lower limb arterial vessels in contrast-enhanced multi-detector Computed Tomography (CT). The authors devised a scoring system with a maximum score of 10 if all the named arteries matched in grading of lumen narrowing by the atherosclerotic plaque matched its counterpart artery in the opposite limb. This scoring methodology will alert the vascular surgeon to take into consideration the opposite limb vessel if there is a high score and manage it accordingly.

MATERIALS AND METHODS

A retrospective observational study was conducted in the Department of Radiology at DRPGMC, Tanda and AIIMS, Bilaspur, Himachal Pradesh, India, from January to December 2024.

Inclusion and Exclusion criteria: It included patients with PAD diagnosed clinically, by exertional calf pain relieved by rest (intermittent claudication) with diminished or absent distal pulses and an Ankle-Brachial Index (ABI) ≤0.90., while those with prior lower limb interventions or non-atherosclerotic vascular disease were excluded.

Study Procedure

CT imaging protocol: Contrast-enhanced CT of the lower abdomen and lower limbs was performed on a 16-slice MDCT machine (Brilliance 16 Philips). CT images were obtained by administering 100 mL of non-ionic contrast medium with 300 mg/ml iodine concentrations intravenously using an 18 G cannula via the ante-

cubital/another accessible vein at a rate of 3.5-4.5 mL/s with a pressure injector (Medrad-Vistron CT Injection System). The scan was started after automatic bolus tracking reached the threshold of 100HU at the abdominal aorta at the level of renal artery origin.

CT parameters are the following:

- Patient position: Supine
- Reconstruction interval: 0.8 mm
- Slice thickness: 0.5 mm
- Pitch: 1.25
- Increment: 1 mm

Image analysis: For every patient, 10 pairs of arteries in both limbs were analysed namely the common iliac, external iliac, internal iliac, common femoral, superficial femoral, deep femoral artery, popliteal, anterior tibial, posterior tibial and peroneal. For the extent of stenosis, grades were used, having the following percentage range of occlusion, i.e., 0 to 24%- grade I, 25 to 49%- grade II, 50 to 74% -grade III and 75 to 100%- grade IV. For multi-level occlusion, the maximum stenotic level was taken into consideration. Data were collected systematically by a single observer to minimise interobserver variability. The authors devised a symmetry scoring system to objectively assess mirrored atherosclerotic involvement in the lower limbs. Each of the 10 named arteries was compared with its counterpart on the opposite limb, and a score of 1 was assigned if both arteries showed the same grade of lumen narrowing (graded I-IV based on percentage stenosis). Scores from all paired arteries were summed, with a maximum possible score of 10 indicating complete symmetry across all evaluated vessels. This method allows for a simple yet systematic evaluation of mirror imaging of plaques, aiding clinical decision-making for vascular intervention.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS v26 and R v4.4.1. Descriptive analysis was done and represented through frequency, percentages, mean and standard deviation. The appropriate tests of significance were applied, taking a level of significance, $p<0.05$. The ANOVA and post-hoc Tukey test were performed to find the symmetry score difference among the age groups of 30 to 50, 51 to 70 and 71 to 90 years. The t-test was applied for comparison of the symmetry score according to the gender of participants. Pearson correlation was done between the symmetry score and the age of participants. A Spearman's correlation was run to determine the relationship between patients' right and left arterial blockage.

RESULTS

According to the distribution pattern of patients' age group, the 30-50 age group had 6 (24%) patients, the 51-70 age group had 10 (40%) patients, and the above 71 years of age group had 9 (36%) patients. There was a total of 25 patients, of whom 21(84%) were male, and 4(16%) were female [Table/Fig-1]. The distribution of the symmetry score of nine was seen in 10 patients, i.e., 40%. [Table/Fig-2].

Characteristics	Frequency (N=25)	Percent
Age group		
30-50 years	06	24.0
51-70 years	10	40.0
71-90 years	09	36.0
Gender		
Male	21	84.0
Female	04	16.0

[Table/Fig-1]: Distribution of participants according to age group and gender. Mean (SD) symmetry score was 7.92 (1.82)

There was a statistically significant difference between age groups as determined by One-way ANOVA (F=5.118, p=0.015). A Tukey post-hoc test revealed that the mean symmetry score was significantly different between the age group of 51 to 70 years and 71 to 90 years, p=0.011. There was no statistically significant mean score difference between age groups of 30 to 50 and 51 to 70 (p=0.321) [Table/Fig-3].

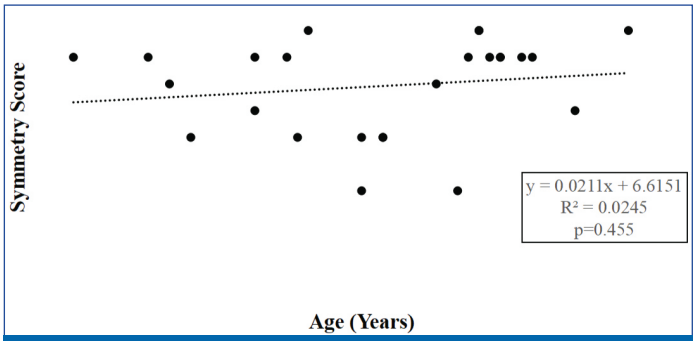
Symmetry score	Number of participants (N=25)	Percentage
4	2	8.0
6	5	20.0
7	2	8.0
8	2	8.0
9	10	40.0
10	4	16.0

[Table/Fig-2]: Symmetry score of lower limb arteries (Range 1-10).

Age group in years	Number (%)	Symmetry score			F	p
		Mean±SD	95% confidence interval			
30-50	6 (24%)	8.00±1.265	6.67	9.33	5.118	0.015
51-70	10 (40%)	6.80±2.098	5.30	8.30		
71-90	9 (36%)	9.11±0.928	8.40	9.82		

[Table/Fig-3]: Comparison of symmetry score according to age group of participants (One-way ANOVA with Welch statistic).

Identical grades of stenosis in corresponding right and left vessels were observed in 18 out of 25 patients (72%), with a strong positive correlation between right and left arteries (r=0.89, $p<0.05$), indicating a high prevalence of mirror imaging of atherosclerotic plaques in the lower limbs. A correlation between the symmetry score and the age of participants was not found to be significant, p=0.455 [Table/Fig-4].



[Table/Fig-4]: Correlation between symmetry score and age of participants.

Although a statistically significant difference in symmetry score was observed between sexes, interpretation is limited due to the small number of female participants [Table/Fig-5].

Gender	Number (N=25)	Symmetry score Mean±SD	t	p-value
Male	21	7.67±1.88	3.296	0.004
Female	4	9.25±0.50		

[Table/Fig-5]: Comparison of symmetry score according to the gender of participants.

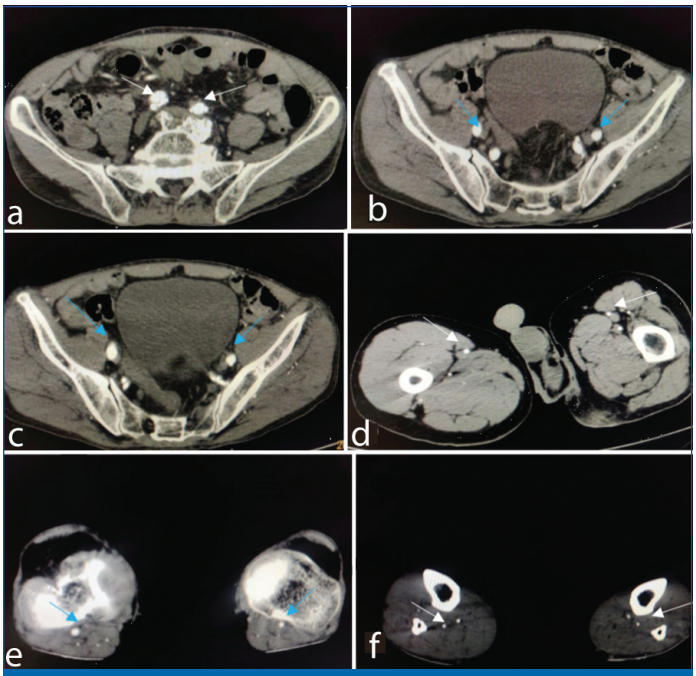
There was a strong, positive correlation found between right artery blockage and Left arteries blockage, which was statistically significant ($p<0.05$) [Table/Fig-6]. "Arterial stenosis grading was recorded for all paired arterial segments and used as ordinal data for correlation analysis." Few representative images are shown in [Table/Fig-7,8].

DISCUSSION

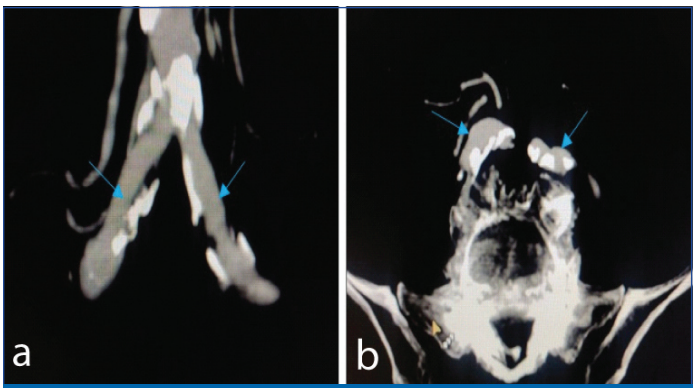
In the present study, the authors tested the hypothesis that there is a correlation between the grade or amount of atherosclerotic plaque. The plaque is similar in the left and right arterial tree of the lower limbs, and this hypothesis has been supported in previous studies, of which one

Name of vessel	Number	Spearman's correlation coefficient rho (ρ)	p
Common iliac artery	25	0.620	0.001
External iliac artery	25	0.597	0.002
Internal iliac artery	25	0.765	0.001
Common femoral artery	25	0.694	0.001
Superficial femoral artery	25	0.886	0.001
Deep femoral artery	25	0.898	0.001
Popliteal artery	25	0.718	0.001
Anterior tibial artery	25	0.897	0.001
Posterior tibial artery	25	0.788	0.001
Peroneal artery	25	0.897	0.001

[Table/Fig-6]: Spearman's correlation between right and left arterial stenosis grades for each of the 10 named lower limb arteries.



[Table/Fig-7]: A 65-year-old male patient a known smoker presenting with intermittent claudication CTA was done and the axial images (a-f) of the arterial tree shows atherosclerotic plaques involving Bilateral Common iliac arteries (grade II luminal narrowing) (white arrow in a,d,f), superficial femoral arteries, and distal arteries symmetrically (grade I luminal narrowing) whereas asymmetrically the external Iliac arteries (grade I luminal narrowing on right side and grade II on left) and popliteal arteries (grade I luminal narrowing on right side and grade II on left (Blue arrows in b,c,e), thus the symmetrical score is 8/10.



[Table/Fig-8]: A 63-year-old female patient a known smoker presenting with gangrene left great toe CTA was done and reformatted coronal images (a,b) the axial image (b) shows atherosclerotic plaques involving bilateral common iliac arteries (grade II luminal narrowing on the right and grade III on left (Blue arrows), rest of the arterial tree was having symmetrical involvement of atherosclerosis, thus the symmetrical score is 9/10.

study was carried out by Adams GJ et al., suggested that if patients present with atherosclerosis in one carotid, they are likely to have disease in the contralateral carotid [3]. Their study demonstrated that the carotid artery atherosclerosis is a rather symmetrical disease, particularly in the degree of calcification of plaques within the arteries [3].

Systemic factors, such as plasma cholesterol levels, play an important role in the symmetry of atherosclerotic plaque grades in the body's vessel wall. Local factors, such as blood turbulence, particularly at arterial bifurcations, also play an important role in the symmetrical grading of lumen narrowing in atherosclerotic plaques throughout the body due to shear stress [4]. One of the earliest studies done by Walden R et al., in 1985, analysing symmetry in the distribution of lower limb atherosclerosis, observed 53-76% inter-leg symmetry in the distribution of atherosclerotic plaques [9]. In their two studies involving tibio-peronial trunks and anterior tibial arteries, respectively, Szpinda M et al., and Szpinda M et al., found high correlation coefficients of symmetry of left and right vasculature [10,11]. However, Bossuyt J et al., found atherosclerotic lesions are more prevalent at the right than at the left femoral artery [12].

Friedman MH et al., in their study hypothesised that there are "geometric risk factors" for the occurrence of atherosclerosis at the aortic bifurcation [4]. And there exists a physiological symmetry in human vessels, thus geometric as well as haemodynamic factors play a role in the symmetrical distribution of atherosclerotic plaques of the arteries. He also suggested that shear stress on endothelial function and proliferation of smooth muscle cells play role in the symmetrical formation of atherosclerotic plaques.

When the authors statistically analysed the data for the correlation between the grades of atherosclerosis in the two lower limbs, they found a strong, positive correlation between blockage in the right and left arteries, which was statistically significant.

Limitation(s)

The small sample size of 25 patients limited the generalisability of the findings. CTA may overestimate stenosis in heavily calcified vessels, and the scoring system relies partly on visual assessment, which could introduce observer bias. Additionally, the study was conducted at a single centre, and long-term clinical outcomes based on the symmetry score were not evaluated.

CONCLUSION(S)

The patient's PAD must be evaluated for a symmetric lesion of Atherosclerosis in the contralateral limb and a symmetric score may be done, and vascular Surgeons may decide beforehand the management of the arterial tree. As per this study, atherosclerosis tends to be symmetrical and more so with increasing age.

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